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Innovation for Economic Resilience: Strengthening Ukraine's Human Capital and Science Sector

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Executive Summary

Innovation is a critical driver of economic growth and resilience, which is particularly evident in Ukraine today. Military and healthcare innovations, enabled by prior investments in fundamental research, highlight the importance of science and innovation, especially during times of crisis and war. This policy paper emphasizes the need for the Ministry of Economy to consider issues related to science and innovation policy, as fundamental research is an essential foundation for effective innovation policy. Moreover, support for applied research related to military technologies can have both economic benefits and increase defense capabilities to contribute to war-time and recovery needs.

Key Recommendations:

- **Develop Human Capital:**
    - Support current scientists within Ukraine and those abroad by providing funding for research.
    - Implement policies to retain and nurture the next generation of researchers, including training programs in areas related to war-time and recovery needs.
    - Encourage collaboration with the Ukrainian scientific diaspora, leveraging their expertise for policy advice and innovation.
    - Expand current income tax exemptions of international funds received for scientific research in Ukraine.
- **Integrate with International Scientific Networks:**
    - Increase international collaboration to access resources, knowledge, and funding opportunities, including leveraging Ukraine's expertise in military technologies.
    - Build stronger ties with international research institutions and foster relationships with Ukraine's diaspora and global scientific community.
    - Co-finance proposals for grants from Horizon and other EU research funds.
- **Promote Regional Innovation Development:**
    - Establish a regional innovation development program to foster resilience across Ukraine's regions, focusing on investment in universities and research infrastructure.
    - Strengthen the role of regional universities in innovation ecosystems, using them as key anchors for local economic development.
    - Create opportunities for more interactions between universities/research institutions and businesses, including a legal framework for these interactions and tax incentives, including for industry-university collaborations in military technologies

1. Introduction

Innovation is essential for economic growth and resilience, and its importance is particularly evident in Ukraine today. On the battlefield, cutting-edge advances in military and healthcare technologies have played a pivotal role in Ukraine's defense efforts, underscoring the crucial impact of innovation in times of crisis. These innovations, however, build upon prior advances in more fundamental, or basic science. For example, fundamental research across a range of fields, including aerodynamics, control theory, and wireless communication (and many others), has made modern drone technology possible.

In this policy paper, we stress that attention to fundamental research is a critical foundation for effective innovation policy. Increasing evidence points to the important role of public investments in basic science and R&D for long-run productivity growth (Kantor and Whalley, 2023; Babina et al, 2023; Dyevre, 2024). It is crucial for the Ministry of Economy to be involved in activities related to science and innovation policy.[1] While most immediate questions are often more directly under the purview of the Ministry of Science and Education, economic policies in the areas of taxation, employment and intellectual property, and entrepreneurship, are all interlinked with science and innovation policies.

We discuss several priority areas for policies to support the science and innovation sector in Ukraine, with a key focus on the development of human capital to contribute to economic recovery and growth. We suggest policies and programs that are key for bolstering Ukraine's science and innovation sector in the short-run as well as making it a driving force of victory and recovery in the longer-run.

It is challenging to measure innovation in an economy. Measures typically used in the West are patents, but patenting is not as common or relevant in Ukraine. Ukraine currently ranks 55th out of 132 economies in the 2023 OECD Global Innovation Index (GII). Even prior to the full-scale invasion in 2022 and the 2014 war, Ukraine's scientific productivity was relatively low

[1] Bezvershenko and Kolezhuk (2022): "...functions of forming and implementing government policy in the R&D sphere are not clearly delineated between the Ministry of Education and Science, other ministries, the national academies of sciences, the National Research Foundation (NRFU) and the central executive authorities"

compared to other countries (but similar to other countries in Eastern Europe) and Ukraine had a long history of scientific cooperation with Russia.

Macroeconomic models point to the core importance of science and innovation activities, and particularly the number of people, or human capital, working in the research and development (R&D) or the "ideas" sector, for long-run economic growth (Romer, 1990; Jones, 2005). Increased innovation and technological improvements produced by individuals working in this sector increase labor productivity and contribute further to knowledge diffusion.

Since the full-scale invasion, Ukraine has lost human capital through emigration, direct death and trauma caused by the war, and occupational mobility into sectors outside of science (Ganguli and Waldinger, 2023). Without these individuals at the 'top of the pyramid' to contribute to science and innovation activities and to train the next generation of students in Ukraine, Ukrainian human capital is threatened. At the same time, Ukrainians have gained expertise in critical military and health technologies during war-time, which can be leveraged for international collaborations and commercialization going forward. Post-war recovery and economic growth in Ukraine will depend on a system that supports current scientists and develops a new generation of researchers and innovators going forward.

In addition to human capital, physical capital is important for scientists to do research. During the reconstruction period, there will also be an opportunity for Ukraine to "build back better" the existing science and innovation system. Ukraine still has outdated infrastructure and lasting features of the Soviet system, including the weak link between research and teaching, and low levels of commercialization of research (Bezvershenko and Kolezhuk, 2022).

We highlight three priority areas related to (1) developing human capital and preventing long-term human capital losses, (2) integration with international scientific networks, particularly to be posed to leverage international funding programs, (3) regional innovation development programs including investment in universities and research infrastructure to ensure economic resilience in the future. These areas all aim to both support the "bright spots", or Ukraine's current areas of strength in science and innovation, including recent advances in military technologies, and to build capacity in areas that have not been Ukraine's traditional areas of expertise.

In the remainder of this paper, we first provide background on the impacts of the full-scale Russian invasion in 2022 on human capital and the science and innovation sector. While science and education policies are typically considered as areas for the Ministry of Education and Science, and development of military technology as areas for the Ministry of Defense, in the current situation and for the long-run development of the Ukrainian economy, it is critical for the

Ministry of Economy to consider the following areas as part of its activities and to consider opportunities for horizontal coordination.

Human capital development. Domestic and international support for scientists in Ukraine to continue to do research and train students is critical. In the short-run, funding for scientists to continue their research, even in small amounts, is critical. We suggest considering expanding current tax policies which exempt international funds received for scientific research in Ukraine from income tax. Moreover, targeted investments in training and R&D investment, particularly in areas related to war-time and recovery needs, can spur innovation and increase productivity. An important consideration is maintaining engagement with scientists both in Ukraine and those who have gone abroad. Ukrainian scientists inside and outside of Ukraine can also be an important source of expertise for policy advice.[2]

Integration with the international scientific community. While many Ukrainian scientists collaborate with scientists in other countries, more integration with the international scientific community is critical, as it will be a channel for additional resources and access to knowledge. Many Ukrainian scientists are receiving international funds currently, but there is an opportunity to engage more with international partners. There also will likely be opportunities to leverage Ukraine's expertise in military technologies in these collaborations. A promising instrument is fostering connections with the Ukrainian diaspora and international experts eager to help in reconstruction efforts. Another is to co-finance proposals for grants from Horizon Europe and other EU and international sources.

Investments for regional development. Much of Ukraine's science and innovation activities are heavily centered in Kyiv, and other areas like Kharkiv that have been important locations have been heavily affected by the war. An important part of Ukraine's innovation strategy is to develop a regional innovation program that can benefit from international funding programs, like the EU smart specialization program, and developing universities as important anchors for these regional innovation ecosystems around the country. More opportunities for interactions between universities, research organizations, and businesses can foster innovation ecosystems where basic research done at universities/research organizations can more quickly lead to applied research and subsequent commercialization and entrepreneurship. This can be facilitated by a legal framework for these interactions and tax incentives such as for science parks and for industry-university collaborations in military technologies.

[2] Skorokhod, Oleksandr. "Scientific diaspora — a unique asset for post-war recovery of Ukraine": https://scienceatrisk.org/whitepaper/the-scientific-diaspora-is-a-unique-capital-for-ukraines-postwar-recovery

2. Background: Trends and Impacts of the War

In this section, we provide some background on trends in science and impacts of the war. Since the full-scale Russian invasion of Ukraine, the science and innovation sector has been impacted in several ways. Most critically, there has been (1) a loss of human capital, as many scientists have not been able to do their research in Ukraine and others have left the country; (2) loss of physical capital, through the destruction of university buildings, research facilities, and other infrastructure; and (3) changes in international collaborations and access to international communities for Ukrainian scientists.

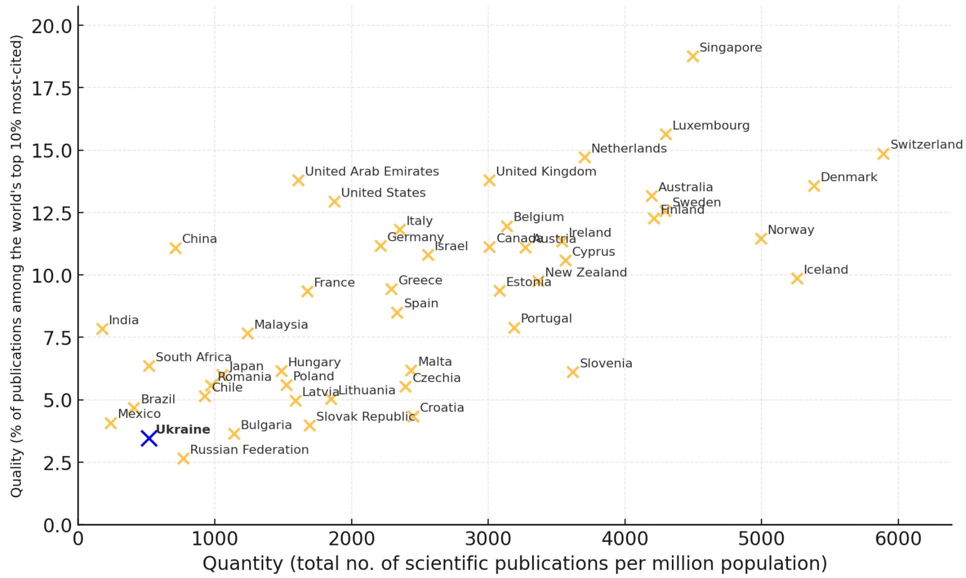
While it is still early to quantify the impacts of the 2022 full-scale Russian invasion on Ukrainian science, the impacts are already evident. Survey-based evidence suggests that the war has already resulted in a large emigration wave from Ukrainian universities. In 2022, the Ukrainian Ministry of Science and Education estimated that approximately 6,000 of a total of 60,000 researchers, or 10%, left Ukraine in the first few months of the full scale invasion in February 2022 (Irwin 2023). De Rassenfosse et al. (2023) report by fall 2022 an emigration rate of approximately 19% among a sample of scientists surveyed early in the war. Such survey-based estimates potentially suffer from selection biases, as those who respond to surveys may not be a random sample of the population of academics. Hence, emigration rates may either be over or underestimated. Ganguli and Waldinger (2023) use information from 535 top-publishing scientists and estimate emigration rates using changes in affiliations. They estimated that 5.4 percent of these elite scientists have already emigrated from February 2022 to summer of 2023.

Ukraine was ranked 55th out of 132 economies in the 2023 Global Innovation Index (GII).[3] This is a slight improvement from 57th in 2022, but a decline compared to being 49th in 2021, 45th in 2020 and 47th in 2019. Among European countries, Ukraine ranked 34th out of 39. In terms of inputs into the index, Ukraine ranks 47th in “Human capital and research” (49th in 2022, and 44th in 2021), 59th in “R&D” (58th in 2021), 36th in “Knowledge and technology outputs” (33th in 2021) and 27th in “Knowledge creation” (29th in 2021).

Ukraine’s scientific productivity is relatively low compared to other countries, but similar to other countries in Eastern Europe. Figure 1 shows scientific papers per million population and the percentage of publications among the top 10% cited for Ukraine relative to other countries. This shows that Ukraine can improve on both margins compared to other countries (OECD 2022).

[3] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023/ua.pdf

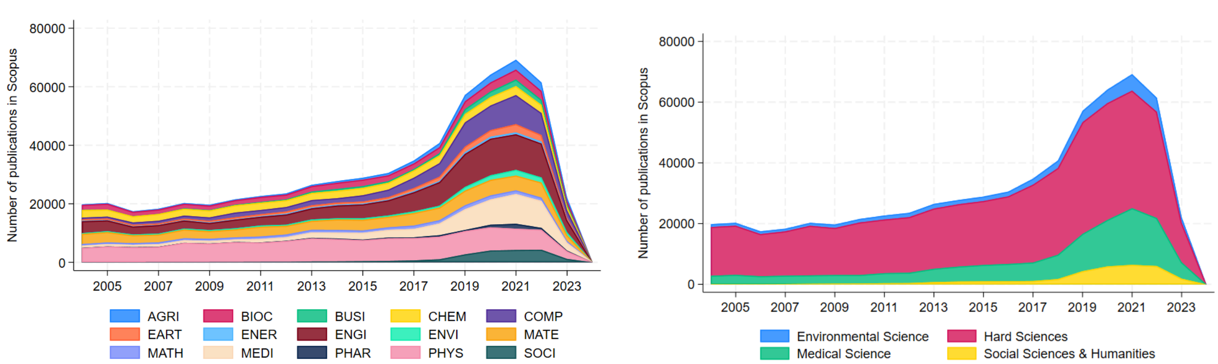
Figure 1. Scientific papers per million population and the percentage of publications among the top 10% most cited



Source: OECD calculations based on Scopus Custom Data, Elsevier, Version 1.2024, April 2024. oe.cd/scientometrics

Figure 2 shows the number of papers published by Ukrainian scientists by field in the Scopus database. Prior to 2017, most papers were published in the field of physics. Some fields had higher quality science and publications in top journals. After 2017, there was growth overall in papers published in Scopus, with large increases in some fields like computer science, engineering and medicine. The reason for this growth after 2017 is likely due to a number of factors, such as changes in requirements for obtaining a PhDs, move towards publishing in more English language journals, evolving interests of new scientists. More research is needed to understand the importance of these factors.

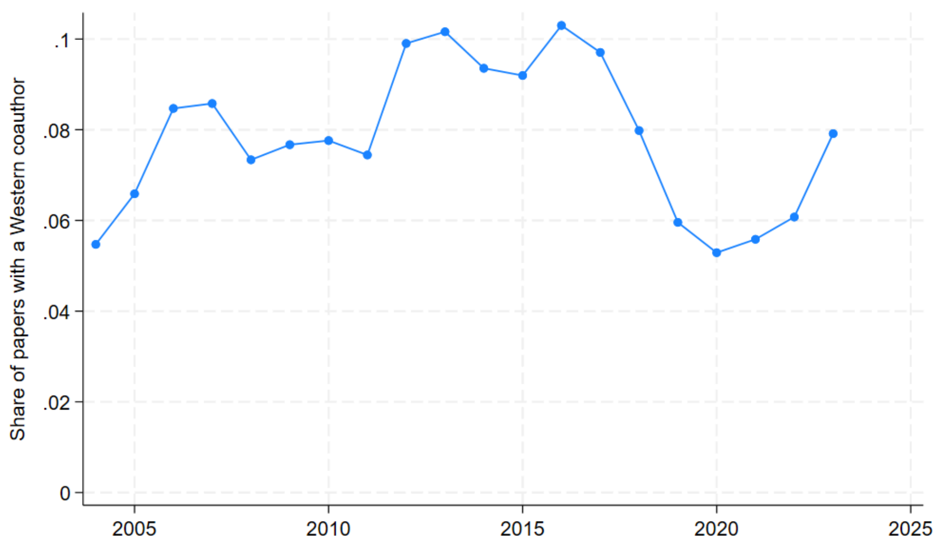
Figure 2: Total Publications by Ukrainian Authors in Scopus, by Field



Source: Scopus Publication Database. Scopus areas are aggregated into Environmental Science (ENVI, EART, ENER), Medical Science (AGRI, BIOC, DENT, HEAL, IMMU, MEDI, NEUR, NURS, PHAR, VETE), Hard Sciences (CENG, CHEM, COMP, ENGI, PHYS, MATE, MATH), and Social Sciences & Humanities (ARTS, BUSI, DECI, ECON, PSYC, SOCI).

Ukraine has traditionally had a history of scientific cooperation with Russia. While Ukrainian scientists become more integrated with the wider international scientific community after the end of the USSR, in many fields international cooperation is very low and there is a lot of variation by field. Since 2014, and especially after 2022, this cooperation has (obviously) almost stopped.

Figure 3: Share of Papers with a Western Coauthor

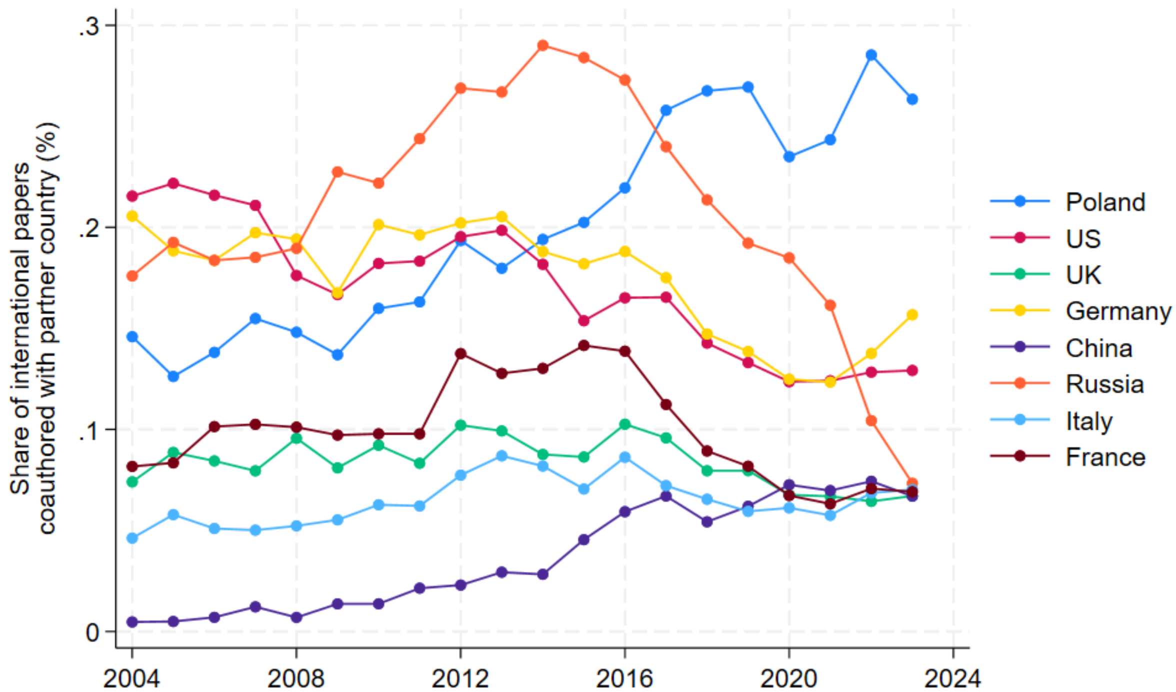


Source: Scopus Publication Database

Figure 3 shows the share of papers published by a Ukrainian coauthor with a coauthor from a Western country. The share has changed over time, with a peak of approximately 10% of papers published with a Western coauthor in 2014-2016. However, there is heterogeneity across fields; some fields like physics and medicine have had a relatively high share of papers with international coauthors, with more than 20% of papers in some years with an international team. Yet others, like engineering, have been low.

Ukraine's top partners in international scientific collaborations are shown in Figure 4. The decline in collaborations with Russia beginning in 2014 and an increase in collaborations with Poland and Germany is evident in recent years (also see discussion Van Noorden 2023).

Figure 4. Ukraine's Top Partners For International Collaborations



Source: Scopus Publication Database

3. Priority Policies For Ukraine's Science & Innovation Sectors

a. Preventing Loss of Human Capital

Human capital - or the knowledge and skills embodied in people - is critical for economic growth and economic resilience. The main threats to human capital since the full-scale invasion are emigration, direct death and trauma caused by the war, and occupational mobility into sectors outside science. The economics literature shows there are significant long-run consequences of losing scientific human capital (Waldinger 2016), but post-war investments in areas that are most impacted by the war can lead to greater innovation (Bergeaud and Chaniot, 2024). Thus, future economic growth depends on effective policies to both preserve current scientific human capital and be well-situated to develop it in the future.

The Ukrainian Ministry of Science and Education estimates that approximately 6,000 of all 60,000 researchers, or 10%, left Ukraine since the start of the full-scale war (Polishchuk et al., 2022). Other estimates are similar (De Rassenfosse et al., 2023; Ganguli and Waldinger, 2023; Lutsenko et al., 2023).

These direct losses of scientists abroad can have compounding effects. Without teachers and mentors, this can lead to disruptions in university and PhD training for the next generation (Ganguli, 2014). Thus, losing the "top of the pyramid" can be a threat to long run human capital development and the future science and innovation activities in Ukraine. Trends even before the full-scale invasion show that Ukraine was experiencing a decline in human capital, with a lower number of researchers relative to the population since 2017 and a decline in the number of science doctorates produced.[4] These trends will only be exacerbated by the war.

Moreover, there has already been a decline in skills of Ukrainian students at earlier ages before the war. For example, in the 2022 Programme for International Student Assessment (PISA), which assesses the knowledge and skills of 15-year-old students in mathematics, reading and science, Ukrainian students had levels of proficiency in several areas (mathematics, reading, and science literacy) below the OECD average. The 2022 assessment showed declines in learning relative to the 2018 PISA.[5]

In the short-run, funding for scientists to continue their research, even in small amounts, is critical. Evidence from other settings suggests that even a small amount can help scientists continue to do their research (Ganguli 2017). This includes funding from international and domestic sources for both scientists who remain in Ukraine and to those who go abroad.

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[4] Innovation inputs, page 7: https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023/ua.pdf

[5] https://www.oecd.org/publication/pisa-2022-results/country-notes/ukrainian-regions-18-of-27-78043794/

Opportunities for short-term stays abroad for scientists or virtual scholar programs can both help scientists continue to do their research and stay in the science sector, as well as provide an opportunity for increased access to knowledge and resources abroad.

Examples of international programs funded by universities and other organizations are Scholars at Risk (SAR), Universities for Ukraine (U4U), Shevchenko Scientific Society, Duke University, University of California - Berkeley and the University of Massachusetts Amherst.

An open question is the taxation of funds that scientists receive within these programs. Currently, international funds received for scientific research in Ukraine are exempt from income tax if they meet special requirements. According to subparagraph 165.1.1 of Article 165 of the Tax Code of Ukraine (TCU), amounts of international awards, scholarships, and grants in the field of scientific and scientific-technical activities are not included in the total monthly (annual) taxable income of the taxpayer if they meet some conditions. However, if international grants or research funds do not meet the requirements for international agreements ratified by the Verkhovna Rada or are not properly registered, such funds are subject to taxation as regular income. **Expanding the exemptions so that all international funds received for scientific research in Ukraine can be exempt from income tax, without adding additional bureaucratic barriers, and in general, making it easier to receive funds for researchers is needed.**

A related issue is the ability of universities to use grant money and other revenue. **Public universities and research institutions should have more financial freedom - for example by being public non-profit enterprises**, they would be able to more easily use grant money and also additional money which they earn, such as by renting out unused facilities.

Targeted investments in training can help researchers remain in science and even accumulate further scientific human capital, including training in fields with military applications, can contribute to war-time and recovery needs. This can include exchange programs/funding for PhD studies abroad and domestic research-oriented educational programmes.

Evidence from other settings suggests that these programs can have positive impacts on the economy. For example, during WWII, the U.S. government made R&D investments via the Office of Scientific Research and Development (OSRD) by awarding contracts to firms and universities to conduct war-related research. These investments subsequently increased employment and entrepreneurship in high-tech clusters (Gross and Sampat, 2020; Gross and Sampat, 2022). Other evidence from the Cold War-era Space Race shows that public R&D investments increased manufacturing value added, employment, and capital accumulation in space related sectors (Kantor and Whalley, 2023). Analysis from Ukraine also shows that public sector investments since 2014 have been critical for the growth in companies developing military-related technologies, such as drones and UAVs (Ganguli and Motrenko, 2024).

After the war has ended, it will be important that there are incentives and **conditions for Ukrainian scientists who have gone abroad to return to Ukraine**. Fellowships and large research grants to do science in Ukraine could be effective tools to encourage such return migration. In other war and conflict situations, return migration has been relatively limited (e.g., Becker et al., 2023; Grüttner, 2022). Evidence from return migration in other contexts, however, points to potentially significant benefits to the home country in terms of knowledge spillovers and productivity gains (e.g., Bahar et al., 2024; Kahn and MacGarvie, 2016; Fry and Ganguli, 2023).

As an example, China has implemented a number of national and local programs to try to attract and incentivize Chinese citizens who are abroad back to China. The Thousand Talents Plan (TTP) is the most well-known and has a range of incentives for return to Chinese institutions, such as high salaries, research funding, and benefits such as housing support (Shi et al, 2022).[6] However, in the United States this program is regarded as "malign", so great care should be given in designing returnee programs (NAS, 2024).[7]

In the meantime, migrants and the larger Ukrainian diaspora can be **engaged in scientific collaborations, and their expertise can be used for policy input and advising.**[8]

b. Integration into International Scientific Community

As evident in the previous section, scientific cooperation with western scientists has been increasing but there is much variation across fields and regions. Programs to encourage collaboration and integration with western scientists will help provide Ukrainian scientists with access to funding and resources, and it is important to have this on Ukraine's agenda to get international support in the future.[9] Ukrainians have gained valuable expertise in the development of military and health technologies, such as drones, demining, and prosthetics, and there should be opportunities to leverage Ukraine's expertise in these collaborations. A key aspect will also be engaging with the Ukrainian diaspora that is abroad and eager to help in reconstruction efforts.

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[6] It is unknown how much the Chinese government spends on these programs or how effective they are in incentivizing return. According to a 2017 press release from the Ministry of Human Resources and Social Security, 50,000 Chinese citizens had returnees through various incentive programs (Zwetsloot, 2020). While such a program with a focus on salaries may be too costly for Ukraine to replicate, non-monetary incentives may also be effective.

[7] For example, the U.S. CHIPS and Science Act of 2022 defines a Malign Foreign Talent Recruitment Program as "any program, position, or activity that is sponsored by a foreign country of concern that includes compensation in exchange for activities that may violate research security regulations." https://new.nsf.gov/research-security

[8] Skorokhod, Oleksandr. "Scientific diaspora — a unique asset for post-war recovery of Ukraine": https://scienceatrisk.org/whitepaper/the-scientific-diaspora-is-a-unique-capital-for-ukraines-postwar-recovery

[9] https://nap.nationalacademies.org/read/26795/chapter/1#3

An important consideration is the move away from scientific collaboration with Russia. As evident in Figure 4, scientific collaboration with Russia was declining after 2014, when it was around 30% of Ukraine's international papers, to approximately 14% in 2022 (Van Noorden, 2023). Ukrainian scientists who previously relied on Russian scientific collaboration will likely need to find new collaborators and may need to change the direction of their research.

Programs that will build capacity and create opportunities for connections with international scientific teams are critical so that Ukrainian scientists are well-positioned to be part of international funding. Initially, this should be focused on areas in which Ukraine is already strong and has expertise, but also a longer-run eye towards developing other areas that will be growing and have potential for funding opportunities in the future.

One example of such an initiative is the UC Berkeley-Ukraine Innovation Hubs, a network of innovation centers being developed in key industry and research centers across Ukraine in collaboration with UC Berkeley, the AI for Good Foundation, the Ukrainian Ministry of Education and Science, the Ukrainian Ministry of Economy, KSE, Kyiv Mohyla Academy, and a variety of local academic and international stakeholders. Each hub is adapted to the needs, realities, and potential of the region in which it is located.

The initiative focuses on creating spaces that bridge the local-international innovation divide by (1) encouraging collaborative scientific work in key disciplines for Ukraine's future economy, (2) building a culture of innovation and entrepreneurship that encourages local community actors to participate in creating new ventures, and (3) ensuring the scientific, capital, and business resources are in place to accelerate such activity, from state-of-the-art research laboratories, to native Ukrainian venture capital funds, to business and intellectual property legal support.

Innovation hubs that sit at the heart of Ukraine's vibrant urban communities can help to enable the economic engine for sustainable growth in areas that will make Ukraine competitive on a global scale, while naturally addressing key challenges within Ukraine's internal markets and society. Ukraine is perfectly located as a global trade hub, and has the opportunity to attract new scientific advances that need to be tested and productised in a business-friendly environment. The UC Berkeley-Ukraine Innovation Hubs are already laying the foundation for major advancements in soil decontamination and yield improvements of staple crops, ground-penetrating radar technology, food as medicine, and countless other areas that will have an impact on Ukraine's immediate needs, while providing a substrate to catalyze economic growth during and beyond the war.

In parallel, it is important to reinforce other channels that Ukrainian researchers have already utilized to gain access to global resources and networks. For example, Ukrainian researchers in high energy physics are part of large influential global teams like the ones at CERN in Switzerland. Even with modest further investment, Ukraine can leverage existing expertise in areas like computational biology and contribute to global teams working on these topics. Another area is IT, where Ukraine initially gained expertise through outsourcing but soon became a critical leader.

There are several existing programs for 'elite' scientists who have international collaborators, but additional programs can be developed. For example, the U.S. National Science Foundation and the national funding organizations of 5 European countries announced a research initiative in August 2023 called the International Multilateral Partnerships for Resilient Education and Science System in Ukraine (IMPRESS-U).[10]

Ukraine has previously participated in European funding partnerships, including participating in the EU Horizon 2020 and EURATOM Research & Training (2014–2020) programmes as an associated country. Under Horizon 2020, Ukrainian researchers have participated in 230 projects involving 323 participants for a total funding request of €45.5 million. In EURATOM R&T (2014–2020), Ukrainian entities received approximately €4.9 million for fusion and fission activities (Bezvershenko and Kolezhuk, 2022).

Given the significant challenges Ukraine faces during the war and its recovery phase, all eligible organizations should actively pursue opportunities in Horizon Europe. Engaging businesses, research entities, non-profits, and local governments not only brings additional funding but also fosters strong international partnerships that facilitate the transfer of expertise, knowledge sharing, and trust building. From 2021 to March 14, 2024, Ukrainian applicants submitted 1,169 applications to the Horizon Europe program, which is 0.37% of all applications. Of these, 137 grant agreements were signed (1.3% of all signed) for a total of EUR 36.62 million (0.12% of all funding). Despite the challenges posed by the war, Ukraine now ranks 6th among the associated countries in terms of funding received, improving from 7th place in the Horizon 2020 program.

The funding distribution for Ukraine's participation in Horizon 2020 and Horizon Europe reveals notable shifts. In Horizon 2020, private organizations (excluding higher and secondary education institutions) received the largest share at 23.1%, which decreased to 14.8% in Horizon Europe. The combined funding for higher and secondary educational institutions and research institutions was 17.1% in Horizon 2020 and slightly decreased to 15.8% in Horizon Europe. Meanwhile, funding for public organizations dropped from 6.1% to 2.7%.

[10] https://new.nsf.gov/news/nsf-announces-international-multilateral; NSF is joined by the Estonian Research Council, the Latvian Council of Science, the Research Council of Lithuania, Poland's National Science Centre, the Polish National Agency for Academic Exchange, the National Research Foundation of Ukraine, the U.S. National Academies of Sciences, Engineering, and Medicine, and the U.S. Office of Naval Research, as well as private donors and foundations.

c. Regional Innovation Development

Economists have pointed to the important role of 'place-based' or regional innovation policies to develop innovation ecosystems that lead to more inclusive economic development. This approach suggests that the productivity of a researcher depends not only on the individual researcher's skills and resources, but also on the extent to which researchers in that location can build on each other's knowledge and discoveries, and participate in different stages of commercialization (Guzman, et al 2024). This approach places an emphasis on a better understanding of the specific latent strengths or bottlenecks facing a region (Guzman, et al 2024; Gruber and Johnson, 2019).

For Ukraine, a priority for regional economic resilience lies in a dedicated approach to developing regional innovation ecosystems. This approach should have two main aims: **developing a national and regional innovation program that can benefit from international funding programs**, like the EU smart specialization program, and **developing universities as important anchors for these regional innovation ecosystems throughout the country**.

For Ukraine, because regions have been affected differently during the war, a region-specific approach is especially important. As of March 2023, the Ukrainian Ministry of Education and Science reported that 3,145 educational institutions (such as schools and universities) had experienced physical destruction due to bombing and shelling. This means that close to 30 percent of all research and higher education institutions had experienced at least some war-related destruction of physical capital.

In recent years, both the U.S. and EU have an emphasis on developing regional innovation programs. In 2023, the U.S. launched a new national innovation program - the U.S. National Science Foundation's Regional Innovation Engines (NSF Engines) program, which was authorized in the "CHIPS and Science Act of 2022" (Section 10388) and is led by the NSF Directorate for Technology, Innovation and Partnerships (TIP).[11] The program is aimed at supporting the development of "diverse regional coalitions of researchers, institutions, companies and civil society to conduct research and development that engages people in the process of creating solutions with economic and societal impacts." Through the process, NSF Engines will train and develop the local workforce and grow regional innovation ecosystems throughout the U.S.[12]

[11] https://new.nsf.gov/funding/initiatives/regional-innovation-engines/about-nsf-engines

[12] On January 29, 2024, the NSF awarded the inaugural NSF Engine awards to 10 teams spanning universities, nonprofits, businesses and other organizations across the United States. Each awardee team will receive an initial $15 million over the next two years with the potential to receive up to $160 million each over the next decade.

Bezvershenko and Kolezhuk (2022) describe Ukraine's experience with regional innovation development through the smart specialization framework, an industrial and innovation framework that takes into account the initial conditions of a region and shows how R&D and innovation policies can influence the economic, scientific and technological specialisation of a region and thus its productivity, competitiveness and economic growth path (OECD 2013).

In 2017, some Ukrainian regions started developing their 'smart specialisation strategies' (S3s). S3s are based on an analysis of strengths and potential of a regional economy and on an 'entrepreneurial discovery process' with a wide stakeholder involvement, including research organizations, universities, and science parks. During the entrepreneurial discovery process, stakeholders find out what is feasible based on their combined capabilities and agree upon their joint priorities. Thus, research and higher educational institutions find their place in the specialization and knowledge based development of a region by (1) performing research that is later utilized by local businesses, the government and the community, (2) preparing relevant human capital and (3) providing expertise. Since 2021, smart specialisation has been a mandatory part of regional development strategies (S3Ua) and it can be used for sustainable reconstruction of Ukraine.[13]

The European Commission has discussed with stakeholders a possible transformation of S3 into smart specialisation strategies for sustainability (S4), and Ukraine should be positioned to be involved in these initiatives.

Notably, under Pillar I of the Ukraine Plan, one of the key reforms focuses on strengthening regional policy development and implementation, specifically through economic activity restoration, human capital development, and economic growth leveraging territorial potential and regional smart specialization. To achieve these objectives effectively, it is essential to secure dedicated funding from the Ukraine Facility to support scientific potential development throughout the implementation process.

A key aspect of regional innovation development is supporting the development of Ukrainian universities. Universities play a central role in place-based innovation ecosystems. Evidence from various settings show that universities make local regional economies more innovative and are good for economic growth and development. Howard, Weinstein and Yang (2022) show for the US that regional universities make their local economies more resilient. Andrews (2023) shows that US counties that had a college established had large increases in patenting compared to runner up counties that did not get a college. Recent evidence also documents the important role of government funding for productivity of university researchers. Babina et al. (2023) show how negative US federal funding shocks reduced high-tech

[13] See https://s3platform.jrc.ec.europa.eu/ukraine; https://s3platform.jrc.ec.europa.eu.

entrepreneurship and publications among university researchers. These shocks did increase patenting, although the patents tended to be of lower quality.

Data suggests that approximately 35% of Ukrainian infrastructure in universities has been damaged during the war, and as discussed in the previous section, many scientists and teachers have left during the war. Evidence from Germany during World War II and France in World War I suggests that while the loss of human capital is most detrimental, damage to physical capital also negatively impacts scientific productivity, but these effects can be mitigated through investments in rebuilding universities and even "building back better" (Waldinger 2016; Bergeaud and Chaniot, 2024).

Priorities for Ukrainian universities and public research institutions going forward include **repair and modernization of physical infrastructure and using the large Ukrainian diaspora abroad to access knowledge and resources abroad.** If there are resources dedicated to modernizing the infrastructure, this can also help to attract not only Ukrainian researchers who have left to return to Ukraine, but also to attract foreign researchers to do research in Ukraine in the future. In the future, it will also be important to continue and systematically support the system of review and evaluation for institutions and individual grants as it is also necessary for creating conditions for the return of emigres and increasing the quality of science being done in Ukraine.

There is also scope for cooperation across universities and research institutions within Ukraine, including the cooperative and strategic use of research infrastructure. In April 2021, the Ukrainian Government approved the Concept of the State Program on Research Infrastructure (RI) development until 2026. The program, initially set in two stages, aimed to establish regulations and an organizing committee, modernize operations, and create financial support tools for RI by the end of 2022. The second phase, planned from 2022 to 2026, focused on establishing and operating various organizational and legal forms of RIs. However, due to the ongoing war, progress on this initiative has been suspended.[14]

More opportunities for interactions between universities/research institutions and businesses can foster innovation ecosystems where basic research done at universities/research institutions can more quickly lead to applied research and subsequent commercialization and entrepreneurship. This can be facilitated by a legal framework for these interactions and tax incentives such as for science parks and for industry-university collaborations in military technologies. This is critical especially to foster an innovation ecosystem where basic research done at universities/research institutions can more quickly lead to applied research and subsequent commercialization and entrepreneurship. There are several

[14]https://scienceatrisk.org/en/whitepaper/doslidnytska-infrastruktura-v-umovakh-povoiennoho-vidnovlennia-vid-poriatunku-do-zrostannia

models for such interactions, such as science parks or science cities located near universities, and a role for international efforts such as the UC Berkeley-Ukraine Innovation Hubs discussed earlier. Developing new tax incentives, and supporting current initiatives such as the proposed special tax regime for research in science parks (Diia.City - Science.City) outlined in the Government's Priority Action Plan for 2024, can incentivize and stimulate scientific and innovation activities in these locations.

Finally, to better incentivize Ukrainian businesses to invest in R&D at universities and research institutions, and to discourage the use of gray schemes for tax optimization, such as creating 'individual entrepreneurs' (ФОПи) and fake LLCs (ТОВ) around public research institutions and universities, **it would be advantageous to exempt value-added tax (VAT) for all non-budgetary sources of research funding.** This could reduce costs and encourage private sector participation in funding research and providing resources into the public sector, as well as provide incentives for public institutions/researchers to work with business directly.

4. Concluding Remarks

It is critical for the Ministry of Economy to be involved in activities related to science and innovation policy. While most immediate questions are often more directly under the purview of the Ministry of Science and Education, economic policies in the areas of taxation, employment and intellectual property, and entrepreneurship, are all interlinked with science and innovation policies and contribute to economic resilience and future economic growth. Moreover, support for applied research related to military technologies can have both economic benefits and increase defense capabilities to contribute to war-time and recovery needs. Given that the Ministry is responsible for implementing the Ukraine Plan - a key instrument for Ukraine's recovery, reconstruction, and modernization - it is crucial to ensure dedicated funding allocation from Ukraine Facility to support science and innovation development in Ukraine. The Ministry of Economy can use the National Council of Ukraine on Science and Technology Development for horizontal coordination within the government and build a system of science for policy, and also leveraging diaspora for science policy advising and engagement.

In this paper, we have highlighted three priority areas that are especially important for the Ministry of Economy to consider going forward, including:

- developing human capital and preventing long-term human capital losses;
- integration with international scientific networks, to be poised to leverage future international funding programs;

- regional innovation development programs including investment in universities/research institutions and research infrastructure, and incentivizing university-industry collaborations, to ensure economic resilience in the future.

These areas all aim to both support the “bright spots”, or Ukraine’s current areas of strength in science and innovation, including expertise gained in military technologies - and also to build capacity in areas that have not been Ukraine’s traditional areas of expertise. Sustained “emergency” funding is needed for those who are actively doing high-quality science already, but funding and longer-term strategies are also needed for scientists and regions that need to “catch up”.

References

Andrews, M.J., 2023. How do institutions of higher education affect local invention? Evidence from the establishment of US colleges. American Economic Journal: Economic Policy, 15(2), pp.1-41.

Babina, T., He, A.X., Howell, S.T., Perlman, E.R. and Staudt, J., 2023. Cutting the innovation engine: how federal funding shocks affect university patenting, entrepreneurship, and publications. Quarterly Journal of Economics, 138(2), pp.895-954.

Bahar, D., Hauptmann, A., Özgüzel, C. and Rapoport, H., 2024. Migration and knowledge diffusion: The effect of returning refugees on export performance in the former Yugoslavia. Review of Economics and Statistics, 106(2), pp.287-304.

Becker, S. O., V. Lindenthal, S. Mukand, and F. Waldinger (2023). Scholars at Risk: Professional Networks and High-Skilled Emigration from Nazi Germany. American Economic Journal: Applied Economics.

Bergeaud, A and J.B. Chaniot, 2024. “The missing workers: Innovation and demographics after World War I”, Mimeo.

Bezvershenko, Y. and Kolezhuk, O., 2022. Transforming Ukraine's research and development to become a driving force of reconstruction. In Y. Gorodnichenko, I. Sologoub, and B. Weder di Mauro (eds), Rebuilding Ukraine: Principles and policies, CEPR Press.

De Rassenfosse, G., Murovana, T. and Uhlbach, W.H., 2023. The effects of war on Ukrainian research. Humanities and Social Sciences Communications, 10(1), pp.1-11.

Dyevre, A., 2022. Public R&D spillovers and productivity growth. Mimeo, available at: https://conference.nber.org/conf_papers/f205900.pdf

Ganguli, I. (2014). Scientific brain drain and human capital formation after the end of the soviet union. International Migration 52(5), 95–110.

Ganguli, I., 2017. Saving Soviet science: The impact of grants when government R&D funding disappears. American Economic Journal: Applied Economics, 9(2), pp.165-201.

Ganguli, I. and Motrenko, A., 2024. "War-Torn Innovation: The Development of Military Technologies in Ukraine," University of Massachusetts Amherst, Mimeo.

Ganguli, I. and Waldinger, F., 2024. War and Science in Ukraine. Entrepreneurship and Innovation Policy and the Economy, 3(1), pp.165-188.

Gruber, J. and Johnson, S., 2019. Jump-starting America: How breakthrough science can revive economic growth and the American dream. Hachette UK.

Grüttner, M. (2022). The Expulsion of Academic Teaching Staff from German Universities, 1933–45. Journal of Contemporary History 57(3), 513–533.

Guzman, J., Murray, F., Stern, S. and Williams, H., 2024. Accelerating innovation ecosystems: The promise and challenges of regional innovation engines. Entrepreneurship and Innovation Policy and the Economy, 3(1), pp.9-75.

Howard, G., Weinstein, R. and Yang, Y., 2022. Do universities improve local economic resilience?. Review of Economics and Statistics, pp.1-51.

Irwin, A., 2023. The fight to keep Ukrainian science alive through a year of war. Nature, 614(7949), pp.608-612.

Jones, C.I., 2005. Growth and ideas. In Handbook of economic growth (Vol. 1, pp. 1063-1111). Elsevier.

Kahn, S. and MacGarvie, M., 2016. Do return requirements increase international knowledge diffusion? Evidence from the Fulbright program. Research Policy, 45(6), pp.1304-1322.

Kantor, S. and Whalley, A.T., 2023. Moonshot: Public R&D and growth (No. w31471). National Bureau of Economic Research.

Lutsenko, A., Harashchenko, N., Hladchenko, L., Korytnikova, N., Moskotina, R., and O. Pravdyva (2023) The Results of The Survey on The Needs of Ukrainian Scientists (First Wave Report). Max Planck Institute for Innovation & Competition Research Paper No. 23-03.

National Academies of Sciences, Engineering, and Medicine (NAS). 2024. International Talent Programs in the Changing Global Environment. Washington, DC: The National Academies Press. https://doi.org/10.17226/27787

OECD, 2022. "Building back a better innovation ecosystem in Ukraine", OECD Policy Responses on the Impacts of the War in Ukraine, OECD Publishing, Paris, https://doi.org/10.1787/85a624f6-en

Polishchuk, Y., V. Moskvina, I. Degtyarova, M. Galat, and L. Makaruk (2022). Assessing The Needs of Ukrainian Scholars in Dangerous Circumstances. Working Paper 6413145, Zenodo.

Romer, P.M., 1990. Endogenous technological change. Journal of Political Economy, 98(5, Part 2), pp.S71-S102.

Shi, D., W. Liu, and Y. Wang (2023). Has China's young thousand talents program been successful in recruiting and nurturing top-caliber scientists? Science 379(6627), 62–65.

Tax Code of Ukraine (TCU). https://zakon.rada.gov.ua/laws/show/2755-17#Text

Van Noorden, R., 2023. Data Hint At Russia's Shifting Science Collaborations. Nature, 615, p.199.

Waldinger, F. (2016). Bombs, Brains, and Science: The Role of Human and Physical Capital for the Creation of Scientific Knowledge. Review of Economics and Statistics 98(5), 811–831.

Zwetsloot, R., 2020. China's approach to tech talent competition: Policies, results, and the developing global response. Global China.

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