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EFFECTIVE POLICIES TO FOSTER HIGH-RISK/HIGH-REWARD RESEARCH

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Foreword

This report analyses policies and research funding mechanisms, designed to foster high-risk high-reward (HRHR) research, and their effectiveness, taking into account contextual factors. It is aimed at policymakers and the research funding community interested in fostering more risk-taking in scientific research portfolios. It identifies gaps in existing data on HRHR research, and explores promising practices for fostering HRHR research in a variety of contexts. It also proposes policy recommendations.

The project that forms the basis for this report was initiated by the OECD Global Science Forum (GSF) in 2019. It builds on earlier GSF work, particularly a project on Effective Operation of Competitive Research Funding Systems (OECD, 2018[1]). This project has proceeded simultaneously with other related projects on transdisciplinary research (OECD, 2020[2]) and mission-oriented research policies (Larrue, 2021[3])..

The main element of this project was a survey of individual HRHR research funding schemes in different countries, complemented by targeted interviews. This was supplemented by an analysis of HRHR research-oriented programmes reported in the OECD STIP Compass Database[1]. An international workshop organised in April 2020 provided expert input on the major issues and challenges faced by funders in supporting HRHR research. This workshop, originally planned for Brussels, Belgium, became a virtual workshop[2] because of the COVID-19 pandemic. Findings from the survey, data, workshop, interviews, a literature review, and supporting data were analysed together to produce this report.

The emergence of the global COVID-19 pandemic necessitated some modifications to the project design and focus. In addition to shifting a planned physical workshop to an online workshop, the Expert Group collected examples of rapid-response research funding programmes designed to support immediate research responses to the pandemic. Some of these programmes are intended to explore high-risk high-reward approaches to the pandemic and are included in this report; other rapid-response funding mechanisms are discussed in separate OECD publications on tackling COVID-19[3].

The project has been overseen by an international Expert Group whose members (appendix 1) were nominated by the Global Science Forum. This Group was chaired by Jessica Robin (United States) and Heug-Deung Hong (Korea) and assisted by consultants Kei Koizumi and Diogo Machado. This report was drafted primarily by Kei Koizumi and the OECD GSF Secretariat – Frédéric Sgard – with input from all Expert Group members.

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This report analyses policies and research funding mechanisms designed to foster high-risk high-reward (HRHR) research, and explores promising practices for fostering HRHR research in a variety of contexts. The underlying concern is that failure to encourage and support research on risky, 'out-of-the-box' ideas may jeopardise a country's longer-term ability to compete economically, harness science for solving national and global challenges, and contribute to the progress of science as a whole.

The analysis in this paper is primarily based on a survey of individual HRHR research funding schemes in different countries, complemented by targeted interviews. This survey was supplemented by an analysis of HRHR research-oriented programmes and by the feedback from an international workshop that included all relevant stakeholders.

Executive summary

An increasing concern of the scientific community in recent years is that research funding processes have become too conservative and encourage only incremental advances in science and technology. As a result, there have been a number of calls for a change in funding processes and increased funding to support high-risk/high-reward (HRHR) research. The underlying concern, from a policy perspective, is that failure to encourage and support research on risky, 'out of the box' ideas may jeopardise a country's longer-term ability to compete economically, to harness science for solving national and global challenges, and to contribute to the progress of science as a whole.

This report explores "Effective Policies to foster High-Risk/High-Reward research". Five key policy questions for HRHR research frame the work, namely:

1. What different funding instruments are used and what are their advantages and disadvantages?
2. What evidence (if any) exists of the effectiveness of these different instruments?
3. What is the most appropriate instrument to use in a particular context?
4. Are there alternative and/or complementary non-funding policies that can be implemented, and in what context?
5. What are the roles, responsibilities and constraints of different actors in promoting high-risk research?

To explore these issues, HRHR research was analysed through two main lens: first, research funding mechanisms, and second, contextual factors and supporting policies outside core research funding mechanisms that have been utilised to help foster HRHR research.

HRHR research funding mechanisms

There are many research funding mechanisms designed to foster HRHR research and much policy experimentation is taking place in this area. There are thus a diversity of options for policymakers to consider when seeking to foster HRHR research, each relying on different working and management processes.

One key distinction is the degree to which funding mechanisms centre on HRHR research. Four main funding categories can be identified:

- Funding mechanisms specifically designed to support HRHR research and that are supporting such research as a primary goal;
- Funding mechanisms that have HRHR research as their primary mission within a broader set of objectives;
- Funding mechanisms in which supporting HRHR research is a secondary goal or an important consideration in the proposal evaluation process;
- Funding mechanisms geared toward supporting scientific research with multiple possible goals including advancing scientific knowledge, achieving economic outcomes, or advancing societal outcomes, although there are no clear criteria for fostering HRHR research.

In addition to these four predominant categories, several other less prevalent but interesting mechanisms were identified, such as “people-based” awards, scientific prizes, and internal funding from research institutions, which can all play an important role in fostering HRHR research.

Studying the working and management processes of these funding mechanisms reveals the importance of taking a portfolio management approach to supporting HRHR research. This places considerations of risk and reward at the research portfolio level rather than the individual project level.

Contextual Factors and Supporting Policies

In addition to funding, certain contextual factors and non-funding policies can be conducive to HRHR research. While insufficient by themselves to foster HRHR research in the absence of the necessary research funding, they are important to ensure the success of targeted research funding schemes.

Key contextual factors and policies include:

- Political support for risk-taking and long-term commitment. This was found to be probably the most important factor for success but also the most challenging;
- Tenure, promotion, and advancement policies at research institutions. There are powerful incentives in the current system for researchers, especially early-career researchers, to be conservative in their research in order to be more certain of securing the publication outputs against which they will be evaluated. Promoting HRHR research requires a change in the human resource policies of research institutions and in research assessment more broadly;
- Indicators for HRHR research. While traditional research indicators tend to promote conservatism, more novel and appropriate indicators do exist and can, when used judiciously, help to foster HRHR research by quantifying the ‘riskiness’ of a research project or portfolio, allowing researchers, research managers, and others to adjust risk to an appropriate level. This report includes a specific proof of practice case study for one such novelty indicator.

Conclusions

The study finds that there is no “one-size-fits-all” funding instrument, with the most efficient approach depending on the context. While this report puts forward an inventory of HRHR research programmes, these differ along several dimensions and decision makers have several options to choose from in designing a HRHR research funding scheme. Being clear on the strategic objective of the programme can however help narrow down the options.

Drawing lessons and recommendations is difficult, as many HRHR research programmes have not been evaluated rigorously because of their relative newness. Those that have been evaluated have used expert panels and a mix of traditional quantitative indicators or qualitative evidence. There are, however, growing options for indicators of novelty to help evaluate HRHR research programmes.

To complement funding, enabling actions at the level of research institutions, such as revision of tenure and promotion policies, can be valuable. Policymakers can also provide political long-term support for risk-taking and long-time horizons for research. Science funding agencies can experiment with different approaches for fostering HRHR research within competitive funding processes; and research institutions can nurture researcher careers by rewarding risk-taking and providing seed or bridge funding to incentivise HRHR research.

Recommendations

The findings of the report underline the complexity of research systems and the need for complementary policies and actions from different stakeholders. Policy action to foster HRHR research is required from governments, research funders and research performing institutions, ideally working in together and in synergy. These actions fall into six main areas as follows:

1. **Research funders are encouraged to experiment with existing and new approaches to foster HRHR research**. This report offers several ideas for research funders to consider, both for designing new programmes or re-designing existing ones to foster HRHR research.
2. **Research funders and government policymakers are encouraged to implement a portfolio approach in the management and evaluation of HRHR research**. Using a portfolio approach allows for a better risk-management at all levels, and can increase incentives for funding management, evaluation panels and individual researchers to take risks.
3. **Research funders, government policymakers, and research institution decision makers are encouraged to implement contextual policies and practices to encourage researchers to take scientific risks**. This includes: adopting a long-term vision, both for funding and expectations; redesigning individual evaluation and promotion policies at research institutions to provide researchers with environments more conducive to HRHR research.
4. **As newly established HRHR research programmes mature, research funders are encouraged to evaluate their impacts rigorously, not only their scientific, societal, and economic impacts but also evaluating the programmes' impact in fostering or discouraging HRHR research**. Although most funders are likely to rely primarily on expert (peer review) post-hoc evaluation, funders are also encouraged to develop and utilize quantitative indicators in their evaluations as well. Funders are encouraged to share novel approaches for evaluating impact with the broader community.
5. **Interested countries and researchers are invited to further research, develop, and utilise indicators for evaluating the riskiness of research, especially in impact evaluation of HRHR and other research**. Despite the increasing number of programmes intended to foster HRHR research inventoried in this report, there are few useable indicators for evaluating the riskiness of research proposals or results.
6. **Funding agencies are encouraged to collect and share data on HRHR research programmes that enables their comparison to more-traditional research programmes**. Additional data and research on some important issues would be useful, such as knowing whether the recipients of HRHR research funds are the same as recipients of traditional grants and if not how they vary in terms of gender, career stage, or other variables. It would also be important to understand in more depth how specific HRHR research funds or policies differ from traditional research funds/policies in their design and their impact. Among funding mechanisms, there is a shortage of literature on the effectiveness of prizes, challenges, and other alternatives to peer-reviewed research grants in fostering HRHR research.

Examples of good practices, including an analysis of the pros and cons of different funding allocation and management approaches, are provided throughout this report (see for, example, tables 2 and 3).

Introduction

Background and history

An increasing concern in recent years is that research funding processes have become too conservative and encourage only incremental advances in science and technology (Montgomery et al., 2014[4]; American Academy of Arts and Sciences, 2008[5]). As a result, there have been calls for a change in these processes and increased funding to support high-risk/high-reward (HRHR) research. Supporting research, however, is not just a question of funding. At the research system level, disciplinary and institutional structures, research careers and precarity, cultural norms in the science community, research evaluation systems, and strategic prioritization processes all have an impact on the type of research that is conducted.

An underlying concern is that failure to encourage and to support research on risky, 'out-of-the-box' ideas may jeopardize a country's longer-term ability to innovate and compete economically, to harness science toward solving national and global challenges, and to contribute to the progress of science as a whole. This concern was already articulated in a 2007 report from the US National Academies titled "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future." (Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology et al., 2007[6]) The report identified, at the request of the US Congress, factors that contribute to the United States' eroding competitiveness in the global economy. The decline in support of "high-risk or transformative research," particularly in the physical sciences, engineering, mathematics, and information sciences was identified as one such factor. The report states that "reducing the risk for individual research projects increases the likelihood that breakthrough, 'disruptive' technologies will not be found—the kinds of discoveries that yield huge returns." The report, subsequently influential in US science policy making, calls on the US government to institute policy measures specifically to foster more high-risk, high-reward research. This led to legislation including the America COMPETES Act of 2007 and a congressional hearing in 2009 to encourage US science funding agencies to foster HRHR research (US Government, 2009[7]).

Other regions and nations have also expressed concerns over increasing conservatism in research and have implemented policies to counteract the trend. As early as 2005, the European Commission acted through its New and Emerging Science and Technology (NEST) initiative, within the Sixth Framework Programme (FP6), specifically to "support unconventional and visionary research with the potential to open new fields for European science and technology, as well as research on potential problems uncovered by science." [4] EU member nations individually also started similar programmes: the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) established the Reinhart Koselleck Projects in 2008 to encourage researchers to pursue "innovative, high-risk projects."[5] Likewise, the Japanese government in 2009 formed the Funding Programme for World-Leading Innovative R&D on Science and Technology (FIRST Programme) to advance 'leading-edge research and development' to counteract the tendency of Japanese researchers to avoid risk in their projects[6].

Throughout the world, then, concerns about conservatism in research choices have manifested not only in reports and dialogue, but have also led to experimentation in policies to foster and encourage high-risk, high-reward research.

Both scientific and political considerations may lead to underfunding of HRHR research. There are three main considerations in this regard. First, as suggested in a recent study of NIH funding mechanisms

(Packalen and Bhattacharya, 2018[8]), because research funding agencies visibly spend public money, they need to show (promising) results, manifestations of improvements for society, as well as technological breakthroughs, arising from the research they support (Hegde and Sampat, 2015[9]). This consideration leads to a preference for supporting ideas that have already shown promise rather than ideas for which promise cannot be foreseen. Second, scientific review panels, for reasons related to their composition, remit and process, tend to reward projects that are evidently feasible over projects that carry the risk of not achieving their initial objectives (e.g. (Nicholson and Ioannidis, 2012[10]). Third, vested interests from influential individuals or parties may also undermine the development of original avenues of research (Azoulay, Fons-Rosen and Zivin, 2019[11]).

Traditionally, high-risk research was expected to be funded through core institutional funding mechanisms which, not being allocated to specific projects and not directly linked to the need for results, are thought to allow greater latitude to scientists for risk-taking. Competitive research mechanisms have also been developed since the 1950's specifically for this purpose. The now 60+-year-old US Department of Defense's Defense Advanced Research Projects Agency (DARPA) is often cited as a longstanding successful high-risk, high-reward programme model. At the time of its founding it supported then risky computer science research on packet switching that led decades later to the high-reward outcome of the Internet. Several programmes have subsequently attempted to replicate DARPA's model (the US Department of Energy's ARPA-E to advance energy research is a recent high-risk, high-reward programme modelled on DARPA[7]). These have been joined by a variety of other programmes that use peer review for competitive proposals focused on supporting high-risk high-reward research (Gewin, 2012[12]).

Such competitive mechanisms have also been developed across the World. The European Research Council, for example, was established in 2007 to support bottom-up research without predetermined priorities and with the aim of inviting risk-taking from applicants. In the United Kingdom, the Economic and Social Research Council has developed a dedicated "Transformative Research Call." In Germany, the DFG supports Reinhart Koselleck Projects that are specifically targeted at outstanding researchers who wish to carry out exceptionally innovative or high-risk research. And in Japan, the more applied funding programme for "Impulsing Paradigm Change through Disruptive Technologies" (ImPACT) was developed to foster disruptive innovation and encourage research with lower probability of success (high-risk) but with potentially high impact, as well as to foster an entrepreneurial climate.

Different programmes operate with distinct philosophies of how to best fund and manage high-risk research. DARPA, for example, traditionally funds project-based assignments that are aimed at overcoming a defined challenge. Funding recipients are judged on whether they have met specific milestones and funding can be cut if those milestones are not met. At the other end of the spectrum, the NIH Director's Pioneer Award (NDPA) looks to select awardees based on the calibre of the scientists who apply, with little to no focus on the actual project they propose to undertake with the funds. There are a number of recent experiments with institutional funding mechanisms and 'hybrid' institutional-competitive funding mechanisms to encourage HRHR research. In addition, the perception that traditional funding processes are not supporting transformative ideas has also led many non-governmental organizations (charities, private foundations, associations, etc.) to develop their own methodologies to support HRHR research related to their specific interests.

Despite the experimentation that is taking place and the near-consensus that high-risk high-reward research is an essential component of a national R&D portfolio, there has been little study on the range and effectiveness of mechanisms for funding such research and 'best practices' on how to manage these research programmes. Likewise, there is limited analysis of policies that could foster research environments favourable to HRHR research. In addition, there exist few indicators or tools to manage high-risk research portfolios. There are also no routine indicators for scientific or other risk or indicators of transformation and there is recent evidence that traditional bibliometric measures of scientific excellence do not always correlate with novelty (Wang, Veugelers and Stephan, 2017[13]).

What is High-Risk/High-Reward Research?

There is no standard definition of high-risk, high-reward research or transformative research. High-risk research may also be referred to interchangeably as high-risk, high-reward (HRHR) research or high-risk, high-payoff research or high-risk, high-gain research.

High-risk, high-reward research, as defined by the US National Institutes for Health (NIH), consists of "ideas that have the potential for high impact, but that may be too novel, span too diverse a range of disciplines, or be at a stage too early to fare well in the traditional peer review process."[8] The risk in question, then, is that the research will not produce scientific results leading to societal or economic or knowledge impacts because of its novelty, its position outside of established disciplinary paradigms, or its ambition in tackling challenging questions. Implicit in this definition is a critique of the traditional peer review process as favouring the established over the novel, and favouring work to answer the next logical question in a sequence over ambitious attempts to leapfrog over lines of inquiry.

The US America COMPETES Act of 2007 (US Congress, 2007[14]) defines HRHR research as research projects that: "1) meet fundamental technological or scientific challenges; 2) involve multidisciplinary work; and 3) involve a high degree of novelty." In the literature, however, there are few other definitions of high-risk research. Often, the term and associated terms are used without being defined explicitly. Even in the definitions above, the meaning of high impact or high reward is not explicit, although implicitly the impacts or rewards that are being sought fall into three categories: scientific impacts through knowledge creation; economic impacts through technological breakthroughs and innovation embodied in new value-added goods and services; and, societal impacts through the translation of new knowledge and/or technologies to solve societal challenges. Achieving high impact on any of these three dimensions implicitly requires transformation of existing knowledge, paradigms, technologies, and structures.

Transformative research is often used interchangeably with the terms potentially transformative research (PTR) or transformational research. The US National Science Foundation defines transformative research as research that "involves ideas, discoveries, or tools that radically change our understanding of an important existing scientific or engineering concept or educational practice or leads to the creation of a new paradigm or field of science, engineering, or education. Such research challenges current understanding or provides pathways to new frontiers." (National Science Foundation, 2007[15]) Implicit in this definition is that such transformation is necessarily high impact. It should be noted that NSF, as a basic-research funding agency with a scientific mission, is concerned primarily with scientific impacts rather than economic or societal impacts, but the definition can expand to include economic and societal impacts through transformational technologies, radical changes to technological/economic sectors, or paradigm shifts in framing solutions to societal challenges.

There are few other explicit definitions of transformative research in the literature and those that do exist align closely to the National Science Foundation definition (Trevors et al., 2012[16]). The definition of transformative research thus appears largely similar to that of high-risk high-reward research save for a slightly stronger semantic emphasis in transformative research on the potential impact on (and rewards from) knowledge, technologies or society. Conversely, there is an emphasis on the risk of failure to achieve the initial goals of the project for high-risk, high-reward research. Although risk is not explicitly a part of the NSF definition for transformative research, risk is implicit because research seeking radical changes in understanding carries more risk of failure than incremental research.

It is also worth noting that high-risk, high-reward/transformative research is conceptually distinct from interdisciplinary or transdisciplinary research. Although crossing or transcending disciplinary boundaries is part of some definitions of HRHR or transformative research, inter-/trans-disciplinarity alone is not a prerequisite for HRHR/transformative research since high-risk disciplinary research can also result in new

(scientific) paradigms/concepts. Moreover, not all inter- or trans-disciplinary research is necessarily high-risk and high reward.

It is also important to make a distinction between HRHR research and high-risk research in the medical context, understood to mean medical research that puts humans at risk of adverse health impacts[9]. Obviously, HRHR research is intended to be a positive good, while medical research at high risk of adverse human health impacts is to be managed appropriately.

There are other definitions and policy documents relevant to the task of defining HRHR research. At the cross-national level, the Global Research Council (GRC) has articulated a set of principles for supporting scientific breakthroughs which, although falling short of defining HRHR research, nevertheless encourages nations to support risk taking in research, specifically urging nations to "Encourage risk-taking and tolerate failure in research activities." (Global Research Council, 2015[17]).

What is high reward? As already indicated, most of the discussion around HRHR research focuses on the high-risk portion, relatively little on the high-reward portion. This may be because research rewards are perceived as better understood than research risks, and also because there are multiple categories of reward, from scientific to economic to societal to financial. Whether the reward can be measured by scientific publications, citations, patents, economic activity, demonstrable progress toward a national challenge, or even anecdotal success stories, there is better understanding of the potential rewards of research, and better indicators for evaluating no reward vs. low reward vs. high reward. HRHR research, if successful, can be expected to result in a variety of rewards, which might include highly-cited papers, technological innovations with market impact, or breakthrough solutions to longstanding problems that are greater than the rewards from more-incremental research approaches.

Some of the programmes considered in this report do not define HRHR research for what it is, but rather what it is not. The Netherlands' Off Road programme aims to support 'out-of-the-box' research but defines it primarily by what it is not: "Out of the box is NOT research that: is a continuation within an existing line of research; applies a proven therapy/technique to a new but related problem; is in line with existing model; doesn't really have a new angle; repeats what others have done in a not the same but similar setting."[10]

Canada instituted its New Frontiers in Research Fund (NFRF) in 2018 to support research that is interdisciplinary, international, fast-breaking and high-risk. The NFRF has three streams: Exploration, Transformation and International. The Exploration and Transformation streams have a particular focus on high-risk research. Exploration provides smaller-scale awards and emphasizes support for research that proposes unique directions, challenges current paradigms, and which seeks to enhance understanding of complex and challenging issues. Transformation provides larger-scale awards and factors in risk considering why a proposed project is novel as it relates to the latest methods, concepts, information, and techniques. Exploration does not define HRHR research but rather states, "The following elements are considered to be indicative of projects that do not meet programme expectations with regard to high risk, and are therefore discouraged: research that is the obvious next step; data collection without interpreting underlying mechanisms; professional practice or consulting services (contract research); the set-up and operational management of an institute or a formal or informal group of researchers (network); curriculum development; organisation of a conference or workshop; digitization of a collection or creation of a database; the application of existing technology or the commercialization of a product/process; routine analyses; and/or the acquisition and maintenance of scientific equipment."[11] In addition, high risk is further characterised as defined by elements such as, but not limited to:

- proposing unique directions;
- challenging current research paradigms;
- enhancing understanding of complex and challenging issues;

- bringing new disciplines together with different perspectives, to use novel approaches for solving existing problems; and/or
- developing or adapting frameworks, methods and techniques.

For the purposes of this project, then, it is useful to consider many terms surrounding risk and transformation as being to a large extent interchangeable. This is implicit in the 2007 US report's framing of high-risk or transformative research and also in many other policies, documents, and even legislation that leave key terms vaguely defined. HRHR research, as used in this report, encompasses several other terms: high-risk research; high-risk, high-reward research; high, risk, high-payoff research; high-risk, high-gain research; transformative research; potentially transformative research; and transformational research.

Building on definitions and usage of the above terms in the literature policy documents, and funding announcements, the following working definition of high-risk or transformative research was adopted to guide this project and report:

"High-risk, high-reward (HRHR) research is research that 1) strives to understand or support solutions to ambitious scientific, technological, or societal challenges; 2) strives to cross scientific, technological, or societal paradigms in a revolutionary way; 3) involves a high degree of novelty; and 4) carries a high risk of not realizing its full ambition as well as the potential for high, transformational impact on a scientific, technological, or societal challenge."

Methodology and final report

This project has been overseen by an international Expert Group whose members were nominated by national OECD Global Science Forum delegations (see Appendix 1).

The project began with a review of existing literature on high-risk, high-reward research, past HRHR research programmes, and generic national research funding information collected by Expert Group members.

This report also used the 2018 OECD competitive research funding (OECD, 2018[1]) report as a launch point. That report states:

"Development of mechanisms for interdisciplinary and breakthrough/transformative research seem to be particular challenges. In particular, the challenge seems to be how to create and then maintain processes that recognise interdisciplinarity or transformative research in the face of strong disciplinary and conservative tendencies in the existing system… With respect to encouraging transformative research, the challenge is the difficulty of identifying ex ante which proposed research will ultimately have transformative impacts. In addition to specifically identifying such potential as a criterion that reviewers should look for, systems have experimented with various methods designed to protect such proposals from the possibly adverse effects of 'highly transformative' being seen by some reviewers as risky or unlikely to succeed."

The report develops the insights from the 2018 report in discussing high-risk high-reward or potentially transformative research and how funding agencies and policymakers have addressed the challenge through policies and experiments.

Five key policy questions for HRHR research that helped to shape this project from the outset include:

- What different funding instruments are being used and what are their advantages and disadvantages?
- What evidence (if any) exists of the effectiveness of these different instruments?
- What is the most appropriate instrument to use in a particular context?

- Are there alternative and/or complementary non-funding policies that can be implemented, and in what context?
- What are the roles, responsibilities and constraints of different actors in promoting high-risk research?

In constructing an inventory of HRHR research programmes (Appendix 3), the Expert Group drew from programmes identified as at least partially connected to HRHR research in the OECD STIP Compass Database[12]. The Expert Group used its judgment, referring to further information sources as necessary, to select programmes that have fostering HRHR research as a major focus and supplemented these with additional programmes not found in OECD STIP Compass.

Survey questionnaires were sent to selected funders with identified HRHR research programmes (See Appendix 2 for the survey questionnaire and the funding schemes that were analysed.) The questionnaire collected information on: basic programme aims and functioning; selection criteria for research funding awards; the selection process; the effectiveness of the programme in meeting its goals of supporting high-risk high-reward research; supportive policies assisting the programme in meeting its goals; other relevant issues. An additional question was included to collect information on COVID-19 rapid-response research funding mechanisms – some of which also encouraged HRHR.

To supplement the survey questionnaire, Expert Group members and OECD staff conducted 8 in-depth interviews with HRHR research programme managers and research providers (appendix 3), with particular attention to the contextual factors that support government research funding schemes in fostering HRHR research.

The Expert Group held six meetings between January 2019 and September 2020 and also organised an international workshop in April 2020. Originally scheduled to be held in Brussels, Belgium, the workshop, which examined many aspects of HRHR research based on concrete case studies, was conducted virtually in response to the Covid-19 pandemic. The workshop included members of the Expert Group, international panels of invited experts, GSF and CSTP Delegates, heads of research funding agencies and programmes, and members of the OECD Secretariat (full details and videos available at https://community.oecd.org/docs/DOC-170560).

The goal of this report is to identify useful policy options for government science policymakers, science funders and research-performing institutions. It includes an analysis of the relative effectiveness of different policy mechanisms for fostering HRHR research while fully considering the inherent trade-offs among differing policy approaches.

Findings and analysis

1.1. Overview

This chapter presents an integrated analysis of: the supporting literature on individual HRHR research-related programmes (see inventory in Appendix 3); the responses to the questionnaire from 16 selected programmes (see Appendix 2); stakeholder interviews; and, presentations and discussions from the April 2020 workshop. The different themes of the analysis are organised in two groups: first, funding mechanisms to foster HRHR research, and second, contextual factors and supporting policies, aside from dedicated research funding mechanisms, that have been utilized to help foster HRHR research.

1.2. Funding Mechanisms

Across the world, there are many research funding mechanisms designed to foster HRHR research (see Appendix 3). There has been much policy experimentation in this area, offering robust options for policymakers to consider when seeking to promote HRHR research.

1.2.1. *Dedicated or Secondary HRHR Research Funding Mechanisms*

Although this project initially aimed to develop a typology of HRHR research programmes, it quickly became clear that developing a useful and consistent typology would not be possible, because of the wide variation in approaches used to foster HRHR research. Nevertheless some general distinctions can be made among funding mechanisms to foster HRHR research. One key feature is the degree to which a funding mechanism is focussed on HRHR research.

A first category of funding mechanism is the dedicated high-risk/high-reward research programme. This is specifically designed to support HRHR research and has supporting such research as a primary goal. Among the programmes considered in this project (see Appendix 3), such dedicated programmes are in the minority. They include the US National Institutes of Health's High Risk High Reward Research portfolio of programmes, each of which supports a slightly different group of researchers. Similarly, France's OH Risque programme, from the ANR (Agence Nationale de la Recherche) is dedicated to research, "involving a very high level of scientific risk but with strong potential for scientific, technological and possibly economic impacts."[13] The United Kingdom's UK Research and Innovation (UKRI) Tools and Resources Development Fund (TRDF): Transformative Research Opportunities is another example of a dedicated HRHR research programme, explicitly designed to support "'high-risk high reward' pilot studies."[14]

Although not as explicit in their title, other programmes have nevertheless become synonymous with supporting HRHR research. As mentioned in the introduction, these include the US Defense Advanced Research Projects Agency (DARPA), which has been supporting such research for over 60years, and other US 'ARPA's.

A second category of programmes has supporting HRHR research as part of their primary mission within a broader set of objectives. This is, for example, the case for the Japan Moonshot Research and Development initiative, for which the programme solicitation includes numerous references to "high-risk high-impact R&D" and also calls for "destructive innovation" with researchers encouraged to aim for "ambitious projects that are more than just extensions of conventional technology." This initiative is actually seven distinct programmes aimed at different societal goals overseen by four agencies; HRHR research is the unifying theme.[15]

The US National Science Foundation's RAISE programme is another example of a research programme that aims at supporting "bold, interdisciplinary" projects. RAISE requires that research efforts include two or more intellectually distinct disciplines, with the expectation that combining different lines of research will generate transformational advances.

A third category comprises research funding mechanisms in which supporting HRHR research is a secondary goal or an important consideration in the proposal evaluation process. This is perhaps the most common category for the programmes in this report's inventory. The European Research Council's Consolidator Grants are one example of this category, as are programmes such as the US National Science Foundation's EArly Grants for Exploratory Research (EAGER). The Science Foundation of Ireland's Frontiers for the Future programme has frontier knowledge as a primary goal, but high-risk high-reward research is an important consideration in the proposal evaluation process. Similarly, Poland's MAESTRO programme is another basic-research programme with supporting HRHR research as a secondary element[16].

The Research Council of Norway's ENERGIX programme is an interesting example. The programme's primary goal is to foster energy breakthroughs, but a key strategy for the programme is to pursue "ground-breaking innovation for the development of entirely new energy concepts." ENERGIX activities "are to promote radical and ground-breaking solutions – novel approaches and radically innovative technologies that may result in major leaps in improvement in efficiency, use or cost levels throughout the energy chain, from energy resources to energy consumption."[17] It appears, then, that although promoting HRHR research is not a goal in itself for this programme, fostering such research is core to achieving the programme's primary energy goal. Another one of RCN's programmes, AQUACULTURE, takes a similar approach of fostering HRHR research toward the primary goal of enhancing the aquaculture industry.

A potential fourth category is research funding mechanisms geared toward supporting scientific research with multiple possible goals including advancing scientific knowledge, achieving economic outcomes, or advancing societal outcomes, in which researchers are encouraged to pursue high risk or potentially transformative approaches. Such mechanisms often have no clear criteria for HRHR research. One example is the Czech Republic's EXPRO, a programme to support excellence in basic research that began in 2018. This programme has multiple objectives, including helping Czech researchers become more competitive in European Research Council programmes. Peer reviewers of proposals are asked to evaluate the riskiness of the project and the potential significance of the project's impact as part of their proposal evaluations.[18]

Table 1. HRHR research funding mechanism categories

HRHR focus	Examples
HRHR primary focus/dedicated programme	US NIH HRHR programme, France ANR OH Risque programme, Switzerland SNRF Sinergia, Germany DFG Reinhart Koselleck Projects
HRHR one of the main foci	Japan Moonshot R&D programme, US NSF Raise programme, Canada NFRF Exploration programme, Ireland SFI Frontiers for the Future Programme
HRHR secondary goal/among many criteria	Europe ERC grant programme, US NSF EAGER programme, Poland MAESTRO programme
HRHR not an explicit criteria but risk-taking/transformative research is encouraged	Czech EXPRO programme, Portugal exploratory Research projects, Korea Alchemist project

Source: authors' analysis

1.2.2. *Calls for Proposals*

Although this may seem obvious, the Expert Group found that calls for proposals for programmes aimed at fostering HRHR research normally indicate that judgments of risk-taking and potential for transformation will be central to the proposal evaluation process. NIH's Pioneer Award, for example, states to potential applicants, "Successful NIH Director's Pioneer Award applicants are expected to propose highly innovative, and hence inherently risky, approaches to address or solve exceptionally important problems of relevance to NIH. While a new research direction may have as its foundation the applicant's prior work and expertise, it cannot simply be an obvious extension or scaling up of a research enterprise. Rather, a new research direction must reflect a fundamental new insight into the solution of a problem, which may derive from the development of exceptionally innovative approaches and/or from the posing of radically unconventional hypotheses." Japan's Moonshot programme stresses in multiple ways that funded projects must be HRHR: proposals "must be based on a bolder ideas than conventional ones and be challenging and innovative, with a strong impact expected on future industry and/or society."[19]

Other programmes state clearly at the outset to potential applicants that HRHR research approaches are strongly preferred or mandatory. These criteria extend not only to projects but also to people. Although it was a one-time solicitation, France's OH Risque programme in 2014 had a call for proposals "offering bold

researchers the necessary funds to start exploring innovative concepts or new paradigms with very high potential."

1.2.3. *Evaluation and funding allocation mechanisms*

This report's inventory of HRHR research programmes is mostly comprised of government programmes to support research with awards being granted through a competitive process, Various methods of evaluating and allocating funds are used for HRHR research programmes, as summarised in Table 2.

Table 2. HRHR research proposal evaluation processes and criteria

Options	Description/rationale	Pros and cons	Examples
Traditional peer review based on scientific excellence	External expert panel reviews proposals	Pro: Established mechanism Con: can encourage conservatism	European Research Council Consolidator Grants
Traditional peer review with requirement for collaborative, interdisciplinary, or breakthrough research ideas in all proposals	These types of research tend to be more HRHR	Pro: Easy to write in proposal solicitations Con: Collaborative, interdisciplinary, and breakthrough do not equal HRHR	Swiss National Science Foundation Sinergia
Traditional peer review making HRHR research an explicit selection criterion	HRHR research needs to be defined for both applicants and reviewers	Pro: Allows focus on HRHR research Con: Reviewers may need to be trained to evaluate HRHR in research proposals	NIH HRHR research programmes Canada NFRF Exploration
Peer review/anonymised	Double-blind' peer review means reviewers do not know the identities of applicants, and vice versa	Pro: Reduces bias against certain categories of applicants (early-career researchers, women, members of minority groups) Con: Reduces information available to reviewers, including track record	Swiss National Science Foundation Sinergia
Peer review/golden vote	Peer review panel with each panel member a "gold" vote to allow them to protect a promising proposal even if other panel members rate it negatively	Pro: Encourages proposals that may be outside the mainstream or attract very varied ratings Con: Discourages reviewer consensus	China National Natural Science Foundation
Multistage	Can use a combination of panel review, mail review, programme-manager review, and interview	Pro: Allows one stage specifically to focus on high-risk high-reward nature of proposal; initial stages can triage out unpromising ideas Con: Labour and time intensive	Research Council of Norway ENRGIX Netherlands Off Road
Segmenting competitions by career stage	Separate programmes for early-career, mid-career, and established researchers can encourage earlier-career researchers to take risks in research proposals	Pro: Early-career researchers may be more inclined to take risks yet fear career repercussions for doing so Con: Not directly connected to HRHR research	ERC starting vs advanced Grants
Programme manager/director	Programme manager/director reviews and selects proposals internally	Pro: Reduces burden, removes conservative tendencies of peer review Con: Limits expertise to one manager	US DARPA US NSF RAISE Japan Moonshot R&D Programme

Source: authors' analysis

Peer Review in Proposal Evaluations

The traditional mechanism used for project selection and research funding is peer-review. Most of the HRHR research programmes considered in this project use peer-review evaluation to make funding allocations decision but take steps to ensure that peer-review panels do not discourage HRHR research approaches. The Swiss National Science Foundation's Sinergia programme, began as a collaborative research programme and reformulated in 2016 to foster transformative research. It uses several strategies within its peer-review processes to ensure HRHR research is supported: requiring collaborative, interdisciplinary, and breakthrough research in all proposals; promoting the inclusion of early-career applicants as leads or team members. A dedicated standing peer-review panel has been set up to preserve a "Sinergia culture" for advancing the programme's aims, and a special emphasis is put on fostering the out-of-the-box aspects of proposals.[20]

The European Research Council incorporates considerations for fostering HRHR research in its peer-reviewed research grants. This project focused on analysis of the ERC's Consolidator Grants for mid-career researcher, but similar features are present for ERC's Starting Grants (early-career researchers) and Advanced Grants (for established researchers). The ERC designs its schemes with the following features to encourage HRHR research: 1. applicants know that, in order to be successful they must propose a truly ambitious project; 2. evaluators are strongly advised to reward risks; and 3. grants are substantial with a mean duration of 5 years.[21] ERC has a number of successful grantees who were previously rejected by their national funding agencies because their proposals were considered too risky.

NIH's HRHR research programmes explicitly cite the high-risk, high-reward nature of research proposals as a selection criterion in peer review. NIH's New Innovator Award programme, for example, states as a selection criterion: "The reviewers are looking for convincing evidence that the applicant is an exceptionally creative Early Stage Investigator who is proposing a bold new approach that has the potential to produce a major impact on a broad area of research relevant to NIH." In the Pioneer Award programme, applicants are told, "Particular emphasis will be given to the investigator's track record of creativity and impact, the innovativeness of the research approaches, and the potential of the project, if successful, to have a significant impact on an important research problem relevant to NIH." It should be noted that the peer review process differs within the four different NIH HRHR programmes: the Pioneer Award utilizes a three-stage evaluation process, the first two steps a traditional mail peer review followed by a peer-review panel and a third stage that includes an in-person panel interview; the New Innovator award and Early Independence award have a traditional mail peer review followed by a -review panel and a third stage review by a "Council of Councils" of high-level NIH personnel; and the Transformative Research Award uses *anonymised review* in the first two stages of mail and panel review, with biographical information then being included for 3rd panel review.

Multiple stages of review, as employed in NIH's HRHR research programmes are a common strategy for dedicated HRHR research programmes. Other programmes also use multiple review stages: the Research Council of Norway's ENERGIX programme uses a peer-review panel for the first stage, and in-person interviews for the second stage before an international referee panel. The same is true for the Netherlands'Off Road programme, the interview in this case taking the form of a 'pitch' or presentation by the applicants on their proposal, in which they are specifically questioned about the novelty or 'out-of-the-box' character of the work. Poland's MAESTRO programme also uses two stages, the first a proposal evaluation by peer reviewers and the second an interview.[22]

Canada's NFRF has five selection criteria for peer review panels to consider: interdisciplinarity, equity, diversity and inclusion (EDI); high risk; high reward; and feasibility. While criteria weighting varies between the Exploration and Transformation streams, each stream assigns the high-risk and high-reward criteria the heaviest weights. In three competitions since 2018, Exploration assigned weights of 40% each of the overall score to high-risk and high-reward, with project feasibility accounting for 20% and the two other

criteria – interdisciplinary and equity, diversity and inclusion – being assessed on a pass or fail basis. In comparison, the first Transformation competition will conclude in 2021 and weighted high reward at 60%, and high risk and feasibility at 20% each. EDI and interdisciplinarity were again pass or fail. Similarly, the Netherlands' Off Road programme makes a judgment on the 'out-of-the-box' character and originality of the research an explicit evaluation criterion, and weights it at 50% of the evaluation score.

UKRI's TRDF: Transformative Research Opportunities has 8 primary selection criteria, of which one relates to HRHR research: novelty of research. The Scientific Excellence criterion explicitly includes novelty and also significant potential for broader impact.[23] Poland's MAESTRO programme has "pioneering/ innovative nature of the research problem addressed" as one of 10 criteria.

There may be additional considerations for government funding schemes that promote HRHR research to address societal challenges. Here, relevance of potential research impact to making progress toward solving challenges is an additional factor in proposal evaluation, although this potential impact may be difficult to evaluate. HRHR research may complement other research that supports incremental progress towards defined challenges. Because expectations are high, support for research on "Societal challenges" can tend to favour 'what we already know' or 'more of the same'" and therefore funding agencies face additional challenges in established HRHR approaches alongside more-incremental approaches.[24] Complex societal challenges, such as the Sustainable Development Goals, require transdisciplinary research that combines perspectives from different disciplines and different stakeholders, in a process that is inherently high-risk with potential for high return. Such research has particular requirements in terms of funding and support that overlap and extend beyond those required for other types of HRHR (see (OECD, 2020[2]).

The OECD 2018 Competitive Research Funding report described some strategies for proposal-evaluation panels to protect highly transformative ideas from being dismissed as too risky or unlikely to succeed (OECD, 2018[1]). One is to combine referee scores in ways that can assist risky proposals [such as discarding low score(s)]. Another mechanism is to allocate each panel member a "gold" vote to allow them to protect a promising proposal even if other panel members think it would be too risky. The National Natural Science Foundation of China (NSFC) uses this approach, such that if a proposed project is deemed not suitable for funding by the majority of external reviewers, it may nevertheless be funded if it is recommended by 2 or more panel review experts on the basis of novelty. Other programmes have experimented with a "go/no-go" or stage-gate system in which projects evaluated as risky are funded for an initial trial period (a year) and must show some promise before receiving full funding.

One challenge identified by the 2018 report is counteracting the so-called "Matthew effect," in which peer review proposal evaluations rely on applicants' previous grant and publishing success rather than the merits of the proposal. This effect makes it difficult for new investigators with new ideas to be funded.

In response, some funders are experimenting by conducting proposal reviews without reference to CVs or researcher biographical information, putting the emphasis on the idea and not the person. The Swiss National Science Foundation, responding to challenges that became apparent in supporting HRHR research through its Sinergia programme, established the Spark programme in 2019 with the aim of supporting HRHR research specifically through innovative approaches. The main innovation in its peer-review panel system is the format of the application: it consists of a project plan only and is fully anonymized without CVs or other personal identifiers.[25] Another innovation is there is no panel discussion, only the aggregation of individual scores to discourage regression to the mean in individual reviewers' scores after group discussions. So far, there have been some practical challenges in implementation, including the difficulty in assuring that reviews are truly 'blind' and the challenge of reconciling discordant reviews. There is also an apparent gender bias (favouring male applicants), but nevertheless the early results are promising in terms of identifying and supporting HRHR research applications.

Even within a traditional peer-review process, there are actions that can be taken to foster HRHR research. At a minimum, funding agencies can instruct reviewers to reward or not overtly penalise risky proposals. The reviewers of RCN's AQUACULTURE programme are instructed to reward riskiness in their proposal reviews and not to be negatively influenced by high risk. Despite this guidance, programme managers found that it was difficult for international reviewers to support riskiness.[26] Overall, there is a notable absence of initiatives, in which reviewers have been explicitly trained in how to evaluate research proposals to reward risk, or assess potential high-reward impacts. Such training, if available, would be a useful complement to other efforts to ameliorate review processes.

One approach that the report does not specifically examine but that could be considered is raising success rates. If conservatism in peer review and discouragement of HRHR research is one result of low success rates, then it follows that raising success rates could be a mitigation strategy. But since the most straightforward way to increase success rates is to increase the total amount of funding available, as a strategy it is difficult to execute when budgets are limited.

There are other strategies to increase success rates, such as limiting the number of proposals or discouraging applications, but those are difficult to implement unless they involve a real dialogue between potential applicants and the funding programme management. Many of the HRHR research programmes considered for this report have success rates that are not substantially different from other research programmes. The four NIH HRHR research programmes, for example, have success rates that range from 10% to 24%, similar to the overall 19 percent NIH-wide success rate. Research Council of Norway's ENERGIX programme reports a success rate of 14%.[27]

The COVID-19 pandemic represented a serious and novel challenge to research proposal evaluation mechanisms. The pandemic spread rapidly and required an immediate response from researchers. Incremental approaches, looking for "low-hanging fruits", were often favoured in order to test existing solutions to this new disease. However, traditional peer-review mechanisms often proved to be inadequate in this emergency context and fast-tracked reviewing processes were implemented by most research funders. In parallel, the novelty of the disease and scale of the challenge encouraged some research funders and institutions to pursue HRHR using crowd-sourcing initiatives aimed at attracting ideas and input from research teams outside traditional research community silos (OECD, 2021[18]). Although the current activity did not analyse the new funding mechanisms that have been established, the lessons learned from the crisis may have a long-term influence on the way funders assess research proposals, including for HRHR research.

The programme manager review model

One approach to allocating funds while fostering HRHR research is to bypass peer review and rely on the judgment of funding-agency programme managers. The iconic example is US DARPA, which has relied on programme manager evaluation of competitive proposals for decades specifically to foster risk-taking approaches to mostly technological challenges. DARPA, whose model dates back to the late 1950s, selects programme managers, mostly on rotation from outside the government sector for 3-5 year terms, and empowers them to allocate research funding based on their own expert judgment rather than through a peer review process. Although there are internal reviews of allocation decisions at various levels of the organisation, there really is no external peer review of DARPA funding decisions, and often not even open calls for project proposals. Instead, simplified calls for ideas and concepts in short white papers tend to be used.

Perhaps surprisingly, although DARPA supports HRHR research, the agency is not especially long term in orientation. DARPA programme managers themselves rotate continually, so there is little institutional support for long-term projects. DARPA is known to prefer 'fast failures' to long-term successes, and therefore programme managers have the power to ask funded investigators to try different approaches or

even to terminate funding and redirect it to another investigator if a risky idea turns out to be unpromising. DARPA is thus prepared to accept unusually high short-term risk in allocating funding but tends not to have patience with research that does not quickly show at least some reward and fulfil intermediate, near-term technical milestones.

The DARPA model of a strong programme manager has been inspirational for HRHR research programmes around the world, most obviously in the US where other ARPAs including ARPA-E (energy), IARPA (national-security) intelligence, and BARDA (biological countermeasures) have followed. The model has been taken up in other nations. One notable example is Japan's ImPACT programme, which like DARPA recruits programme managers from industry or academia for up to 5-year secondments and empowers them to create and fund research teams to work on ambitious national challenges requiring risky research and technological breakthrough to solve.

For the Moonshot Research and Development Programme, which is a successor to the ImPACT programme, the equivalents to the DARPA programme managers are known as Programme Directors (PDs). The PDs in turn build a research portfolio (3 to 13 projects per PD[28]), respective projects being managed by Project Managers (PMs). PMs are granted authority and flexibility to promote their respective projects.[29] The PDs are appointed by the respective government agency, and the PMs are selected by the by the respective government agency in consultation with the PDs through open call process from academia and industry. Key to both PMs' and PDs' success is a wide social network of researchers inside and outside Japan with specialized knowledge relevant to the project, and the project management skills necessary to bring together and lead a diverse project team.

This programme-manager model can also be used by funding agencies that otherwise rely on peer review as a core proposal evaluation strategy. The US National Science Foundation (NSF), while holding to competitive peer review evaluation for most of its proposals, has introduced smaller programmes relying on programme-manager evaluation for making funding awards. One, the EArly-concept Grants for Exploratory Research (EAGER) programme, specifically aims to encourage "… exploratory work in its early stages on untested, but potentially transformative, research ideas or approaches. EAGER awards are evaluated according to the same criteria as all NSF awards – intellectual merit and broader impacts – in which one of the questions is "To what extent does the proposed activity suggest and explore creative, original, or potentially transformative concepts?" but programme managers also evaluate additionally and specifically the transformative and/or high risk/high reward nature of the concept.

The EAGER programme has the added benefit of reducing burden, both through simplifying proposals and removing the need to convene peer review panels (although programme managers have the authority to commission external reviews). Another burden-reduction strategy comes from its high success rate (generally about ~70%) which is related to an informal preselection mechanism: investigators must discuss their ideas with a programme manager before submitting a proposal. Another benefit is time: proposals can be reviewed and either rejected or funded in a fraction of the time of regular peer review.[30] The median length of awarded funding in the EAGER programme is 2 years, shorter than many of the other mechanisms discussed in this report and shorter than the 3-year median for all NSF awards.

The NSF also sponsors a related programme, the NSF Rapid Response Research Program (RAPID) which, is designed to support projects requiring rapid funding and thus has an expedited merit review process. The programme is specifically for projects "having a severe urgency with regard to availability of, or access to data, facilities or specialised equipment, including quick-response research on natural or anthropogenic disasters and similar unanticipated events." The RAPID mechanism is the primary mechanism by which NSF responded to the need to fund Covid-19-related research in 2020; this mechanism allows ideas to move from solicitation to proposal to evaluation to funding decision in a few weeks.[31]

This programme-manager-evaluation model is also used in the NSF Research Advanced by Interdisciplinary Science and Engineering (RAISE) programme to support interdisciplinary research. All RAISE awards must be HRHR research, as well as interdisciplinary. It is intended to foster bold interdisciplinary research and the projects are larger (up to USD 1 million) and longer (5 years) than EAGER awards.

1.2.4. *Project Management and Duration in HRHR Research*

There is a preference for longer than normal research awards among the HRHR research programmes identified in this report. The rationale is to take the pressure off investigators to quickly produce published papers or other outputs or to apply for follow-on research grants, instead offering them the opportunity to take riskier approaches that may not produce short-term results.

All four of NIH's HRHR research programmes, for example, provide 5-year awards, in contrast to average award length of 3 years in NIH's standard portfolio. The recently-launched Japan Moonshot programme also envisions 5-year projects (though with the possibility of projects as long as 10 years), as do DFG (the German Research Foundation Reinhart Koselleck Projects). Consequently, these programmes tend to offer larger total awards than other schemes, with the Reinhart Koselleck Projects offering up to EUR 1.25 million, or EUR 250 000 per year.[32] NIH's Transformative Research Award (TRA) has a 5-year standard award length and in addition states "No limit on budget."[33] DARPA's awards are 3 to 5 years in length for projects showing satisfactory progress.

Table 3. Project Management and Duration in HRHR Research

Options	Description/rationale	Pros and cons	Examples
Longer-term support	~5-year awards rather than the standard 3 years, to offer investigators the opportunity to take riskier approaches that may not produce immediate results	Pro: Eases pressure on investigators to produce immediate results or write follow-on proposals Con: large resource commitment for agencies	– NIH HRHR research programmes – Germany DFG Reinhart Koselleck Projects
Short-term support, or seed funding	6 months to 2 years; Used primarily to de-risk a promising research idea in advance of a potential full funding proposal	Pro: Seed funding can support exploratory work on ideas without a full commitment of resources Con: If successful, requires further funding	– Netherlands Off Road UKRI TRDF: Transformative Research Opportunities
Hands-off project management by funders	Offer more flexibility to investigators in HRHR research programmes by reducing the number of progress or project reports, reducing required paperwork, and otherwise reducing burden	Pro: Allows researchers to focus on research Con: Active management can be helpful to researchers	– NIH HRHR research programmes
Active programme management	Intense discussions and continual communications between programme staff and researchers	Pro: Allows for elaboration of ideas, problem solving around obstacles Con: Time and resource-intensive	– US DARPA – Japan Moonshot R&D Programme

Source: authors' analysis

Other programmes have taken slightly different approaches to extend the length of promising projects. France's OH Risque programme had a 2 x 2 year system in which successful applicants' projects were initially funded for two years, but with a Go/No-Go decision at that time leading potentially to two additional years of funding. The Go / No Go stage gate made it possible to minimize the financial risk for projects which, at the end of the second year, showed gaps or had encountered obstacles. DARPA's programme managers use similar approaches, periodically evaluating the progress of projects and making go/no-go decisions.

That said, other HRHR research programmes have shorter awards, although these programmes tend to be for exploratory research grants or seed funding. They provide small amounts of funding for a short period of time primarily to de-risk promising research ideas in advance of potential full funding proposals. The Netherlands' Off Road programme is an example; awards typically last for 12-18 months, with a cap of EUR 100 000 in funding. UKRI's TRDF: Transformative Research Opportunities provides funding for 6 to 18 months to develop early-stage ideas. In response to the Covid-19 pandemic, the US Department of Defense launched a HRHR research Newton Award for Transformative Ideas, which awarded 6-month, 50 000 USD awards to develop novel conceptual frameworks or theory-based approaches related to the pandemic. The expectation was that some of these Newton awards would lead to fully-funded research projects at a later stage.[34]

Among HRHR research programmes that use peer review, there is a tendency for programme managers to take a hands-off approach to project management. Funders have consciously tried to offer more flexibility to investigators in HRHR research programmes by reducing the number of progress or project reports, reducing required paperwork, and otherwise reducing the administrative burden. For example, NIH's four HRHR research programmes do not, unlike NIH's standard research grants, require detailed budgets as part of the proposal and therefore do not involve programme managers in detailed project management, following timelines, evaluating expenditures against budgets, etc.

Of course, for programme-manager review models the tendency is for programme managers to be highly active in project management. DARPA's hands-on project management style is legendary, involving monthly calls between managers and funded researchers, and more-frequent communications with intensive information exchange. Japan's recently-launched Moonshot R&D programme envisions an "elaboration period" to refine the proposed R&D projects through intense discussion between programme directors and selected project managers. This period will involve: refinement and elaboration of project ideas with scenarios; consideration of ethical, legal, and societal implications of research; and, specification of requirements for organizational and research infrastructures. Although less intense, the consultation is expected to continue throughout the entire project performance period.

1.2.5. *'People-based' awards as a HRHR research strategy*

Despite concerns about bias and exclusion, the balance of evidence suggests that the Matthew effect is at least partially due to the fact that many successful researchers are innately creative and risk taking and therefore come up with creative new ideas (Bol, de Vaan and van de Rijt, 2018[19]). Therefore, it is not surprising that the approach of funding solely the idea and not the person is not a strategy that is widely adopted by HRHR research programmes.

Rather, it is not uncommon for HRHR research programmes to support the person rather than the idea or project on the basis that project-based funding may discourage risk taking. The pressure to package a researcher's ideas into a discrete, 3 year fundable project favours established ideas or projects that are the logical extension of past research. Moreover, a project proposal creates the expectation that the researcher will strictly follow what has been proposed over the funded period, without allowing for the uptake of new ideas and approaches that may emerge over the course of the work.

'People-based' research awards give the recipients the freedom to be creative, sometimes for a longer time period than traditional project-based research awards, and allow researchers the flexibility to change course midstream in response to emerging research topics or even to recover from failed experiments. They also have the virtue of reducing paperwork and proposal-preparation burden; without descriptions of budgets, project milestones, and other features of a project proposal, people-based award applications can be shorter than a standard project proposal. One NIH HRHR research programme, the Pioneer Award, has a 5-page limit for its core research proposal section to be completed with a description of an investigator's suitability for an award, innovativeness, and ideas rather than details of a specific project.

NIH's other HRHR research programme applications are shorter also than standard NIH awards and focus on the investigator's qualifications, innovativeness, and ideas rather than on a specific project.[35]

Germany's Reinhart Koselleck Project scheme is midway between a project-based and people-based approach. Proposals are a maximum of 5 pages in length, and reviewers are asked to look for evidence that the PI(s) are capable of executing the HRHR research idea.

1.2.6. *Nongovernmental Organisations and HRHR Research Funding*

While governmental organisations provide the large majority of the resources allocated to HRHR research, non-government organisations, and particularly private foundations, can also play an important and complementary role. Nongovernmental organisations often have more freedom in defining their objectives and developing their operating procedures, and do not have the same financial accountability requirements as public organisations. This can lead them to be more risk-tolerant and/or be more prone to support research in unchartered territories provided that the research contributes to their overall mission.

In the United States, the Howard Hughes Medical Institute (HHMI) has been a leader in supporting research that may be too high risk for government funding agencies to support and has been successful enough that the US National Institutes of Health (NIH) has copied the HHMI approach in establishing its dedicated HRHR programmes. HHMI is a pioneer in placing 'big bets' on outstanding scientists and for supporting 'people not projects.'[36] Although the exact funding mechanism of HHMI - hiring most of its funded investigators as HHMI staff while allowing them to either remain at their home institutions or work from the HHMI campus - may not be replicable widely, the theory that such an approach would allow investigators to take on risky scientific ideas without fitting them into a defined-term project has worked well.[37] Other ingredients necessary to make people-based awards possible, including longer-term funding averaging 7 years at a time, have also proved to be durable. HHMI investigators are regularly evaluated in seminars and other presentations to HHMI staff.

Denmark's Lundbeck Foundation, recognising some of the previously mentioned limitations of peer review, has set aside 10% of its research funding on alternatives to classical peer review evaluation to identify the most-deserving innovative grants. This funding has allowed for experiments in proposal evaluation, including: use of anonymous proposals to force reviewers to focus on the idea not the person or CV; allowing review panel members one decisive 'golden vote; and, a combined peer review and lottery system for some competitions, the lottery serving to reduce both proposer and reviewer burden.[38]

Nongovernmental organisations supported by public funds also support HRHR research. One example is the Human Frontier Science Programme (HFSP), which has been established and financially supported by national governments as "an international collaboration in frontier life sciences research" with a specific remit to support "high-risk, interdisciplinary, intercontinental, collaborative, fundamental life science research." and "transformative and paradigm shifting research".[39] The HFSP distributes research grants and postdoctoral fellowships through a peer-review process that takes into account the riskiness or potentially transformative nature of research proposals.[40]

1.2.7. *Scientific prizes and HRHR*

Another potential way of allocating research funds is the use of incentive prizes or challenges. This is a promising approach with long historical roots. In the 18th century, the original incentive prize was offered by Great Britain's Parliament for an accurate method of determining a ship's longitude to any inventor who could provide a solution. Incentive prizes, where a cash reward is offered to a scientist or other inventor who can provide the solution to a scientific or technological challenge, have been used by national governments and other funders since then.

In recent years, governments have expanded the uses of prizes and challenges specifically to foster more high-risk, high-reward approaches to solve societal and scientific problems. The United States, in legislation enacted in 2010, granted all US science agencies the authority to conduct prize competitions to spur innovation.[41] A progress report on the legislation states: "Prize competitions and challenges have an established record of spurring innovation in the private and philanthropic sectors. This progress report details examples of how well-designed prize competitions and challenges, integrated into a broader innovation strategy, have enabled Federal agencies to: pay only for success and establish an ambitious goal without having to predict which team or approach is most likely to succeed; Reach beyond the "usual suspects" to increase the number of solvers tackling a problem; and to identify novel approaches, without bearing high levels of risk…"[42]

The progress report points out one advantage for funding agencies in using incentive prizes for fostering HRHR research: it is low risk for the funding agency because the risk is borne by competitors for the prize, and the agency pays out only if there is a successful result. But it is high risk for competitors because they bear all the financial costs of conducting research toward a prize, with no guarantee of being compensated. As such, this tool is not applicable in many circumstances, and is primarily useful for well-defined scientific and technical challenges where competitors have the possibility of recouping some costs (through patents, new commercial products) even if they are not successful in the competition. But the other advantages are potentially compelling for funding agencies: paying only for success, reaching a broader community than an agency's usual funded researchers, and identifying potentially novel approaches by specifying a desired result without specifying an approach.

HRHR research-oriented agencies such as DARPA have used incentive prizes (such as the series of DARPA Grand Challenges)[43] to engage a broader community of researchers than the traditional applicant pool for scientific research grants, and to encourage 'out-of-the-box' ideas that might not be reviewed favourably in peer review. Nongovernment organizations such as the X Prize Foundation also use incentive prizes to encourage high-risk high-reward approaches to solving scientific and technical problems, including a recent prize competition for developing rapid covid-19 testing solutions.[44] The X Prize Foundation in particular has longstanding experience in using incentive prizes, dating back to 1994. Funding agencies are already experimenting with mixed grant/prize models for fostering HRHR research. Ireland's Future Innovator Prize, for example, operates mostly as a standard multi-stage research grant competition to foster HRHR research, with winners of the first competition stage receiving a small starter/idea/validation grant followed by a smaller group of second-stage competition winners receiving a larger research grant.[45] But the innovation is that one team receives a 'prize' of additional research funding to further develop their idea at the end of the second-stage period. Thus, this model incorporates the competition element that is key to incentive prizes along with peer-review selection to identify proposals for funding.

1.2.8. *Importance of a Portfolio Approach*

The study heard repeatedly from programme managers and policymakers on the importance of taking a portfolio approach to supporting HRHR research, so that considerations of risk and reward are placed at the research portfolio level rather than the individual project level.

The portfolio approach to managing science is an imperfect analogue to managing investment portfolios, where multiple investments are grouped together for analysis and financial return (as well as investment risk) is evaluated at the portfolio level rather than analysing each individual investment. For financial investments, a portfolio approach is a tool for managing risk and maximizing financial returns. Similarly, when research projects are grouped together and evaluated as a portfolio, then both the high-risk part and the high-reward part of HRHR research can be managed. If high-risk high-reward research projects are risky enough that, for example, one in ten projects will really produce new knowledge or a significant

impact, then there is unlikely to be political support for continuing a research programme in which 90% of projects are not delivering expected breakthrough, and there will be pressure to reduce the riskiness of research projects. But if programme managers build portfolios of projects, then a portfolio of 10 projects would, in the same example, be likely to yield at least one major success, and if the HRHR research projects are truly high-reward then the successful knowledge or impact of the one project could more than justify the investment in 10 projects.

Managing at the portfolio level enables risk-taking and allows impacts from successful projects to be balanced against less successful projects. It also allows programme managers to place 'bets' on multiple potential approaches to a challenge or scientific question and to consider these multiple approaches as a systemic whole instead of a collection of individual projects (Wallace and Rafols, 2015[20]).

A portfolio approach can actually be used at different levels of the system:

- At the programme level, as described above, to spread the risk over different research projects; this often means that the programme management or evaluation panel requires a certain level of discretionary power to support a percentage of HRHR proposals;
- At the agency level, to have a mix of traditional and HRHR funding schemes, the latter often having a different selection process;
- At the national/strategic level, to allow for mission-oriented or priority programmes on selected areas in which a country wishes to foster breakthroughs and is ready to accept higher risk in the use of public funding.

The interest of having a portfolio approach was underlined by several experts at the project workshop, both to ensure support in a political system adverse to perceived failures and to allow programme managers and researchers to support risky research ideas in reaching for ambitious impacts.

Finally, a portfolio approach may also be of interest in the impact assessment of HRHR research funding schemes. While traditional research funding programmes tend to be evaluated through the use of bibliometric indicators applied for every and each of the funded projects, this methodology has little meaning for HRHR research programmes, as each individual project has a higher risk of not delivering the expected results on time. However, when considered together, a portfolio of HRHR research projects may be delivering higher-impact publications (with greater novelty – see ahead section 2.4) than a similar portfolio of 'standard' projects.

1.2.9. *Internal or Institutional Funding to Support HRHR Research*

There is potentially an important role for core or non-competitive institutional funding in supporting HRHR research. Traditionally, core funding - such as the research funding provided by universities to their investigators on the basis of a standard formula or as part of recurrent annual research support provided without competition - has served as a guaranteed source of stability for generations of researchers. The thinking is that such core funding allows researchers to pursue their risky, innovative, or potentially transformative ideas without fear that a failure would cost them the next competitive research grant or, for non-tenured researchers, their job. But it is equally plausible that formula funding entrenches conservatism by allowing researchers to keep pursuing the next incremental steps of their ongoing research without external accountability. Unfortunately, there is little research indicating which effect predominates in core funding.

Core funding can also encourage competition and HRHR research if a share is allocated to specifically encourage HRHR research. The University of California Irvine (UCI), for example, provides internal funding (supplemented when available by unrestricted philanthropic research funding) to faculty researchers through a competitive process in which faculty research ideas are peer reviewed by internal faculty-led

teams. These relatively modest awards (in comparison to US federal research awards) allow funded faculty teams to do preliminary work on research ideas, which serve to de-risk new ideas and may eventually lead to full-scale research awards from federal research funding agencies.

Other US universities have similar programmes: the University of Michigan, for example, in summer 2020 concluded a 7-year MCubed programme to use internal funds to seed teams for preliminary de-risking research on high-risk research ideas.[46] An intriguing feature of this programme is that a proposal required at least three researchers from at least two different university departments; thus, in addition to fostering HRHR research it also fostered interdisciplinary research.

Similarly, in France, competitive research funding schemes provided at the national or European level are not generally considered to be supportive of HRHR research, and neither are evaluation policies and career incentives for laboratories and researchers. Paris Sorbonne University, like UCI, finds institutional core funding alone too limited to adequately support HRHR research throughout the whole university, as most core resources go to basic operations of laboratories. This is why Sorbonne University decided to set aside enough resources for its own internal seed-funding mechanism for HRHR research (Emergence) and at the same time supported the creation of multidisciplinary institutes which have, among other goals, the objective to foster innovative solutions related to societal challenges. The Emergence programme is limited to 100,000 euros per project, enough for seed funding to de-risk an idea but not to carry out a complete project, and limited in time to 24 months, again not sufficient for a full project.

Although these examples demonstrate that internal core funding can be deployed to support HRHR research, many research institutions face a difficult challenge as these resources are increasingly used to cover fixed costs. There is often little left to support risky projects, even if researchers often prefer this type of funding with no strings attached which, in theory, allows for more risk taking. Rather than using core resources spread over all their research units to support HRHR research, research providers may be able to better foster HRHR research using a competitive process for allocating their limited “free” internal funds in order to provide a critical mass to specific projects.

1.2.10. *Impact Evaluation of HRHR Research Programmes*

An underdeveloped aspect of HRHR research funding mechanisms, and indeed research funding in general, is impact evaluation. This study found few examples of HRHR research programmes that have been rigorously evaluated to assess whether they have indeed fostered risk-taking or have helped to produce higher rewards or more significant impacts than other approaches. Many of the programmes that were surveyed reported that they were established too recently to conduct an impact evaluation, recognizing that research impacts are often apparent only over the longer term, especially for fundamental research and other research at the (risky) frontiers of knowledge. Indeed, a significant proportion of the programmes in the inventory have been established in the past decade, meaning that for 5-year project funded after a 1 or 2-year start-up period the scientific and other impacts are only now beginning to appear.

Some longstanding HRHR research programmes have conducted impact evaluations, looking at not only scientific, economic, and societal impacts but also at the programmes’ capacity to foster risk taking in research. The ERC has evaluated its programmes annually in recent years, using both qualitative and quantitative measures with specific questions in the qualitative impact evaluation on whether funded projects were HRHR research projects and whether the risk component influenced the research results.[47]

The NIH HRHR research programmes have been repeatedly evaluated and found to foster not only enhanced impacts but also to foster researchers’ willingness and ability to move beyond incremental research toward high-risk research.[48] US DARPA’s portfolios have been continually evaluated over the decades of DARPA’s existence with a rigor made possible by DARPA’s defence mission, permitting DARPA programme managers to set and track progress toward ambitious yet well-defined technical

targets (Reed, 1990[21]) (Carpenter, 2008[22]). Norway's AQUACULTURE is notable in that its home agency, the Research Council of Norway, has undergone numerous external evaluations[49] which have demonstrated that RCN systems for evaluating projects for funding were too conservative, fostered incremental research, and did not support radical changes. In response, AQUACULTURE and FRIPRO, another Norwegian HRHR research programme, were developed to foster HRHR research.

There appears to be little consistency in impact evaluation methodologies. There is no standard 'formula' for evaluating HRHR research' success in fostering either high risk or high reward. One reason for the lack of a standard is, as stated previously, the lack of a standard category of "HRHR research", of standard proposal evaluation procedures and programme management, or of a standard impact objective among programmes aiming for a variety of scientific, technical, economic, or societal outcomes. The main consistency among impact evaluations, where they have been conducted, is the commissioning of an (internal or external or combination) expert panel to evaluate programme impacts[50]. Expert judgment, a standard feature of peer review whether of papers, proposals, or programmes, is a de facto best practice as it is the only consistent practice. There are a few exceptions to this, where contract evaluators or programme staff have conducted evaluations.

There are other forms of programme assessment. The US NSF commissioned an assessment of its INSPIRE programme[51]. Though not an impact evaluation per se, it did evaluate whether projects submitted, reviewed, and awarded under the pilot were different than those under other NSF funding opportunities. The majority (70 percent) of INSPIRE PIs reported that they had not submitted their INSPIRE project to another funding mechanism and thought that it was unlikely or very unlikely that their project would have been funded outside of INSPIRE. Eighty percent of INSPIRE PIs indicated that they proposed their most high-risk, high-reward research ideas to the INSPIRE programme. In addition to an analysis of the awards and a comparison of these awards with similar, non-INSPIRE interdisciplinary awards, this analysis sought input from a panel of experts who reviewed INSPIRE and non-INSPIRE awards to assess whether INSPIRE funded interdisciplinary and potentially transformative awards differently than other NSF programmes. The expert reviewers scored INSPIRE summaries significantly higher for high-risk and out-of-the-box/original characteristics, although they were indistinguishable on the characteristics related to interdisciplinarity.

Evaluation panels do not rely solely on expert judgment. Such panels often rely on data collected or compiled by programme managers to assist in panel deliberations, including but not limited to bibliometric data on funded projects, researcher bibliometric and other data, investigator reporting on project outputs and outcomes. Occasionally in-person interviews with, or presentations by, funded investigators are also organised.

These data are not specific to riskiness or reward, and so they may be helpful but not determinative in evaluating whether a programme fostered HRHR research. There is room to improve the methodologies for evaluating the high risk and high reward aspects of research programmes, with one priority being to develop standard indicators that could be used by evaluators (see ahead 2.4).

1.3. Contextual Factors and Supporting Policies

In addition to policies for funding research, this project also examined contextual factors that result in a supportive environment for HRHR research and non-funding policies that have been instituted in order to create a more conducive environment to perform HRHR research. These contextual factors and supporting policies, although insufficient by themselves to foster HRHR research in the absence of the necessary research funding, are important for ensuring the success of HRHR research funding schemes.

1.3.1. *Political Support for Risk-Taking and Long-Term Orientation*

Perhaps the most important contextual factor underpinning public investment in HRHR research is long-term political support for risk-taking in research. Long-term support requires patience, which may be in short supply among policymakers who are eager for tangible results to justify public investments in research. Long-term support also requires a tolerance for failure, the nature of high-risk research being that many projects will 'fail' in the sense that they will not produce highly-cited published results, or economic or societal impacts. Again, failure tolerance (or risk tolerance) is often a challenge for policymakers who are well aware of the political price to be paid from supporting public investments that yield no tangible outcomes.

In addition to the iconic example of US DARPA programme, there are several striking examples of successful HRHR research requiring long-term patience and risk tolerance among policymakers. One such example is the US NSF's decades-long support of research, infrastructure, and facility operations at LIGO (the Laser Interferometer Gravitational wave Observatory), two laser-based scientific facilities designed to explore the existence of gravitational waves as predicted by Albert Einstein nearly a century ago.

NSF support for LIGO began in the late 1980's when the project was truly risky and the technologies needed to detect gravitational waves did not exist and had to be developed specifically for the project. The high reward came only in 2015 when the LIGO facility, in its early operations, detected and thus proved the existence of gravitational waves, thereby confirming a key part of Einstein's General Theory of Relativity and creating an enormous impact on our understanding of the universe. At numerous times over the preceding decades, US policymakers came close to cancelling or curtailing the LIGO project, but patient and risk-tolerant political support was just strong enough to see the project to completion[52].

Another similar example is the decades of international support for CERN to build and operate the Large Hadron Collider (LHC) despite the risk that the LHC would not discover anything. Fortunately, the new LHC in its early research operations provided the reward and discovered the Higgs Boson, another predicted and important part of our understanding of the universe.

Such long-term support is not easy for governments to provide. Around the world, the political context is that high reward is attractive to governments, but high risk is challenging because public organisations have a strong accountability pressure on their expenditures of public funds. Long-term political support may be provided by government or institutional policies. They can take the form of legislation, official statements by research funders and national research ministries, and declarations by national academies, or statements by multinational bodies such as the Global Research Council. Examples of such policies and statements can be found throughout this report. They signal commitment by nations and funders to support HRHR research, and although such signals are insufficient to foster HRHR research without other policies and practices they are nevertheless guides for programme managers, researchers, university administrators, and others involved in supporting and conducting research.

One potential contextual policy that has not proved to be useful however is setting numerical targets for HRHR research. This activity could find no evidence that any nation other than the United States has attempted to set numerical targets, perhaps because the US experience is widely regarded as unsuccessful. The America COMPETES Act of 2007, in addition to defining HRHR research also, as summarised by the US Government Accountability Office (GAO), "expresses the sense of Congress that each executive agency conducting research in STEM fields should strive to support and promote innovation by setting a goal of allocating an appropriate percentage of its basic research budget toward funding high-risk, high-reward research".[53] The report calls for US funding agencies to devote at least 8% of research budgets to high-risk research. It also requires US federal science agencies to provide annual

reports to the Congress on progress toward setting and meeting the goal. Three years after enactment of the legislation, the GAO found that agencies did not consistently set funding goals for HRHR research and did not consistently report on progress. In subsequent years, agencies did not make further progress. Similar numerical targets were not adopted by other US science agencies or by other national research funding systems.

1.3.2. *Tenure, Promotion, and Advancement Policies at Research Institutions*

In the interviews that were conducted for this report, it was repeatedly stated that tenure, promotion, and career advancement policies at academic research institutions are an important contextual policy influencing HRHR research. As academic researchers are evaluated primarily on research accomplishments as defined by funding and research publications or bibliometric indices such as the H-index, there are powerful incentives for such researchers to be conservative in their research in order to be more certain of securing these easily-quantified outputs. This effect appears to be particularly important for early career researchers (OECD, 2021[18]).

To counteract these incentives, academic research institutions have the opportunity to adjust their tenure and promotion policies to encourage researchers to pursue high-risk high-reward research. In the Netherlands, for example, the Dutch Protocol for Research Assessment was revised in 2020 to shift away from traditional indicators toward new elements, including an emphasis on quality (rather than quantity) of work, focus on team performances, open science, and academic leadership[54]. Although not motivated solely, or even primarily, to foster HRHR research, this shift in assessment is expected to have a positive impact on HRHR research.

Some Universities and research providers have de-emphasized publications and publication indices in evaluating their faculty specifically to encourage more risk taking in research. Others have established internal funding schemes, discussed in the previous section, to specifically support research projects that may be too risky for national funding agencies to support. The University of California Irvine (UCI), assuming that frontier and risky research is increasingly done by teams instead of lone investigators and that faculty need training to work well in teams, has established a Team Scholarship Accelerator Lab[55], which brings together team research experts, best practices in problem solving, a web site, and other resources. One important tool this lab has developed is a template for articulating individual contributions to team science. This tool then becomes important for the promotion and tenure system by focusing evaluations of researchers on actual contributions rather than quantitative indicators or other simplistic metrics that may discourage HRHR research.

There is widespread dissatisfaction with current tenure, evaluation, and promotion systems. Indicators for the evaluation of both labs and researchers do not reward risk-taking. There is a recognised need and demand for updating current evaluation criteria. In France, to take just one example, research assessment is largely conducted by external bodies (HCERES[56] for labs and institutions, CNU[57] for university staff) using traditional criteria for research excellence that do not take into account HRHR research, technology transfer, and other valuable research outputs. It is only when French laboratories are assessed explicitly as to whether they are at the frontier of research that they may be rewarded to some extent for doing HRHR research that has proved to be successful.

Indicators for HRHR Research

Appropriate indicators, when used judiciously, can also help to foster HRHR research by quantifying the 'riskiness' of a research project or portfolio, allowing researchers, research managers, and others to adjust risk to an appropriate level. As risk indicators in the financial sector allow financial managers to balance risk among investments in a portfolio or determine the riskiness of a specific investment, scientific risk indicators can help research managers and policy makers to estimate, increase or decrease desired risk at the project, portfolio, or programme level. Scientific riskiness indicators have long been sought by policymakers (Koizumi, 2011[23]), and in 2020 they are becoming more robust and usable thanks to an increasingly active 'research-on-research' community.

There have been recent advances in building quantitative indicators for HRHR research. For example, to identify transformative innovations, Funk and Owen-Smith developed a measure known as the CD index. This index uses networks of citations to describe the degree to which ideas (embedded in papers or patents) consolidate or destabilize the scientific or technological status quo (Funk and Owen-Smith, 2017[24]).

Similar research is underway to determine the potential transformation of a given research project based on a quantitative measure of intellectual distance from existing work derived from citation and other research-output data. As yet, these advances and ongoing experiments are retrospective and can be utilised only after a research project has resulted in an output such as a publication or patent. There are no proven tools in the literature for identifying a priori the potential for transformation of a research idea, or of identifying the riskiness of a proposal. Even the retrospective measures are not yet robust enough to fully evaluate the effectiveness of research funding schemes at encouraging risk taking in research or delivering transformative results, but they do provide better information on these criteria than traditional bibliographic indicators.

Quantitative indicators of scientific novelty can support policymakers in assessing whether policies are successfully promoting HRHR research. In this regard, the indicator of scientific novelty explored in Wang, Veugelers and Stephan (2017[25]) has potential to capture both the "high-risk" and "high-reward" elements research. Researchers take high risks when trying to explore novel scientific ideas and many of those novel ideas tend to fail. However, some will be successful and become major hits with potential to completely revolutionise the scientific paradigm. HRHR research outputs are likely to be associated with multiple knowledge characteristics, but novelty is particularly well-suited capture the essence of HRHR. Articles scoring high on novelty according to this indicator presented higher variance in terms of citations, suggesting that while many novel articles have a low number of citations, a small fraction of them come to be recognised as scientific breakthroughs with high levels of citations.

A test to further assess the potential of novelty indicators for science policy was carried out during this study (see Box 1 and Machado, 2021). The novelty indicator used by Wang, Veugelers and Stephan (2017[25]) was computed at micro level and aggregated per country, year and scientific discipline. The goal was to test the utility of the indicator to assess countries' performance stimulating risk taking and highly novel research.

Box 1. Proof-of-concept: Novelty indicator to assess HRHR research performance

In this study, a novelty indicator was computed at the level of scientific articles and aggregated at the level of scientific fields, countries and years. Each article had a unique novelty score based on how it is combining different knowledge fields in unexpected/unusual ways. Knowledge fields were represented in terms of scientific journals, which are an imperfect but commonly used proxy. Following the same methodology as in Wang, Veugelers and Stephan (2017[25]), the patterns of journal citations contained in articles' references were explored to measure the extent to which articles are combining knowledge fields in more exploratory/risky ways, the computation making use of SCOPUS Custom Data, Elsevier, Version 5.2019.

Using this method, results showed that for all the considered years, more than 50% of all articles score zero or one in terms of novelty, reflecting the fact that most articles do not attempt to make novel combinations of knowledge fields. Just a very small minority score very high (10 or higher) on the novelty indicator. On average, for the period of 2005-2017, the countries with the highest share of articles scoring among the top 10% most novel in the world were the Netherlands, Switzerland and Denmark followed by the United States and the United Kingdom.

These are also countries that tend to score very high in terms of scientific impact measured through citations. In order to further investigate the relationship between novelty and impact at the country level, the share of articles scoring among the 10% highest novelty against the share of articles scoring among the 10% top cited was analysed. This showed that taking high-risks by making novel combinations of knowledge fields seems to be associated with high-reward, the relationship between novelty and impact, measured with forward citations being positive and strong. The citation performance within articles scoring very high on novelty presented higher levels of variance, with many of the highly novel articles receiving no or very low numbers of citations and others becoming the most highly cited. The overall citation performance of highly novel articles is similar shortly after publication, but increases over time and becomes substantially superior when considering a longer time window. Further details on the methodology used for this case study and on the results generated can be found in the working paper developed in parallel to this activity (Machado, 2021).

While this novelty metric is not a substitute to citation-based indicators, it is a valuable complement. Citation-based indicators such as JIF and H-indexes should not be used in the short-term because they can be biased against novelty and risk-taking, but this novelty indicator is of short-term nature — the indicator can be computed at the time an article is published (or at the research proposal stage if the key references are available). When taking a long-term perspective, the novelty indicator is positively related with citations. Thus, combining the two indicators has potential to help manage risk and reward in portfolios of research projects, making sure that enough risky projects get funded (highly novel) and that in the long-term the portfolio delivers the expected level of reward/research impact (citation performance).

Such indicators are still new, and face challenges including the need for large data sets and high computational intensity. Like most publication-based indicators, they are also mostly retrospective, with time lags inherent between award and research and publication. While not perfect for making ex ante decisions such as proposal evaluation, they could nevertheless provide useful information on the novelty character of earlier work performed by applicants, and thus be more informative than traditional bibliometric indicators. Furthermore, they can be a useful tool for ex post evaluations of high-risk high-reward research to evaluate whether a funding mechanism or policy has indeed fostered this kind of research.

Conclusion and Recommendations

In this conclusion, it is useful to return to the initial questions driving this project.

In response to the question 1) "What different funding instruments are being used and what are their advantages and disadvantages?" this report puts forward an inventory of HRHR research programmes with differences among multiple dimensions. Key differences lie in:

- the degree to which funding programmes centre HRHR research, with supporting high risk, high reward research either as a primary objective in a dedicated programme, a secondary objective, or as one of many objectives;
- the use of peer review or a programme manager in evaluating proposals;
- for peer review, the use of a standard peer review panel or alternate approaches;
- different durations of awards; and
- the use of people-based or project-based awards.

Within these funding instruments, there are few one-size-fits-all solutions and no clear advantages or disadvantages. Rather, the most advantageous approach depends crucially on context. For award duration, for example, this report finds that larger, longer awards (~5 years) can support long-term, ambitious projects rather than the standard ~3 year award and may be advantageous in allowing investigators to take more risks and a more long-term orientation in their research. Shorter and smaller awards of less than two years can be useful to support proof-of-concept research and to 'de-risk' high-risk proposals, which can then be supported by standard awards.

To the question 2) "What evidence (if any) exists of the effectiveness of these different instruments?" here the evidence is largely lacking. Although a number of HRHR research programmes have been evaluated, many have not been evaluated rigorously because of their relative newness, and the ones that have been evaluated have been evaluated by expert panels with a mixed record of utilizing quantitative or qualitative evidence. That said, in the near future there will be more of an evaluation literature on HRHR research programmes as experimental programmes from the past decade are evaluated. And there are growing options for indicators to help evaluate HRHR research programmes.

To the question 3) "What is the most appropriate instrument to use in a particular context?" the report makes clear that there is no single appropriate instrument to use in a particular context; rather, decision makers have several options to choose from in designing a HRHR research funding scheme, along the multiple dimensions listed above. Being clear on the strategic objective of the programme should help narrow down the options.

To the question 4) "Are there alternative and/or complementary non-funding policies that can be implemented, and in what context?" this report highlights a few ideas for complementary policy approaches. Those include research institutions policies such as revised tenure and promotion policies.

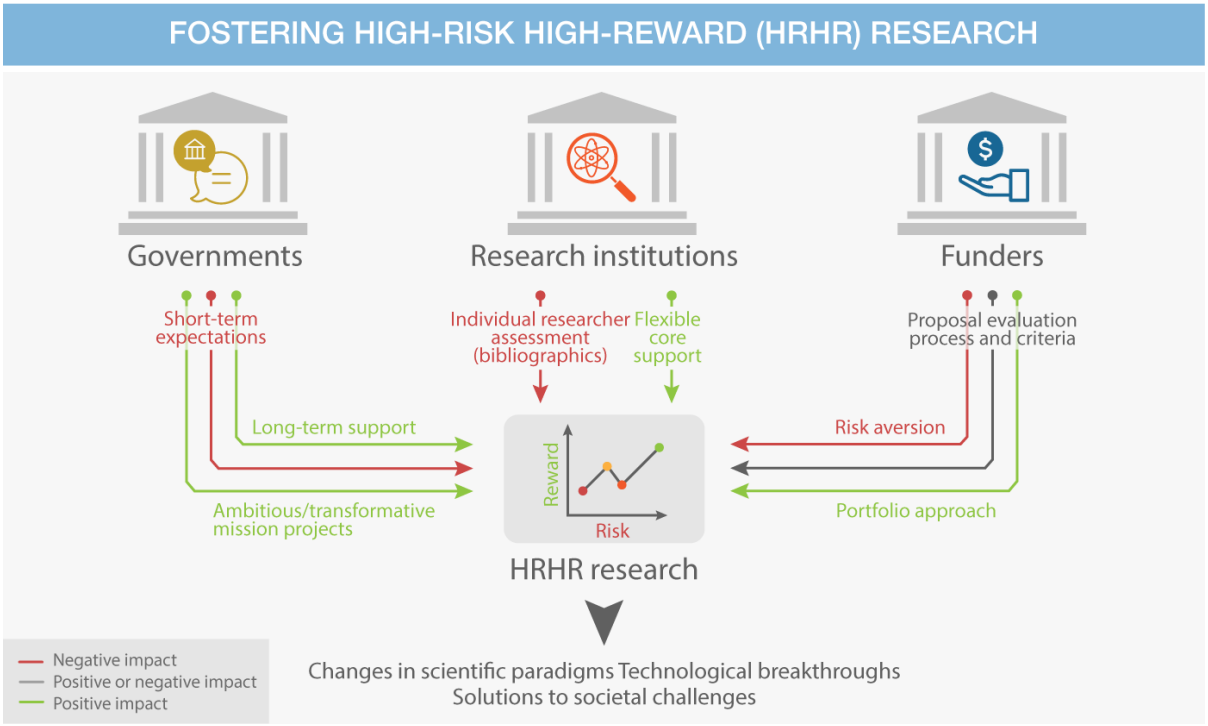
For the final question 5) "What are the roles, responsibilities and constraints of different actors in promoting high-risk research?" the answers appear clearer:

- policymakers can provide political long-term support for risk--taking and long-time horizons for research, in addition of course to robust funding of scientific research;
- Science funding agencies can implement dedicated HRHR research funding programmes that support HRHR research as their principal aim, and adjust other funding schemes so that they encourage rather than discourage HRHR research. There are many opportunities to build on existing experience and experiment with different approaches for fostering HRHR research within competitive funding processes; and

- Research institutions can nurture careers for innovative researchers by rewarding risk-taking rather than conservatism and provide seed or bridge funding to incentivize HRHR research.

Promoting HRHR research is a shared responsibility between governments, research institutions and funders. This report offers multiple ideas and good practices for each of these actors to promote HRHR research. A summary of the potential role and influence of the different stakeholders is presented figure 1.

Figure 1. Impact of research stakeholders on HRHR research



From this report's findings, the Expert Group offers some recommendations for further study and action to extend this project's findings, with the caveat that linking the evidence to recommendations is not straightforward as evidence for many programmes' effectiveness at fostering HRHR research is lacking.

These recommendations are detailed at the beginning of this report and can be summarised as follows:

1. Research funders are encouraged to experiment with existing and new approaches to foster HRHR research, e.g. adjusting reviewing processes and evaluation criteria.
2. Government policymakers and research funders are encouraged to implement a portfolio approach in the management and evaluation of HRHR research.
3. Government policymakers, research funders, and research institutions are encouraged to implement contextual/institutional policies and practices to encourage researchers to take scientific risks.
4. As newly established HRHR research programmes mature, research funders are encouraged to evaluate their impacts rigorously, not only their scientific, societal, and economic impacts but also evaluating the programmes' impact at fostering HRHR research.
5. Interested authorities and researchers are invited to further research, develop, and test indicators for evaluating the riskiness of research.

6. Funding agencies are encouraged to collect and share efficiency and process information on HRHR research programmes in comparison to more-traditional research programmes

In summary, there is growing interest among nations in designing policies and programmes to foster HRHR research and many lessons to be learned from existing practices. The findings in this report should aid nations and research institutions in formulating policies and strategies for fostering HRHR research and in maximising impact and evaluation.

Endnotes

[1] https://stip.oecd.org/stip.html. STIP Compass is a joint initiative of the European Commission and the OECD that aims to collect together in one place quantitative and qualitative data on national trends in science, technology and innovation (STI) policy.

[2] Virtual workshop on "Effective Policies to foster High-Risk/High-Reward research", OECD Global Science Forum, 22 April 2020. Presentations and summaries can be found at https://community.oecd.org/docs/DOC-170560.

[3] https://www.oecd.org/coronavirus/en/policy-responses.

[4] European Commission, Enterprise and Industry Directorate-General. "New and Emerging Science and Technology (NEST) Programme." 2005, https://slideplayer.com/slide/2267295/ .

[5] Response from DFG to the Expert Group survey questionnaire.

[6] https://www.jsps.go.jp/english/e-first/index.html.

[7] https://arpa-e.energy.gov/.

[8] US National Institutes of Health, "High-Risk, High-Reward Research Program," https://commonfund.nih.gov/highrisk.

[9] One example is National Health and Medical Research Council (NHMRC), the Australian Research Council (ARC) and Universities Australia (UA), *National Statement on Ethical Conduct in Human Research (2007) updated 2018* https://www.nhmrc.gov.au/about-us/publications/australian-code-responsible-conduct-research-2018.

[10] Response from the Off Road programme to the Expert Group survey questionnaire.

[11] See program web site at: http://www.sshrc-crsh.gc.ca/funding-financement/nfrf-fnfr/index-eng.aspx. This description is for the NFRF Exploration program.

[12] https://stip.oecd.org/stip.html. STIP Compass is a joint initiative of the European Commission and the OECD that aims to collect together in one place quantitative and qualitative data on national trends in science, technology and innovation (STI) policy.

[13] https://anr.fr/en/call-for-proposals-details/call/oh-risk/.

[14] Response from UKRI to the Expert Group survey questionnaire.

[15] https://www8.cao.go.jp/cstp/english/moonshot/top.html

[16] Response from the National Science Centre Poland to the Expert Group survey questionnaire

[17] Response from the ENERGIX programme to the Expert Group survey questionnaire

[18] https://gacr.cz/en/types-of-grant-projects/

[19] https://www.jst.go.jp/moonshot/en/application/202002/pdf/presentation_e.pdf.

[20] "*From traditional funding schemes toward more out of the box research*," presentation by Marc Zbinden, Swiss National Science Foundation, for the OECD workshop April 2020, https://community.oecd.org/docs/DOC-170560.

[21] "*The European Research Council (ERC)*," presentation by Jean-Pierre Bourguignon, former president of the European Research Council, at the April 2020 OECD workshop, https://community.oecd.org/docs/DOC-170560.

[22] https://www.ncn.gov.pl/ogloszenia/konkursy/maestro12?language=en.

[23] [ARCHIVED CONTENT] TRDF: Transformative Research Technologies - BBSRC (nationalarchives.gov.uk)

[24] "*High Risk / High Reward Research, HRHR programmes on societal challenges"*, presentation by Professor Jens Oddershede, Former Chairman of the Danish Council for Research and Innovation Policy, for the OECD workshop April 2020, https://community.oecd.org/docs/DOC-170560.

[25] "*From traditional funding schemes toward more out of the box research*," presentation by Marc Zbinden, Swiss National Science Foundation, for the OECD workshop April 2020, https://community.oecd.org/docs/DOC-170560.

[26] Response from RCN Aquaculture to the Expert group survey questionnaire

[27] https://www.forskningsradet.no/en/about-the-research-council/programmes/energix/

[28] https://www8.cao.go.jp/cstp/english/moonshot/top.html

[29] https://www.jst.go.jp/moonshot/en/application/202002/pdf/presentation_e.pdf

[30] Response from NSF EAGER programme to the Expert Group survey questionnaire. See also NSF's Proposal and Award Policies and Procedures Guide https://nsf.gov/pubs/policydocs/pappg19_1/pappg_2.jsp#IIE2

[31] https://www.nsf.gov/pubs/2020/nsf20052/nsf20052.jsp

[32] https://www.dfg.de/en/research_funding/programmes/individual/reinhart_koselleck_projects/.

[33] https://commonfund.nih.gov/highrisk/table.

[34] https://basicresearch.defense.gov/News/Articles/News-Display/Article/2273610/dod-announces-recipients-of-the-newton-award-for-transformative-ideas-during-th/

[35] National Institutes of Health, High-Risk High-Reward Research Program, https://commonfund.nih.gov/highrisk

[36] See Howard Hughes Medical Institute, https://www.hhmi.org/

[37] See Howard Hughes Medical Institute, *HHMI: Catalyst for Discovery*, November 2017. https://www.hhmi.org/sites/default/files/about/hhmi-vision-2017.pdf.

[38] "*Let us experiment with how to identify and support innovative research!",* presentation by Thomas Sinkjær, Professor, Head of Talent Programme, Lundbeck Foundation, Denmark, for the OECD workshop April 2020, https://community.oecd.org/docs/DOC-170560.

[39] See https://www.hfsp.org/

[40] The HFSP has an interesting approach to 'risk': "Many applicants do not appreciate what HFSP understands by 'risk'. It is not simply that « It's risky because it may or may not work ». A hand waving « but we hope it will », followed by a few vaguely described experiments, will not convince the reviewers of a full application. What is expected is that according to the team's calculations there is a reasonable chance that it will work - i.e is feasible. This might involve a discussion of the current limiting parameters of a technique, and the novel methods proposed that might bring improvements. Another project might start from observations from a different system to estimate the frequency of events that will be critical for the project. For data analysis it might mean providing an estimate of the number and nature of data points to be collected and a discussion of the appropriateness of a computational tool to handle such a dataset." https://www.hfsp.org/funding/hfsp-funding/research-grants.

[41] America COMPETES Reauthorization Act of 2010, Section 105. Public Law 111-358. https://www.congress.gov/111/plaws/publ358/PLAW-111publ358.pdf.

[42] Office of Science and Technology Policy, *Implementation of Federal Prize Authority: Fiscal Year 2015 Progress Report*, August 2016. https://obamawhitehouse.archives.gov/sites/default/files/fy2015_competes_prizes_report.pdf

[43] https://www.grandchallenge.org/

[44] https://www.xprize.org/prizes/covidtesting

[45] Science Foundation Ireland, https://www.sfi.ie/challenges/future-innovator-prize-18/

[46] https://research.umich.edu/mcubed

[47] "*The European Research Council (ERC)*," presentation by Jean-Pierre Bourguignon, former president of the European Research Council, for the April 2020 OECD workshop, https://community.oecd.org/docs/DOC-170560.

[48] For the most recent evaluations, see https://commonfund.nih.gov/pioneer/programevaluation; https://commonfund.nih.gov/newinnovator/programevaluation; https://commonfund.nih.gov/TRA/programevaluation; https://commonfund.nih.gov/earlyindependence/programevaluation

[49] https://www.forskningsradet.no/contentassets/ea9db93ed204480fa15a61682ed66d9e/evaluering_av_biotek2021.pdf

[50] For example, the US NSF EAGER program is part of the regular Committee of Visitors assessment process for NSF (https://www.nsf.gov/od/oia/activities/cov/covs.jsp)

[51] https://www.nsf.gov/pubs/2016/nsf16023/nsf16023.pdf

[52] "*LIGO: HRHR Success Story",* presentation by Michael S. Turner, Kavli Foundation, former Assistant Director for Mathematical & Physical Sciences, National Science Foundation, for the OECD workshop April 2020, https://community.oecd.org/docs/DOC-170560.

[53] https://www.gao.gov/new.items/d11127r.pdf

[54] "*Researcher evaluation and career development: Room for everyone's talent, Towards a new balance in the recognition and rewards of academics"*, presentation by Johan Huysse, Association of Universities in the Netherlands, for the 2020 workshop OECD April, https://community.oecd.org/docs/DOC-170560.

[55] https://tsal.uci.edu/ Team Scholarship Accelerator Lab at University of California Irvine

[56]https://www.hceres.fr/fr

[57] Conseil national des universités.

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Appendix 1. Expert Group Members

Country	Name	Affiliation
Belgium	Véronique Halloin	FNRS
	Olivier Boehme	FWO
France	Dominique Dunon-Bluteau	Head, Biology-Health Department, Agence Nationale de la Recherche (ANR)
Germany	Burkhard Jahnen	Group leader of the mathematics/engineering sciences group, DFG
	Anke Reinhardt	Deputy group leader of the information management group, DFG
Ireland	Lisa Higgins	Head of Challenge research, Science Foundation Ireland
Japan	Tateo Arimoto	Principal Fellow, Center for Research and Development Strategy (CRDS), Japan Science and Technology Agency (JST)/ Visiting Professor, National Graduate Institute for Policy Studies (GRIPS)
	Kazuhito Oyamada	Fellow, Center for Research and Development Strategy (CRDS), Japan Science and Technology Agency (JST)
Korea	Kiwoo Chun	Senior Researcher, National Research Foundation of Korea
	Seon-HeeSeo	Principal Researcher Center for Underground Physics Institute for Basic Science
	Sun Kun Oh	GSF vice-chair
Netherlands	Judith de Kroon	Senior policy advisor to the board of the Dutch Research Council (NWO)
Norway	Marianne Grønsleth	Special Adviser, Department of Open Researcher Arena, Research Council of Norway
United Kingdom	Jeremy Neathey	Deputy Director for Research and International, Economic and Social Research Council (ESRC), UK Research and Innovation
United States	Jessica Robin	**Directorate for Geosciences (GEO),** National Science Foundation (NSF)
OECD	Kei Koizumi	GSF consultant
	Diogo Machado	GSF consultant
	Yoshiaki Tamura	GSF secretariat
	Frédéric Sgard	GSF secretariat
	Carthage Smith	GSF secretariat

Appendix 2. Survey questionnaire

OECD Global Science Forum
Activity on "Effective policies to foster transformative/high-risk research"

Request for Information April 2020

The focus of this inquiry is funding programmes and supporting policies to foster potentially transformative scientific research, or high-risk, high-reward (HRHR) research.

Addition 1 April: In response to the global COVID-19 pandemic, the OECD in late March fielded a survey on STI (science, technology, and innovation) Policy Responses to Covid-19 to OECD member economies. In support of that effort, this survey has added a few questions on COVID-19 policy responses, including rapid-response research funding mechanisms for COVID-19, in the last section of the survey. We would appreciate your inputs to this new section.

The goal of the activity is to characterize how these programmes and policies are structured and operated in different countries, to synthesize existing evidence on the relative performance of different mechanisms to foster HRHR research in the context of particular policy objectives, and to gather and synthesise available qualitative and quantitative evidence on impacts of different HRHR research funding mechanisms and supporting policies both on the goal of fostering HRHR research and of achieving other national goals including scientific excellence, economic competitiveness, and societal objectives.

For the purposes of this survey and project, we are using the following definition:

"High-risk, high-reward (HRHR) research is research that (1) strives to understand or support solutions to ambitious scientific, technological, or societal challenges; (2) strives to cross scientific, technological, or societal paradigms in a revolutionary way; (3) involves a high degree of novelty; *and* (4) carries a high risk of not realizing its full ambition as well as the potential for high, transformational impact on a scientific, technological, or societal challenge."

For the purposes of this project, it is useful to consider the following terms as being to a large extent interchangeable: high risk research; high-risk, high-reward research; high, risk, high-payoff research; high-risk, high-gain research; transformative research; potentially transformative research; and transformational research.

The purpose of this questionnaire is to collect basic information on the existence and structure of relevant high-risk/high-reward research funding programmes and supporting policies in participating countries, as well as on the existence of any evaluation studies that may have been carried out with respect to these programmes and policies. This information will be synthesized to provide a preliminary baseline of information that will be enriched by more in-depth information collection on specific elements.

Please provide information on the programme or policy we are contacting you about. **Some information has been pre-filled from your country's response to the OECD STIP Database.**

Feel free to skip questions that are not relevant in particular instances.

Please provide information on the HRHR research programme	
Name of programme/policy	
Responsible organization	
Approximate annual total of research funding granted (local currency or equivalent in € or $)	
Terminology used (high-risk/high-reward research, transformative research, etc.)	
Start date (year)	
Definition (of HRHR research or similar concept) used, if defined	
Does this programme utilize a competitive call for proposals?	
If yes, approximate annual number of proposals received	
If yes, Approximate annual number of awards funded / % of success	
Funding unit (project, person, team, center, institution, or other)	
Mean duration of funding per award	
Web site(s)	

Purpose

What are the policy objectives of the Programme? (besides fostering HRHR research; please check (X) all that apply)	
Frontier knowledge/exploring new scientific domains	
Scientific excellence	
International collaboration	
Responding to societal challenges (which one(s)?)	
Economic competitiveness	
Capacity building (infrastructures, human resources…)	
Other (please specify)	

Selection criteria

What are the selection criteria for making awards?	
Are indicators of 'riskiness' or 'potential for transformation' used in selection? If yes, please describe.	

Selection process

Selection mechanism, competitive or not? Which mechanism (peer review panel, programme manager, funding formula, other, or combination; please elaborate as needed)?	
Please provide other relevant information on the selection process, especially with regard to the riskiness or potential for transformation of research.	
Once selected, please describe how selected projects are managed and the role, if any, of a programme manager in managing the programme.	

Effectiveness, and evaluation of programme meeting its goals of supporting high risk high reward research

If there is a website that describes the impact or effectiveness evaluation process for this programme, please provide the URL	
Please indicate which of the following evaluation mechanisms are used	
Quantitative indicators on the effectiveness of the programme in achieving goals, including fostering HRHR research	
If used, please describe the quantitative indicators used, especially indicators on the effectiveness of the programme in fostering HRHR research (or provide URLs)	
Qualitative indicators on the effectiveness of the programme in achieving indicators, including fostering HRHR research	
If used, please describe the qualitative indicators used, especially indicators on the effectiveness of the programme in fostering HRHR research	
External reviews of programme impact, including impact at fostering HRHR research	
If yes, please describe and provide the URL of a recent external review report	
Please describe in general terms how the programme is evaluated, using which metrics/indicators, and against which goals (scientific excellence, economic competitiveness, societal objectives, etc.).	
Have any formal or informal studies or evaluations been undertaken to evaluate how well the programme works *specifically to foster HRHR research*? If so, please provide a copy of any reports from such studies.	

Supportive policies and programmes

What policies are helpful in supporting both the funding of and effectiveness of HRHR research? For example, academic promotion, scientific publishing, reward systems in academia and industry, and research evaluation frameworks.	
Are there similar funding mechanisms to encourage HRHR research in other government funding agencies, other funding bodies, companies, or foundations in your country? Does this programme have regular dialogue with them? Are data from this programme merged with data from other programmes in national reporting? If so, please provide.	

Other relevant information

If there is any other information you would like to provide, please do so below. Thank you.

Research Responses to Covid-19

In response to the global COVID-19 pandemic, on 19 March the OECD Committee on Science and Technology Policy (CSTP) fielded a OECD member survey "**STI policy responses to Covid-19**". In support of this survey and other OECD efforts, we are seeking information on government scientific research funding responses to Covid-19. We would appreciate your help in providing government or other national research-based responses to Covid-19, including rapid-response research funding mechanisms that may have been announced in recent weeks. The data will be made available as quickly as possible to national STI policy makers charged with designing and implementing policy responses to Covid-19. Has your agency or organisation introduced specific funding calls or programmes for rapid-response research funding in response to the Covid-19 crisis? Or taken measures to accelerate the clinical testing of diagnostics, therapies and vaccines for COVID-19 and taken steps to facilitate the entry into market of results? Etc. *Please describe the main features of these new funding mechanisms (time of introduction, funding amount, source and instrument type (grant, prize, etc.)) and provide a website.*

Questionnaire responses:

Country	Funding scheme
Czech Republic	Grant projects of excellence in basic research - EXPRO
France	OH Risque
United States	National Science Foundation EArly-concept Grants for Exploratory Research (EAGER)
Canada	New Frontiers in Research Fund (NFRF)
Japan	Moonshot R&D Programme
Norway	ENERGIX – New concepts
European Commission	European Research Council (ERC) Consolidator Grants
Norway	FRIPRO
Netherlands	Off Road
Germany	Reinhart Koselleck Projects
Ireland	Science Foundation Ireland (SFI) Frontiers for the Future
United Kingdom	UKRI TRDF: Transformative Research Opportunities
United States	Defense Advanced Research Projects Agency (DARPA)
United States	National Institutes of Health (NIH) High Risk High Reward Research Programmes (4 programmes)
Norway	Aquaculture
Poland	MAESTRO

Appendix 3. HRHR Research Inventory
Inventory of High-Risk/High-Reward Research Programmes

Country	Funding scheme
Argentina	STRATEGIC PROJECTS
Australia	NEXT GENERATION TECHNOLOGIES FUND
Australia	ARC CENTRES OF EXCELLENCE
Austria	Innovation Fund: Research, Science and Society
Canada	Canadian Institute for Advanced Research
Canada	NEW FRONTIERS IN RESEARCH FUND
Chile	MILLENNIUM SCIENCE INITIATIVE
Cyprus[1]	RESTART EXCELLENCE HUBS PROGRAMME
Czech Republic	GRANT PROJECTS OF EXCELLENCE IN BASIC RESEARCH
Denmark	GRANTS AND PROFESSORSHIPS FROM THE DANISH NATIONAL RESEARCH FOUNDATION
Denmark	INDEPENDENT RESEARCH FUND DENMARK
European Union	FUTURE AND EMERGING SCIENCE AND TECHNOLOGIES OPEN
European Union	EUROPEAN RESEARCH COUNCIL RESEARCH GRANTS – Consolidator Grants
Finland	ACADEMY OF FINLAND FLAGSHIP PROGRAMME FOR TOP-LEVEL, HIGH-IMPACT RESEARCH CLUSTERS
France	OH Risque
Germany	Reinhart Koselleck Projects
Greece	HELLENIC FOUNDATION FOR RESEARCH AND INNOVATION
Ireland	SFI FRONTIERS FOR THE FUTURE PROGRAMME
Japan	Funding Programme for World-Leading Innovative R&D on Science and Technology (FIRST)
Japan	Impulsing Paradigm Change through Disruptive Technologies Programme (ImPACT)
Japan	Moonshot Research and Development Programme
Korea	Strategy for Advanced National R&D System
Korea	Future convergence technology pioneer programme
Korea	Alchemist Project
Netherlands	Off Road
Netherlands	Diabetes II Breakthrough
Netherlands	Open Mind
Netherlands	Ideas Generator
Netherlands	Open Competition ENW-XS
New Zealand	MARSDEN FUND
New Zealand	STRATEGIC SCIENCE INVESTMENT FUND
New Zealand	ENDEAVOUR FUND
Norway	EnergiX
Norway	FRIPRO
Norway	Aquaculture
Poland	[NCN] MAESTRO ADVANCED GRANTS
Poland	[NCN] Research programmes for advanced researchers
Portugal	EXPLORATORY RESEARCH PROJECTS
Slovenia	ERC COMPLEMENTARY SCHEME
Spain	PROJECTS "EXPLORE SCIENCE" AND "EXPLORE TECHNOLOGY"
United Kingdom	Transformative Research and Development Fund
United States	Early-concepts for Exploratory Research (EAGER)
United States	National Science Foundation RAISE (Research Advanced by Interdisciplinary Science and Engineering)
United States	National Institutes of Health HRHR Research Programs: Pioneer Award
United States	National Institutes of Health HRHR Research Programs: New Innovator Award
United States	National Institutes of Health HRHR Research Programs: Transformative Research Award
United States	National Institutes of Health HRHR Research Programs: Early Independence Award
United States	ARPA-E

United States	Defense Advanced Research Projects Agency (DARPA)
United States	National Science Foundation Special Creativity Extensions
United States	National Science Foundation Ideas Lab
United States	IARPA Better Extraction from Text Towards Enhanced Retrieval (BETTER)
United States	DOD Newton Award for Transformative Ideas during the COVID-19 Pandemic
Foundation (Switzerland)	NOMIS Foundation
Foundation (United States)	Howard Hughes Medical Institute (HHMI)

List of experts interviewed

Funders (including policymakers):

- Seth Cohen (US); Defense Advanced Research Projects Agency (DARPA) programme manager
- Takao Kuramochi (Japan); Deputy Director General of Center for Research and Development Strategy, Japan Science and Technology Agency (JST)
- Shinsuke Okada (Japan); Japan Science and Technology Agency (JST)
- Cosima Crawford (Switzerland); NOMIS Foundation

Performing organisations (including university researchers):

- Pramod Khargonekar (US); University of California – Irvine
- Shin'ichi Kobayashi (Japan); Research Institute for Higher Education, Hiroshima University
- William H. Janeway (United Kingdom); University of Cambridge
- Nathalie Drach-Temam (France); Sorbonne University

[1] Note by Turkey:

The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union:

The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.