Increasing investment in mathematics in changing times

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We reflect on our experience in Japan and the UK in raising mathematics funding, from the public and private sectors, and establishing new mathematics institutes. We hope that some of this information and relevant examples will be of use for mathematicians in other countries.

1

Mathematics in a broad sense includes pure mathematics, statistics and applied mathematics and their interaction with computer science. It is a common language for sciences. Galileo wrote, "Mathematics is the language with which God has written the universe." The Nobel Prize winner E. Wigner talked about "the unreasonable effectiveness of mathematics in the natural sciences." Mathematics is an open innovation that transcends differences in nationality, language, culture, and generation. Such modern areas as cryptographic services, cybersecurity, internet data transmission, computational modelling, machine learning, deep learning, artificial intelligence, quantum computing, financial markets, banking system, insurance system, defence and security are impossible without mathematics.

It is crucial to appreciate that without fundamental mathematics further substantial achievements in modelling, quantum computing, AI, ML, etc., are not possible. Just one example: using fundamental mathematical insights, an interdisciplinary group, including pure mathematicians, led by A. Zhigljavsky (Cardiff University) produced a new type of epidemic modelling with longer term forecasts for the decision makers (links to three related papers are available at the bottom of this International Mathematical Union webpage[1]). Media articles emphasised the increasing role of mathematics in epidemic modelling.[2]

With the disruptive innovations of the current industrial revolution, the need for mathematical knowledge and abilities is increasing. Mathematics helps to develop and stimulate breakthrough innovation in many key fields of the industrial revolution. To be successful in the latter requires such abilities as taking a bird's-eye view on a problem, finding solutions in an integrated way, and generalising, all of which are provided by mathematical mindfulness. CEOs and politicians in several countries have stated that only those countries that invest now more in mathematics can continue to be prosperous and successful. Giant IT companies are proactively recruiting excellent mathematicians whose duties can be compared to those of university researchers. In comparison with many other areas, in mathematics one can move very quickly from investment to a productive phase once the latter is expected. Without increasing the mathematical mindfulness of the population, inevitable problems with employment in sectors where AI replaces humans may have very drastic consequences.

Serious problems affecting mathematicians these days are well known. The shortsighted race to a higher number of publications and a higher citation index often results in pressure to produce short-term work that essentially brings only minor improvements to known results. Some mathematicians are losing the enthusiasm and passion for long-term research and adopt the most pragmatic attitude concerning what and when to study in mathematics. They are forced to specialise narrowly, which leads to an emphasis on technical perfection as opposed to innovation, and on presentation rather than substance of work. Specialisation in a small area and lack of knowledge of even adjacent areas are becoming more and more typical. Following this path eventually makes it more arduous to think in broader terms, to learn new areas or concepts, to study new groundbreaking theories, to develop in new directions. Associated issues are lack of inventiveness, fear to look too far away or think non-linearly, more widely spread imitation, fear to stand alone in scientific endeavour, and consequently increasing dependence on other people's opinions without studying on one's own. Following this path by many directly harms the future of mathematics. These trends affect young researchers even stronger. New mathematical institutions and centres will apply efforts to address these problems. The proposed creation of an EMS Youth Academy may be useful. For another initiative reported to the EMS, see this talk[3]. In Japan,

[1] https://www.mathunion.org/corona

[2] https://www.nzz.ch/wirtschaft/wenn-mathematik-menschenleben-rettet-und-milliardenkosten-spart-ld.1552780?reduced=true

[3] https://euro-math-soc.eu/system/files/uploads/6.%20Fesenko_young_0.pdf

through programs such as CREST and the activities of IMI (see the next section), an increasing number of the younger mathematicians are trying to take a broader interest and perspective.

Most researchers in other sciences, including experimental quantum physics and quantum computing, are often not aware of developments in mathematics in the recent decades. At the same time, researchers in other sciences complain about the inability of some pure mathematicians to explain their work or just their novel ideas to them. Much needs to and can be improved in relation to the increasing inability of mathematicians to explain their research even to wider groups of mathematicians (see, e.g., this message[4] of the president of the EMS). Despite so many changes related to new forms of accessing information and communication, mathematics is taught in almost the same way as fifty and more years ago (even though the recent two years have brought some changes). The task of modernising the ways and forms of passing the mathematical knowledge to the diverse range of young people is complex and huge. By increasing funding of mathematics and at the same time improving the ways to teach mathematics, carry out research, and administer grant distribution, countries have the opportunity to stimulate and support long-term impact developments.

2

Mathematics is the foundation of plenty of advanced technologies driving modern society. There are several Japan Science and Technology Agency math programs[5] such as CREST, PRESTO, ACT-X; these are separate from the Japan Society for the Promotion of Science (JSPS) grants. The CREST[6] and PRESTO programs have a long history that begun in 1995 in other fields; the first CREST mathematical sciences programs only started in October 2007.

To meet the global demand in many scientific and technical fields in terms of research personnel skilful in mathematics, M. Wakayama worked for years on establishing the Institute of Mathematics for Industry (IMI)[7] at Kyushu University. It was founded in April 2011, becoming the first institute in Asia for industrial mathematics. Two years later, IMI was authorised as the Joint Usage/Research Center by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, thus becoming a national centre.

IMI was established

> by amalgamating and reorganizing pure and applied mathematics into a flexible and versatile form, with a view to serving as the foundation for developing future technologies. Problems that emerge from the requirements of industrial sectors are, though their targets are clear, in many cases yet to be formulated mathematically. History tells us that many useful technologies originate in mathematical theories being created by flexible and free ideas, without any intention of application. While helping to solve problems requiring short-term solutions and to develop technologies currently in demand in cooperation with industry and other fields, the IMI actively promotes basic and fundamental research in mathematics that will serve as seeds for future innovative, difficult-to-foresee technologies. […] Furthermore, it is one of the important missions of the IMI to use these outstanding research activities for education.[8]

In 2018 METI (the Ministry of Economy, Trade and Industry) initiated and together with MEXT hosted an Industry-Academia Round Table Discussion on the role of mathematics and science[9]. A summary of the report "The Coming Era of Mathematical Capitalism – How the Power of Mathematics Changes Our Future" includes the following:

> We believe that we have identified the top three science priorities in order for Japan to lead the fourth industrial revolution and to even go beyond its limits: mathematics, mathematics, and mathematics!
>
> It is not too much to say that "winners in the field of mathematics are winners in the fourth industrial revolution." Furthermore, as the end of the Moore's law era is coming into sight, businesses have been advancing a race of the development of computing technologies using new principles, such as quantum computers. In this trend, human resources who may manipulate such technologies should be those who have higher knowledge of mathematics and are able to make full use of such knowledge.
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> What management or social system is suitable to the era of mathematical capitalism, a time in which industries foster human resources expertized in the fields of science and mathematics to bring out their higher ability of mathematics and connect it to innovation? Such a management or social system is expected to be a novel one, different from conventional systems. Despite this expectation, all countries and companies are still working to find specific solutions to this question. If any country or company uncovers an optimal solution to the question ahead of other countries and companies, it will be the winner in the era of mathematical capitalism.[10]

[4] https://euromathsoc.org/magazine/articles/49
[5] https://www.jst.go.jp/kisoken/en/index.html
[6] https://www.jst.go.jp/kisoken/crest/en/index.html
[7] https://www.imi.kyushu-u.ac.jp/eng/
[8] https://www.imi.kyushu-u.ac.jp/eng/pages/about.html?active=message
[9] https://www.meti.go.jp/english/press/2019/0326_004.html
[10] https://www.meti.go.jp/english/press/2019/pdf/0326_004a.pdf

Therein "mathematics" refers to mathematics in a broad sense, as above, and also including quantum theory and other fields that substantially use mathematical expressions, and "mathematical capitalism" is understood in the sense of mathematics becoming and being a crucial source of national wealth.

M. Wakayama also worked on the creation of a new NTT Institute for Fundamental Mathematics[11] in the Nippon Telegraph and Telephone Corporation. This institute opened in October 2021. About 80 % of the research effort of its members will be fundamental mathematics research. It will

> explore diverse and wide-ranging issues in modern mathematics and promote the search for mathematical truth through the development of the necessary language and concepts.

For example, the institute

> will accelerate research geared towards innovations in quantum technology that surpass the capabilities of digital technology, including clarifying the origins of the superior power of quantum computing, which are not yet clearly understood, and devising new cryptosystems that are guaranteed to be unbreakable even by quantum computers.

Mathematics was included in the Cabinet Office's Moonshot Program[12] by emphasising its transversal/horizontal role. This was the outcome of work by M. Kotani (executive vice president of Tohoku University, next International Science Council president) when she served as a member of the Council for Science, Technology and Innovation, Cabinet Office.

3

For many years, UK mathematics had been hugely underfunded. One of the more recent reports is available at this webpage[13]. The issues with funding of UK mathematics had been reported at various levels, but that had not led to any substantial improvement.

Sharing and discussing some general articles about recent achievements, such as this text on the work of S. Mochizuki[14] and this article on the work of C. Birkar[15], with decision makers proved to be successful in attracting their attention and support to the needs of mathematics.

In August 2019 I. Fesenko was asked by D. Cummings, at that time the senior advisor to the Prime Minister, to "assemble a group of mathematicians … coordinate the effort … produce the best possible roadmap for funding mathematics" in the UK. Various observations by Cummings about mathematics and mathematicians can be found in his blog[16]. Here are three extracts:

> A visit to the classic Bell Labs of its heyday would reveal many things. One of the simplest was a sign posted randomly around: "Either do something very useful, or very beautiful". Funders today won't fund the second at all, and are afraid to fund at the risk level needed for the first. […]
> A […] risk aversion is present in the science funding process. Many scientists are forced to specify years in advance what they intend to do, and spend their time continually applying for very short, small grants. However, it is the unexpected, the failures and the accidental, which are the inevitable cost and source of fruit in the scientific pursuit. It takes time, it takes long-term thinking, it takes flexibility.

> To get things changed, scientists need mechanisms a) to agree priorities in order to focus their actions on b) roadmaps with specifics. Generalised whining never works. […] Scientists also need to be prepared to put their heads above the parapet and face controversy. Many comments amounted to 'why don't politicians do the obviously rational thing without me having to take a risk of being embroiled in media horrors'. Sorry guys but this is not how it works.

> Courses such as Politics, Philosophy and Economics […] do not train political leaders well. They encourage superficial bluffing, misplaced confidence (e.g. many graduates leave with little or no idea about fundamental issues concerning mathematical models of the economy […], and they do not train people to make decisions in complex organisations. […] Universities need new inter-disciplinary courses. […] It would be great if Oxford created alternatives to PPE such as *'Ancient and Modern History, Maths for Presidents, and Coding'*.

A draft of I. Fesenko's proposal was considered at the first meeting of a group of mathematicians with officials at 10 Downing Street in August 2019, for the final version of his proposal see this page[17]. Two further meetings at No. 10 discussed aspects of new additional funding and problems affecting effective support of mathematics research and produced executive summaries.

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[11] https://group.ntt/en/newsrelease/2021/10/01/211001a.html
[12] https://www8.cao.go.jp/cstp/english/moonshot/top.html
[13] https://www.eu-maths-in.eu/wp-content/uploads/2018/05/EraOfMathematicsReport.pdf
[14] https://ivanfesenko.org/wp-content/uploads/2021/10/rpp.pdf
[15] https://www.thetimes.co.uk/magazine/the-times-magazine/caucher-birkar-from-asylum-seeker-to-fields-medal-winner-at-cambridge-xrz5t7ktj
[16] https://dominiccummings.com/
[17] https://ivanfesenko.org/wp-content/uploads/2021/10/mathsproposal-2.pdf

Members of the group included (not a complete list): J. Norris (University of Cambridge), D. van Dyk (Imperial College London), J. Greenlees (University of Warwick), I. Gordon (University of Edinburgh), J. Keating (Heilbronn Institute for Mathematics Research and University of Oxford).

At the end of January 2020, a new additional funding of 300 million GBP for the next 5 years was announced by the UK government[18]. Its volume increases the previous research math funding approximately 2.5 times. The new funding aims to support more PhD students and postdocs, to provide more grant funding, and to enlarge funding of the Isaac Newton Institute for Mathematical Sciences and the International Centre for Mathematical Sciences. The first 1/3 of the funding became available from the 2020/2021 academic year.

Masato Wakayama specialises in representation theory, number theory and mathematical physics. Recently, he has been working on the mathematical structure of quantum interactions such as asymmetric quantum Rabi models in relation to the Riemann hypothesis and problems in arithmetic geometry. His and N. Kurokawa's zeta function workshops in Okinawa, held since 2000, are famous worldwide. He is head and fundamental mathematics research principal of the NTT Institute for Fundamental Mathematics; principal fellow of Center for Research and Development Strategy of Japan Science and Technology Agency; chair of Mathematical Sciences Subcommittee of Moonshot Research and Development Program[19], Cabinet Office of Japan; scientific advisor & senior advisor of RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program[20]; professor emeritus of Kyushu University. His previous positions include professor and distinguished professor in mathematics, dean of the Graduate School of Mathematics of Kyushu University, the first director of the Institute of Mathematics for Industry, executive vice president of Kyushu University, and vice president and professor of Tokyo University of Science. He was visiting fellow at Princeton University, visiting professor in the University of Bologna and the distinguished lecturer at Indiana University.

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[18] https://www.gov.uk/government/news/boost-for-uk-science-with-unlimited-visa-offer-to-worlds-brightest-and-best

[19] https://www.jst.go.jp/moonshot/en/about.html

[20] https://ithems.riken.jp/en/members/#scientific-advisors

[21] https://ivanfesenko.org/wp-content/uploads/2022/02/scpage.pdf

[22] https://projecteuclid.org/journals/kodai-mathematical-journal/volume-45/issue-2/Explicit-estimates-in-inter-universal-Teichm%c3%bcller-theory/10.2996/kmj45201.short