Integrating Bespoke IP Regimes for Quantum Technology into National Security Policy

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1 sentence synopsis: *The world needs articulated quantum-innovation policy mechanisms (tailored to the unique physics of the very small).*

Abstract

The adoption of applied quantum technologies by the markets raises cross-disciplinary questions about balancing their disruptive societal effects. It raises questions on how our innovation architecture should be constructed, so that benefits will be distributed equally and risks proportionally addressed. Responding to these challenges we find that policy makers should treat quantum as something unique and unprecedented, but should also learn from history.

In this light, we examine the need for an innovation mechanism tailored to the counterintuitive physical characteristics of quantum technology, particularly in the quantum computing, quantum sensing and quantum communication domains, which includes quantum-AI hybrids. Besides that, we find that it is useful to draw parallels between regulating neighboring fields, for many reasons.

From a cross-disciplinary lens, we connect quantum technology to fair competition and intellectual property, including patents and trade secrets. Ideally, IP and antitrust law should work together in concert to prevent quantum from exacerbating actual inequalities. This may require reform of both doctrines and clarification of their interface. We consider pro-quantum antitrust enforcement, waiving and pledging IP - including issuing compulsory licenses -, democratizing essential technology and analyze quantum-startups' value appropriation strategies.

Some of the best startups in the development of quantum computers, sensors and communications systems have strongly relied on IP protection -including trade secrets about hardware and software- to raise funding from private investors. Yet we wonder whether key concepts and appliances in quantum that are currently enclosed, should be democratized to address tensions between equal access & winner-takes-all effects, and conflicts between openness & control.

We recommend building upon pluralistic innovation mechanisms tailored to adjacent fields such as AI, biotechnology, nanotechnology, semiconductors and nuclear, each characterized by a long investment and R&D phase coupled with uncertain outcomes and rewards, and a Pandora's Box of probabilities and unknown risks.

Given the political reality of a world divided in two tech blocks with incompatible ideologies, standards and values, plus the multiplied societal benefits and safety & security threats,

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vulnerabilities and risks associated with dual use quantum technology, we suggest that countries should be able to treat quantum applications similar to fissionable materials.

In this spirit, we propose to integrate bespoke IP regimes into national security law. We conclude that we can effectively integrate quantum-specific IP regimes into national security policy by adding a new security exception to article 73 (b) (iv) TRIPS. This will give countries the [strategic] option to exclude quantum technologies from IP protection and suspend the enforcement of patent and trade secret rights, similar to fissionable materials.

One fundamental question is whether we want technological information disseminated widely or want it hidden. The theory behind art. 73 (b) (i) TRIPS was to *prevent* disclosure and dissemination of knowledge by suspending IP on fissionable materials, whereas the rationale of art. 73 (b) (iii) is to *encourage* disclosure and dissemination of knowledge by suspending IP, for instance on vaccines. Therefore, the article 73 national security exception regime can [in theory] be invoked in the service of both goals: widely disclosing crucial information, and keeping it secret. As a main rule, the interests of owners of IP rights must be balanced against competing public interests such as national security, fundamental freedoms, privacy and equality rights.

A novel article 73 (b) (iv) TRIPS exception will give countries like the US, China and The Netherlands the opportunity to integrate handcrafted IP regimes for quantum technology into their national security policy. These measures can be seen as a risk-based restriction - in the public interest - of IP incentivized innovation.

In practice however, it may be harder to exclude state of the art quantum materials from IP protection as compared to fissionable materials as in that case most of the breakthroughs came directly from National Labs that are funded in a different way, often by governments spending public money. On the other hand, it might be easier to block disclosure and dissemination of future game changing discoveries since the Trump administration set up the US funding through the National Labs. Therefore, we may have a repeat play with basic science innovations emerging in secrecy rather than in the private sector.

With that, we can distinguish cycles of disclosed and secret development of transformative technologies, with history repeating itself under the influence of global power shifts. Stated differently, we are witnessing historic recurrence of cycles of open en closed innovation. Similarly, IP history shows a pendulum swing between stages of underprotection and overprotection. This means that for applied quantum technologies we are heading towards a scenario of overly stretched IP rights (overprotection) in combination with progress made in secrecy (undisclosed information), which both interfere with the innovation process.

The above illustrates the importance of employing alternative incentive and reward systems to advance innovation within the quantum domain. Beyond IP, policy makers have an array of options to incentivize creative and technological progress, such as state funding, direct spending, competitions, subsidies, prizes, fines, labor mobility law, tax law, education, immigration policy, and attracting talent.

To manage our own inventions, rules need to evolve with technology. Lacking an innovation theory of everything, we attempt to formulate the correct questions on openness -including the rewards of open research and innovation- versus developer and user controls, before giving definitive, all compassing answers. We end with an urgent call for further multidisciplinary qualitative and empirical research on the issues raised.

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INTRODUCTION

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In this light, we examine the need for an innovation mechanism tailored to the counterintuitive physical characteristics of quantum technology, particularly in the quantum computing, quantum sensing and quantum communication domains, which includes quantum-AI hybrids. Besides that, we find that it is useful to draw parallels between regulating neighboring fields.

From a cross-disciplinary lens, we connect quantum technology to fair competition and intellectual property (IP), including patents and trade secrets. We consider pro-quantum antitrust enforcement, waiving and pledging IP, democratizing essential technology and analyze quantum-startups' value appropriation strategies.[2]

We recommend building upon pluralistic innovation mechanisms tailored to adjacent fields such as AI, biotechnology, nanotechnology, semiconductors and nuclear, each characterized by a long investment and R&D phase coupled with uncertain outcomes and rewards, and a Pandora's Box of probabilities and unknown risks.

Given the political reality of a world divided in two tech blocks with incompatible ideologies, standards and values, plus the multiplied societal benefits and safety & security risks associated with dual use quantum technologies, we suggest that countries should be able to treat quantum applications similar to fissionable materials.

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[2] *See* Top Quantum Computers Startups, Tracxn, https://tracxn.com/d/trending-themes/Startups-in-Quantum-Computers Last visited October 17, 2021

In this spirit, we propose to integrate bespoke IP regimes into national security law. We conclude that we can effectively integrate quantum-specific IP regimes into national security policy by adding a new security exception to article 73 (b) iv TRIPS. This will give countries the [strategic] option to exclude quantum technologies from IP protection and suspend the enforcement of patent and trade secret rights, similar to fissionable materials.

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I. BENEFITS, RISKS AND DUAL USE

Quantum technology has untold applications, which open an abundance of opportunities that should be enabled, and benefits that should be maximized and equally distributed. It also opens a Pandora's Box of potentially existential risks, which should be mitigated. Right now, quantum is a very early stage family of technologies -comparable to the transistor/semiconductor in the 1960s- which means that not many use cases currently exist beyond cybersecurity, finance and defense, and that the consequences of quantum infused manifestations remain mostly unknown. From this it follows that we must try to proactively deal with unknown, anthropogenic risks to humanity.

Relatedly, dual use applications (which are products and services that can be used for both civil and military purposes, so for good philanthropy and at the same time for evil hacking and nefarious acts) will necessitate export controls & investment screenings, global trade embargos and shared policies around technology transfer.[3] We foresee a heavily regulated market supervised by an agency such as the FDA[4], the European Medicines Agency, an oversight body like the Department of Energy, or by an authority such as the novel European Artificial Intelligence Board that will oversee the EU Artificial Intelligence Act. Hi-risk quantum applications may need to be classified and unacceptable risk applications should be banned.[5]

To a certain extent these controls restrict follow on innovation and the chances of a thriving open inclusive quantum ecosystem, which inevitably results in missed opportunity costs. Naturally, keeping information secret and forbidding to create, use and trade certain appliances comes at a price. Due to the nature of the technology however, the risks may well be too high to advocate openness like we would normally do, in the sense of open research, open innovation, and open IP regimes, without disproportional restraints.[6] In the case of quantum, there are many arguments for a risk-based approach in combination with controlled, responsible innovation.

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[3] *Cf.* Joseph Koller, *The Future of Ubiquitous, Real-Time Intelligence – A GEOINT Singularity*, The Aerospace Corporation (2019), https://csps.aerospace.org/papers/future-ubiquitous-real-time-intelligence-geoint-singularity

[4] *Cf.* Nicholson Price, *Regulating Secrecy*, (2015), https://balkin.blogspot.com/2015/03/regulating-secrecy.html

[5] *Cf.* Mauritz Kop, EU Artificial Intelligence Act: The European Approach to AI, Transatlantic Antitrust and IPR Developments, Stanford University (2021), https://law.stanford.edu/publications/eu-artificial-intelligence-act-the-european-approach-to-ai/

[6] *Cf.* Chris Jay Hoofnagle and Simson Garfinkel, *Law and Policy for the Quantum Age*, Berkeley, 2021

II. LESSONS LEARNED FROM HISTORY AND ADJACENT FIELDS

Our starting point is that we should build upon pluralistic innovation mechanisms[7] tailored to adjacent fields such as AI, biotechnology such as crispr-cas, nano technology and nuclear technology. These fields are each characterized by a long investment and R&D phase coupled with uncertain outcomes and rewards.[8] They share dual use dilemma's as well. Take fissionable materials, that can be utilized to build both nuclear reactors (civil use) and atomic bombs (military use).

Right now, there are practically no use cases nor empirical data available about court cases and disputes about IP in the setting of quantum computing, sensing and communication.[9] Just anecdotal data, and no court decisions. That said, there are already many technologies whose function depends in an essential fashion on the use of quantum materials (e.g., molecules, engineered nanostructures, ultrathin films) or quantum effects (e.g. lasers, Erbium dopes fiber amplifier, SQUID). Many quantum devices have already been patented. Most notably, a variety of lasers. The so-called vertical cavity surface emitting lasers (VCSELs) are critical devices in many applications, including everything from computer mice to the internet. These quantum devices are very inexpensive and are mass-produced.[10]

But when focusing on innovation mechanisms tailored to quantum computing, quantum sensing and quantum communication -including quantum-AI hybrids- we should extrapolate, draw parallels and apply lessons learned from dealing with related technologies. For example, we should learn from declassification of uranium isotopes in the 50ties, which debatably led to a better, safer world.[11] We should draw technology road mapping lessons from pre-competitive cooperation and standardization efforts in the semiconductor field in the 60ties. We should look at guardrails and best practices developed for the nuclear industry, such as controlled innovation, export controls and non-proliferation.

Earlier this year the quantum community issued an urgent call for awareness and regulation, to prevent the things that went wrong with AI (while many quantum-systems are in fact quantum-AI-data hybrids). We need continuous discussions about innovation enablers, that encourage good use and prevent unwanted behavior. Everything quantum has a multiplier effect on benefits and risks. We have to act now before it is too late to apply policy interventions.

In addition to learning from history we have to treat the Quantum Age as something entirely unique and unprecedented, because of its counterintuitive physical properties that are so different from the reality we experience as human beings, and the behavior of things that we can sense around us.[12] This is explained by the general principles of quantum mechanics: superposition, entanglement, and

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[7] *See* Daniel J. Hemel & Lisa Larrimore Ouellette, *Innovation Policy Pluralism*, 128 YALE L.J. (2019), Available at: https://digitalcommons.law.yale.edu/ylj/vol128/iss3/1

[8] *See* Lemley, Mark A. and Burk, Dan L., *Policy Levers in Patent Law*. Virginia Law Review, Vol. 89, p. 1575, 2003, Minnesota Public Law Research Paper No. 03-11, UC Berkeley Public Law Research Paper No. 135, http://dx.doi.org/10.2139/ssrn.431360 . See also Michael A. Heller and Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, (1998), Science, DOI: 10.1126/science.280.5364.698

[9] Of course, a significant amount of empirical data has been gathered on quantum materials and effects.

[10] *See* https://en.wikipedia.org/wiki/Vertical-cavity_surface-emitting_laser

[11] AMOLF, History, https://amolf.nl/about/history-of-amolf Last Visited November 15, 2021.

[12] *See* Mauritz Kop, *Establishing a Legal-Ethical Framework for Quantum Technology*, (February 28, 2021), Yale Journal of Law & Technology (YJoLT) The Record 2021, https://yjolt.org/blog/establishing-legal-ethical-framework-quantum-technology

tunneling.[13] These principles aim to clarify the relationship between matter and energy at the subatomic level. At the nano scale, quantum effects start to be visible and are unavoidable.[14] Given this physical reality, including the manner in which the very small interacts with our familiar macro-level world[15], we need to create quantum-specific guiding principles.[16] We need rules of the road that include concrete action points and codes of conduct for different actors who create, distribute and use quantum infused systems, products and services.[17]

III. THE RIGHT TO EQUAL ACCESS TO QUANTUM TECHNOLOGY

A key guiding principle for the development and application of quantum technology on which there is consensus within the quantum community, is the right to equal access to the benefits of [future general purpose] quantum computers and the [imminent] quantum internet. With equal access we mean that each individual, group, or country is given similar resources or opportunities.

The guiding principle could be formulated as follows: ''*We contribute to fairness, transparency, equal opportunities, shared benefit, non-discrimination, diversity, solidarity and prosperity. This includes implementing and safeguarding net neutrality, avoiding power asymmetries, and providing equal service and access to the quantum internet in a democratic society.''*[18]

This ground rule aims to address an important risk associated with the use of quantum computers: namely that ''*of increased inequality, monopolization through IP, winner-takes-all effects, and a "quantum divide" during the introductory phase, which holds for both companies and countries*.''[19] For both underdeveloped countries and the emerging quantum-startup ecosystem this may mean that equitable solutions are needed to achieve equal results.

Equal access to quantum computation, quantum sensing and quantum communication systems, makes it possible for everyone to do new science, develop new medical, chemical, and logistical applications, and possibly contribute to a safer world. Right now, however, key quantum technology is owned and controlled by a just handful of multinationals, universities and governments.

A similar pursuit of equal access and benefits formed the basis of two recent initiatives. The Open Covid Pledge[20] (to be qualified as sharing knowledge) and the 'TRIPS patent waiver' on COVID-19 vaccines by the WTO[21] (to be qualified as suspending protection).

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[13] *See, e.g.,* PJE Peebles, *Quantum Mechanics*, Princeton University Press, (Apr. 12, 1992), https://press.princeton.edu/books/hardcover/9780691087559/quantum-mechanics

[14] *See, e.g.,* Mark. L. Brongersma, *The road to atomically thin metasurface optics*, Nanophotonics, 10 (1) (2020), https://doi.org/10.1515/nanoph-2020-0444.

[15] *See, e.g.,* Ismael, Jenann, *Quantum Mechanics*, The Stanford Encyclopedia of Philosophy (Winter 2020 Edition), Edward N. Zalta (ed.), https://plato.stanford.edu/archives/win2020/entries/qm/

[16] *Cf.* Elija Perrier, *Quantum Fair Machine Learning*, (2021) arXiv:2102.00753.

[17] *Cf. Will quantum computing make the world better?*, Inspired Research, Oxford University, Department of Computer Science, 2018, https://www.cs.ox.ac.uk/innovation/research-impact/case-quantum-better-world.html

[18] Kop, *supra* note ... (Yale)

[19] *id.*

[20] *See* Jorge L. Contreras, Michael Eisen, Ariel Ganz, Mark Lemley, Jenny Molloy, Diane M. Peters & Frank Tietze, *Pledging intellectual property for COVID-19,* (2021), https://www.nature.com/articles/s41587-020-0682-1

[21] *See* Max Planck Institute for Innovation and Competition, *Covid-19 and the Role of Intellectual Property. Position Statement of the Max Planck Institute for Innovation and Competition of 7 May 2021*, https://www.ip.mpg.de/en/research/research-news/covid-19-and-the-role-of-intellectual-property-list-of-supporters.html

Could we apply these mechanisms of knowledge donation and temporarily overriding patents related to quantum computation, sensing and communication, to avoid monopolies and repair unwanted market power?

Does applied quantum technology in general require quantum-specific IP policy? Or is tampering with the incentive and reward system, traditionally regarded by policy makers as an important driver of technological innovation, unadvisable? How are quantum-startups actually using first mover advantages, patents and trade secrets in their value appropriation strategy? And how about Open-Source Software & Hardware?[22] Or are the risks simply too big to justify complete openness and do we need more user and trade controls instead[23], integrating bespoke IP regimes into national security policy?[24]

IV. SEARCHING FOR QUANTUM SPECIFIC INNOVATION POLICY MECHANISMS

The recent suspension of patents on COVID-19 vaccines has tapped a rich vein of anxiety about the future of international patent law, and outdated intellectual property (IP) incentive/rewards systems in general. Would the world benefit from the WTO and developed countries 'waiving' patents under TRIPS[25] in other industries, such as the quantum technology ecosystem?

In case adjusting the patent system is not advisable nor politically feasible, would universities and large companies pledging IP in key quantum technology – similar to the Open Covid Pledge (OCP)[26] – accelerate innovation and avoid a quantum divide?

To answer these questions, we must first look at how these mechanisms have worked to help contain the COVID-19 pandemic by facilitating access to vaccines, as far as we can determine this at the moment [as we don't have any empirical data yet].[27]

We discuss a few key points.

1. Does the vaccine TRIPS patent waiver actually work well? Is it achieving its goal?

No, either production of vaccines is too complicated for underdeveloped countries, or countries lack an existing industry & supply chain.[28] We expect that the same applies to building scalable quantum computing applications, which is harder than vaccine production and delivery. So waiving seems to be of little use in the applied quantum technology setting from a practical point of view. Further, scholars argue that we should not waive or abolish patents on vaccines, because patents provide legal certainty when licensing proprietary technology.[29] Moreover, commentators contend that

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[22] *Cf.* Erik von Hippel, Democratizing Innovation, MIT Press Ltd (2005)
[23] Chris Jay Hoofnagle and Simson Garfinkel, *supra* note .....
[24] *See* National Security Commission on Artificial Intelligence's (NSCAI), *The Final Report*, March 1, 2021, https://www.nscai.gov/2021-final-report/
[25] *See* Jacob S. Sherkow, Lisa Larrimore Ouellette, Nicholson Price, and Rachel Sachs, *Are patents the cause of—or solution to—COVID-19 vaccine innovation problems? (No!)* https://writtendescription.blogspot.com/2021/03/are-patents-cause-ofor-solution-tocovid.html
[26] Jorge L. Contreras et al., *supra* note ... Nature
[27] In addition to IP rights, market-authorized vaccines (e.g. by the FDA and EMA) are protected by 'regulatory exclusivity' for a certain period of time such as 10 years, in most parts of the world. *See e.g.*, Ephraim Heiliczer, *How will Pfizer and Moderna protect their vaccine patent applications?* CTech, (2020), https://www.calcalistech.com/ctech/articles/0,7340,L-3876233,00.html
[28] Jacob S. Sherkow, Lisa Larrimore Ouellette, Nicholson Price, and Rachel Sachs, *supra* note ....
[29] Max Planck Institute for Innovation and Competition, *supra* note ...

patents facilitate cooperation on technically complex products and protect against imitation. In that view, instead of hindering equal access, patents play an enabling role.[30]

We maintain that waiving IP (suspending protection, issuing compulsory licenses) on quantum soft & hard structures would have no effect in its current limited scope, -similar to COVID-19 vaccines- unless production and confidential manufacturing know how, trade secrets[31] and exclusive testing and safety data will be pooled and shared as well by the leading manufacturers[32], since the patents do not disclose that info very well.[33] This includes negative know how i.e. information about what did not work. What's more, hi-tech facilities such as cleanrooms are expensive, and countries often lack hi-quality production lines, supply chains and skilled workforce.[34] An important practical obstacle is that even with permission to use third party IP in the form of issuing compulsory patent licenses and suspending trade secret protection either ex article 31 TRIPS, or based on the article 73 (b) (iii) TRIPS national security exception[35], companies simply will not manage to (re)produce merit goods that are not easy to replicate, since they lack the necessary production skills.[36]

This conclusion might not apply to the quantum internet though. Here, waiving IP on essential quantum communication devices and systems may indeed hold beneficial, equitable results, especially for developing countries. Therefore, we should differentiate between the various application areas of quantum technology when discussing tailor-made innovation mechanisms.

2. What are the lessons learned from COVID-pledge for respirators so far? Is it helping companies innovate faster, apart from the benevolent gesture? And what if companies do not want to participate? Is it the same thing as Creative Commons for Copyright?

Pledging IP (temporarily sharing knowledge without territorial constraints) can be beneficial when the majority of rightsholders, which are currently just a handful of actors, join the cause. It all stands or falls with the willingness of companies to participate. That willingness -or desired behavior- should be incentivized. Therefore, the pledging IP mechanism could be promising to prevent monopolization and a quantum divide. Its voluntary nature, however, is its Achilles heel. In the case of COVID-19, the exceptional global medical emergency situation incentivized the voluntarily sharing of IP protected respirator manufacturing know how with competitors. Out of solidarity. The quantum setting lacks this incentive, in the form of an acute, visible global health danger that can be solved by the use or development of quantum systems.

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[30] *See* Reto Hilty, *Interfering with patent protection means playing with fire*, (2021), https://www.mpg.de/16579491/patent-protection-vaccines-covid-10-reto-hilty

[31] *Cf.* Sandeen, Sharon K. and Levine, David S., Trade Secrets and Climate Change: Uncovering Secret Solutions to the Problem of Greenhouse Gas Emissions (August 18, 2014). Research Handbook on Intellectual Property and Climate Change, Chapter 17, (Edward Elgar), Available at SSRN: https://ssrn.com/abstract=2490675

[32] *Cf.* Daniel Gervais, *The TRIPS Waiver Debate: Why, and where to from here? (2021),* https://ipkitten.blogspot.com/2021/05/guest-post-trips-waiver-debate-why-and.html

[33] Jacob S. Sherkow, Lisa Larrimore Ouellette, Nicholson Price, and Rachel Sachs, *supra* note ....

[34] *Cf.* Justin Hughes, *Biden decision on COVID vaccine patent waivers is more about global leadership than IP*, USA Today Opinion (2021), https://eu.usatoday.com/story/opinion/2021/05/06/covid-vaccine-patents-biden-boosts-american-leadership-column/4932766001/

[35] *See* Emmanuel Oke, *COVID-19, Pandemics, and the National Security Exception in the TRIPS Agreement*, 12 (2021) JIPITEC 397 para 1, https://www.jipitec.eu/issues/jipitec-12-3-2021/5340; Frederick Abbott, *The TRIPS Agreement Article 73 Security Exceptions and the COVID-19 Pandemic*, South Center Research Paper 116, August 2020, https://www.southcentre.int/research-paper-116-august-2020/. Recent (controversial) article 73 (b) (iii) cases are: *Russia – Traffic in Transit* and *Saudi Arabia – Intellectual Property Rights.*

[36] *Cf.* Jorge Contreras, *US Support for a WTO Waiver of COVID-19 Intellectual Property – What Does it Mean?,* May 7, 2021 https://blog.petrieflom.law.harvard.edu/2021/05/07/wto-waiver-intellectual-property-covid/

The voluntary, open character of IP pledging resembles Creative Commons licensing methods.[37] A step further is to consider models of Open-Source Software and Hardware[38], since there is evidence that these paradigms make for both technically superior and considerably less expensive scientific equipment than privately owned models.[39]

3. Would these mechanisms work for quantum?

Lacking empirical data that documents the global welfare produced by patents, we think it is important in general to connect the dots between the way the IP pledging and waiving experiments have functioned to achieve their goals during the pandemic in this particular medical device & biosciences use case, and the objective of preventing a quantum divide. It is only natural, and common practices in policy making to draw lessons from history and see what was helpful and what went wrong for two reasons: it also strives at eliminating inequality and encouraging equitable distribution and access through IP strategies, and it is also about balancing emerging, transformative technology. Of course, we have to consider the effects of sector-specific medical and health law rules as well. In the case parts of the mechanism have worked well, it would only be logical to apply those parts to a bespoke IP regime for certain hard to replicate applications of quantum technology, using the right incentives.

V. THE FUNCTION OF THE IP SYSTEM

Before deciding on how to change the IP system and tailor it to quantum, we need to understand the concepts, purpose and rationales behind it on a deeper level.

The IP system's main goal is to incentivize and maximize creativity, cultural diversity, technological progress and freedom of expression. Its main objective is to stimulate discovery, manufacturing and dissemination of human inventions and creations. IP laws grant the owner an exclusive right to make public and reproduce relevant subject matter, which includes an economic right of compensation and a legal entitlement to prohibit. Rationales and justifications of IP rights are the promotion of science and useful arts including cumulative innovation, and the authors and inventors right to remuneration i.e. financial reward. IP rights are not absolute, but limited in time and scope. IP rights can also be limited by exceptions such as fair use, as well as by contract, open source and anti-trust law.

Patent law intends to foster technological innovation by affording a limited monopoly to inventors such that they can get a return on their investment. It intends to incentivise the detailed disclosure of discoveries and optimize the apportionment of R&D capacity, by awarding exclusive rights to the inventor. The patent system seeks to provide society with in-depth information on how inventions need to be practiced in order for people to use and build upon them proficiently after the 20 year patent term has expired. Simultaneously, it aims at inventors to design around and improve upon earlier patents.

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[37] *Cf.* Benkler, Y. and Nissenbaum, H. (2006), *Commons-based Peer Production and Virtue*. Journal of Political Philosophy, 14: 394-419. https://doi.org/10.1111/j.1467-9760.2006.00235.x
[38] *See* Pearce, JM 2017 *Emerging Business Models for Open Source Hardware*. Journal of Open Hardware, 1(1): 2, pp. 1–14, DOI: https://doi.org/10.5334/joh.4
[39] *See* Levine, David S. and Sichelman, Ted M., *Why Do Startups Use Trade Secrets?* (April 22, 2018). 94 Notre Dame Law Review 751 (2018), San Diego Legal Studies Paper No. 18-346, Available at SSRN: https://ssrn.com/abstract=3166834

Ideas cannot be [temporarily] monopolized by copyright or patent: they are public domain. Only the expression of an idea can be protected. This is known as the idea/expression dichotomy. Thus, quantum mechanics itself is not patentable, but specific technological applications are, such as the many software and hardware components of a quantum computer.

Examples of IP rights are copyrights, patents, industrial design rights, trademarks and trade secrets. As a main rule, the interests of owners of IP rights must be balanced against competing public interests such as fundamental freedoms, privacy and equality rights. Although there are differences in US and EU IP systems, the Berne Convention, the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and the WIPO Copyright Treaty (WTC), to which most countries of the world are members, unify IP law.

The idea behind IP law is that it should facilitate innovation, instead of hindering or stifling it. However, results vary per economic sector, innovation type and business model.[40] In other words, IP plays different roles in different industries and technologies, with different outcomes as we deal with different actors, products and services.[41] The ensuing IP underprotection or overprotection interferes with the innovation process. Yet IP laws alone cannot prevent market skewness and winner-takes-all effects. Additional innovation tools are needed to accomplish that.

In theory, patent law is technology-neutral, but it appears to be technology-specific in application.[42] So it can work differently even within the quantum domain. This means that it is important to differentiate between the various application areas of quantum technology, such as quantum computing, sensing, metrology, cryptography, internet, and chemistry as well. It will however be difficult for the lawmakers to codify differentiated IP laws. Traditionally, there lies an important role for the courts to articulate patent rules to specific technologies, such as AI, quantum and the biosciences. Courts can profile certain industries or technologies as apt for patent tailoring, with flexible standards.[43] Flexible standards like lowering or raising the obviousness threshold and lowering or heightening disclosure requirements. This could result in patents being easier or harder to obtain in certain sectors or relating to specific technologies.

IP is not the only incentive and reward system that promises to stimulate innovation. Beyond IP, policy makers can use many tools to incentivize creative and technological progress, such as state funding, direct spending, competitions, subsidies, prizes, fines, labor law, tax law, education and [attracting] talent.[44] A forward thinking pluralistic innovation toolkit should integrate law, economics, ethics, labor mobility and immigration policy. It is for a reason that the U.S.'s main innovation hubs have emerged in places where NDA's and non competes are limitedly enforced, where liberal immigration policies attract top R&D talent to leading companies and universities, and where the living conditions are so good that they stay there.

For tech startups and SME's, patents and trade secrets are substitutes as well as compliments of each other. But their value appropriation strategy may well prioritize firs mover advantages over an

[40] Lemley, Mark A. and Burk, Dan L., *supra* note ...; Levine, David S. and Sichelman, Ted M., *supra* note ...
[41] Lemley, Mark A. and Burk, Dan L., *supra* note ...
[42] Lemley, Mark A. and Burk, Dan L., *supra* note ...
[43] Lemley, Mark A. and Burk, Dan L., *supra* note ...
[44] Jacob S. Sherkow, Lisa Larrimore Ouellette, Nicholson Price, and Rachel Sachs, *supra* note .... In case of government funding, the Bayh-Dole Act gives the state "march-in rights" over patents, which includes the right to force licensing of the patent on the invention that was government funded to others. *See* https://law.stanford.edu/2021/11/11/stanfords-mark-lemley-on-the-moderna-ip-dispute-with-us-government/?sf154355632=1

expensive and uncertain patent registration process.[45] In many cases, because of costs and fear of knowledge leakage, SME's chose the trade secret route. However, trade secrets do not protect against reverse engineering and independent creation, which holds the risk of competitors inventing the same solution and patenting it first. Here it is first come first served. On top of that, many innovations are joint, cooperative projects that involves a lot a sharing of information. This makes it difficult to maintain an IP portfolio that contains trade secrets. Besides that, rules and court decisions on copyrights on API's are extremely complex and hard to decipher for startups without a significant budget for specialist legal advice. And sometimes follow-on innovation is so incremental that it doesn't surpass the obviousness threshold, necessary to fulfill the inventive step requirement during patent examination. The result is that in many cases innovation moves on without IP.

So IP is not the whole story. It is not the only incentive & reward system that encourages creation and invention.

VI. EXPERIMENTS AND LEGAL REFORM

Now we understand the function of the IP system, and its limits. But will IP play the role that we expect and want it to play in the context of applied quantum tech?

Let us zoom in on an example: quantum computing. This key domain of quantum technology unites physics, mathematics and computer science. These machines generally contain countless layers of hardware and software components, such as qubits, quantum gates, quantum circuits, quantum machine learning algorithms and the quantum-classical interface. All these components can be protected by an array, by a rainbow of overlapping exclusive IP rights, potentially unlimited in duration. This results in overprotection, patent thickets, stagnation and missed opportunity costs.

Further, and similar to current trends in AI and biotechnology, we predict a shift from patents towards trade secrets. This shift results in a disincentive to disclose ideas and information, effectively monopolizing information and stifling innovation.

IP overprotection will cause legal, economic and de facto monopolies in the hands of a few wealthy first movers. We predict that monopolization through IP will exacerbate inequality and foresee long term patent thickets. This means that for quantum, our untailored IP system enhances existing inequalities vis a vis income, gender, race, northern versus southern hemisphere, SMEs versus multinationals and so on. Which leads to distorted innovation. These are unwanted side effects of the IP system, which go against the public interest. This requires exceptionalism and legal reform.

For the IP side of things legal reform means answering questions about tensions between enclosure, trade secrets, classified state information, lead time, winner-takes-all effects, market barriers for startups, spillovers, free riding, and open innovation. In our view, policy makers should not be afraid to experiment with scope and duration of copyrights and patents (such as shorter protections of 3 to 10 years)[46], strategies to avoid the incentives/access tradeoff without eliminating patents[47], SEP, FRAND and compulsory licensing, international IP pools that include know how and manufacturing knowledge, limiting internalizing positive externalities[48], as well as open source approaches towards

[45] Levine, David S. and Sichelman, Ted M., *supra* note ...
[46] *See* Mauritz Kop, *Quantum Computing and Intellectual Property Law* (April 8, 2021). Berkeley Technology Law Journal, Vol. 35, No. 3, 2021, Forthcoming, https://law.stanford.edu/publications/quantum-computing-and-intellectual-property-law/
[47] Jacob S. Sherkow, Lisa Larrimore Ouellette, Nicholson Price, and Rachel Sachs, *supra* note ....
[48] *See* Lemley, Mark A., Property, *Intellectual Property, and Free Riding*. Texas Law Review, Vol. 83, p. 1031, 2005. Available at SSRN: https://ssrn.com/abstract=582602; Lemley, Mark A. and Frischmann, Brett M.,

software & hardware. This includes introducing forward thinking modalities of property and de facto ownership, commons, quasi-public goods, reimagining state property all the way up to democratizing the technology and enrichment of the public domain.

Some of the best startups in the development of quantum computers, sensors and communications systems have strongly relied on IP protection -including trade secrets about hardware and software- to raise funding from private investors.[49] Yet we wonder whether key concepts and appliances in quantum that are currently enclosed, should be democratized to address tensions between equal access & winner-takes-all effects, and conflicts between openness & control.[50] In fact, in parallel to experimenting with patent scope and duration, a Quantum Treaty or Charter that democratizes essential technologies, formalized by a government issued public domain stamp after a balancing of interests (quasi-CC0) might be worth exploring. The results of these experiments should be visible quickly.

For the sake of time, legal certainty and political feasibility we suggest a nuanced, incremental approach, i.e. a tailored solution instead of an aggressive overhaul of the entire system on the shorter term. On the longer term, we think that policy makers should search for a composition of innovation that goes beyond solidarity, altruism and donation -such as waiving patents and pledging IP. Mechanisms [beyond softer approaches like flexibilities, exceptions & limitations] that are in line with the transformative power of the technology and its distinct metaphysical characteristics.

VII. THE INTERFACE BETWEEN IP AND FAIR COMPETITION

Intellectual property law is entangled with antitrust law: incentivizing innovation through the intellectual property system may increase as well as reduce competitiveness. On one hand, IP creates an incentive to invest that increases competitiveness. On the other, IP's state-granted monopolies - although limited in space and time- [temporarily] reduce competitiveness. Thus, IP hinders competition within the market, but fosters competition for the market. What role could antitrust law play, when encouraging technology and know-how transfer, as well as avoiding impending monopolies and a quantum divide? What would be its strength and limits?

Antitrust law prohibits monopolization, price fixing, cartels, boycott and refusal to give access, and other trade practices that are harmful for the consumers and the market. Coordinated refusals to deal are labeled as boycotts and are prohibited under Section 1 of the Sherman Act.[51] Specifically, NYNEX Corp. v. Discon (1998) states that boycotts involving vertical schemes are subject to the rule of reason, while horizontal boycotts constitute per se violations of the Sherman Act.[52] Although

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Spillovers. 107 Columbia Law Review 257 (2007), Available at SSRN: https://ssrn.com/abstract=898881; Kop, *supra* note .... (Berkeley)

[49] *See* Jeff Vance, *10 hot quantum-computing startups to watch*, Networkworld, February 15, 2019, https://www.networkworld.com/article/3489098/10-hot-quantum-computing-startups-to-watch.html

[50] *Cf.* Kop, *supra* note .... (Berkeley). We realize that democratizing essential quantum technologies and excluding certain appliances from IP can be at odds with the value appropriation strategies of quantum-startups, including their chances of obtaining private equity funding. There is a clear tension between privatizing and democratizing knowledge. Government funding might be a solution.

[51] *See* Section 1 of the Sherman Act, 15 U.S. Code Chapter 1— Monopolies and Combinations in Restraint of Trade, https://www.law.cornell.edu/uscode/text/15/chapter-1; Klor's, Inc. v. Broadway-Hale Stores, Inc., 359 U.S. 207 (1959)

[52] *See* NYNEX Corp. v. Discon, Inc., 525 U.S. 128 (1998), https://supreme.justia.com/cases/federal/us/525/128/

the courts have affirmed the absence of any duty to deal with rivals in the Trinko decision[53], it remains unclear whether it applies to all situations, or solely to regulated industries.[54]

Providing access is not the end of the story. Patent holders can be required to give FRAND licenses when the patent they hold is deemed “essential” to compete on the market. In the space of quantum computing, one will therefore have to study the essentiality of patents very closely.

As mentioned above, antitrust prohibits horizontal collusion in the form of cartels. Empirical studies show that cartels are less likely to be implemented when a market is new and innovative. Antitrust also prohibits monopolization, and forbids mergers and acquisitions when the effects are detrimental to competition and a well-functioning market. It first requires a proof of dominance, generally, at least 50% of the market. As there is no proper, complete quantum market for now, antitrust is holds in check. Second, it requires an abuse of that market power. Here again, there is no evidence of such abuses for the time being.

And what role can antitrust/fair competition law play to avoid winner-takes-all effects?

Antitrust is not meant to avoid winner-takes-all effects. On the contrary, antitrust courts and agencies are encouraging dominance when it results from fair competition. Principally, antitrust law aims to support business activities and trade practices that enable fair and equitable competition. Antitrust only prevents winner-keeps-all when the “keeping” results from anticompetitive practices. In short, antitrust seems mostly ineffective to this day, and not the right tool for ensuring proper competition at such an experimental stage.

However, shaping competition in the sense that it favors the major players is what we may not want. Perhaps we can achieve this goal by introducing a new, pro-quantum enforcement mechanism. Pro quantum antitrust enforcement could protect the emerging quantum marketplace the moment/in case dominant players use their existing market power to affect quantum computing, sensing and communication development.

Ideally, IP and antitrust law should work together in concert to prevent quantum from exacerbating actual inequalities. This may require clarification and reform of both doctrines.

Take trade secrets. Currently, trade secret law has an overly broad definition that is abused by the larger companies, which results in the pendulum swing of IP protection being in a stage of overprotection in various sectors. From an open innovation perspective, we would like to see these trade secrets being returned to the market and to the public domain. However, certain information pertaining to the quantum domain remaining secret might be an entirely good thing that benefits society, from strategic and risk-management perspectives. Moreover, the interface between competition law and privacy & data regulations is unclear, which raises anti-competitive concerns. We need a healthy, quantum technology-specific relationship between trade secrecy and competition law, and legal clarity about their interaction with privacy & data protection.

Dogmatically, antitrust rules should not prevent knowledge sharing and stand in the way of the good sides of IP in general. IP in turn, should not disincentivize or distort innovation, and should not lead to monopolization, as can happen when a market is in a state of IP overprotection (but also underprotection). And in certain cases, we don't want hi-risk quantum driven systems, products and services to enter the market, which will be heavy regulated, similar to the nuclear industry. Given the

[53] *See* Verizon Communications v Law Offices of Curtis V Trinko, LLP, 540 U.S. 398 (2004), https://supreme.justia.com/cases/federal/us/540/02-682/

[54] For a discussion, *see* Andrew I. Gavil, William E. Kovacic, Jonathan B Baker, *Antitrust Law in Perspective*, third edition, pages 639-640), West Academic Publishing (2017).

fact that fair competition stimulates innovation, it is crucial to have clarity about the interface between the role of IP rights and antitrust laws within the context of quantum technology.

VIII. STRATEGIC PERSPECTIVES ON OPENNESS AND CONTROL

Let us now connect research, development and innovation to tensions between openness and control in light of the strategic benefits & risks involved with quantum technologies.

The innovation process can be conceptualized as having various phases: discovery, invention and follow-on invention. With academic and industrial science at the forefront, before creating actual products and services.[55] When discussing openness and control, it is important to differentiate between open science and open innovation. Open science is about sharing knowledge in the discovery phase.[56] Open innovation is about bringing useful creation and inventions to the market, in the form of commercialized systems, products and services.[57] The collaborative nature of open innovation benefits society in most cases, creating network effects, synergetic effects, flourishing ecosystems and jobs. As open science accelerates open innovation, it should be incentivized in general. Because of the advantages of open innovation, this is the preferred option in most cases.[58]

However, threat, vulnerability and risk management is harder in an open innovation setting. And that is exactly what is elemental to balance the expected disruptive effects of quantum, and its unknown risks.[59] There is a tension between open innovation and existential threats and risks pertaining to dual use quantum technologies, comparable to the large impact risks in the nuclear industry.

What if there would be incentives or even regulations that would restrict sharing knowledge with colleague scientists who happen to live in foreign states? So that one state would stay ahead or to prevent dual use? There are many examples to mention, such as the Cold War, the recipe for the atom bomb, key rocket technology and so on.

Given the present-day open science and collaboration trend, for many quantum and nano scientists it would be an outright scandal, or even mark the end of their careers to not make public their latest findings and breakthroughs on preprint servers and leading journals. Quantum physicists and quantum security specialists might totally disagree with this article's approach and prefer complete openness without guardrails, or completely closed innovation, or something in between. But even in that case, it is important to recognize and take into account the difference between open science and open innovation.

In general, we should incentivize sustainable innovation, that is enabled by a clear legal-ethical framework. In this contribution, we are searching for the best quantum-innovation policy mechanism. Since the field is so new and expanding at an exponential rate, but use cases beyond cybersecurity so scarce, we will seek to identify the right questions that would help us in our search.

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[55] *See* Friesike, S., Widenmayer, B., Gassmann, O. *et al. Opening science: towards an agenda of open science in academia and industry*. J Technol Transf 40, 581–601 (2015). https://doi.org/10.1007/s10961-014-9375-6
[56] *id.*
[57] *id.*
[58] *See* Price II, Rai & Minssen, *Knowledge transfer for largescale vaccine manufacturing*, Science, August 2020, https://science.sciencemag.org/content/369/6506/912
[59] Chris Jay Hoofnagle and Simson Garfinkel, *supra* note .....

For example, are the strategic benefits & risks inherent to quantum technologies simply too large to endorse open innovation globally? And is there anything new under the sun that is so different from e.g. AI, bio or nuclear, that justifies a quantum-specific approach?

We think indeed that -perhaps counterintuitively- user controls should be applied and less openness built in, as an exception to the rule of open innovation, due to the huge (strategic) risks associated with quantum. Should this also apply to scientists and developers of unacceptable risk technologies, in early stages of the innovation process?

Our questions can be answered from different perspectives, that are not always aligned.

First, the strategic perspective. Against the backdrop of a battle for technological dominance that involves two separated blocks with incompatible political systems, the US and China[60], rivalry and competition could accelerate innovation.[61] Right now, we can identify a trend towards enclosure, and a trend of innovation and state & venture capitalist investments in R&D taking place along political, ideological lines.[62] The world should however be striving for sustainable, hi-quality innovation that can help answer the big questions we face as humanity, such as climate change. Not for a hi-tech arms race. Instead, we need a spirit of cooperation on big picture trends, in combination with innovation incentivizing competition on specific technological approaches created by industry, and a diversification of research paths. In addition, a misalignment of private and social incentives should be prevented. What we need are economic incentives to do the right thing socially, strategically and innovation wise. Meanwhile, from a strategic democratic perspective, it might be necessary to keep certain information secret, prevent market entrance, exclude it from monopolization through IP, or even expropriate certain real-world applications.[63] These measures, such as licensing authorizations, can be qualified as building in controls for strategic purposes. To ensure that the U.S. stays on par with China's scientific infrastructure, it is clearly time to make smart new investments now and urgently enforce clever IP policies.[64]

Second, the normative perspective. Here, benefits and risks should be equally distributed across society using the proper incentives. Unknown risks should be managed using a risk-based approach. The best innovation usually combines freedom & control. Most long-term quantum applications are still unknown. When the tech comes to age, we better be ready.[65]

Third, the socio-economic perspective, endorsing sustainable, responsible innovation. We should search for an innovation optimum and a Pareto improvement, complete markets, fair competition, network effects and value chains.

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[60] National Security Commission on Artificial Intelligence's (NSCAI), *supra* note ....

[61] *Cf.* Mauritz Kop, *Democratic Countries Should Form a Strategic Tech Alliance*, Transatlantic Antitrust and IPR Developments, Stanford University, (2021), https://law.stanford.edu/publications/democratic-countries-should-form-a-strategic-tech-alliance/

[62] *Cf.* Democracy Technology Partnership Act, introduced by bipartisan Senators Mark R. Warner (D-VA), Bob Menendez (D-NJ), Chuck Schumer (D-NY), Todd Young (R-IN), John Cornyn (R-TX), Ben Sasse (R-NE), Marco Rubio (R-FL), Michael Bennet (D-CO), March 4, 2021, https://www.congress.gov/bill/117th-congress/senate-bill/604?s=1&r=8

[63] National Security Commission on Artificial Intelligence's (NSCAI), *supra* note ....

[64] *See* American Society of Arts and Sciences, The Perils of Complacency, America at a Tipping Point in Science & Engineering, as part of the New Models for U.S. Science and Technology Policy project (2020), https://www.amacad.org/publication/perils-of-complacency

[65] See World Economic Forum, Issue Briefing: What's Next for Quantum Computing?, Sep 8, 2021, https://www.weforum.org/videos/issue-briefing-whats-next-for-quantum-computing-c1ac566ca6

Fourth, the legal-ethical perspective. We need a risk based, agile horizontal -vertical legal-ethical framework.[66]

We argue that from whichever angle one views these challenges, [a strategic perspective (1), defending democracy setting rules of the road, from a risk management/mitigation perspective (2), from a sustainable innovation optimum perspective (3), and from a legal-ethical viewpoint (4),] a certain amount of control/restriction is needed. This includes controls for actors like users and developers, companies and countries. The goal should be equal distribution of benefits & risks.

We should look at a custom-made innovation-mechanism for quantum in terms of how it incentivizes competition, enables openness and control, how it maximizes benefits and mitigates risks, and how it attributes responsibility to developers and users.

IX. A RISK BASED APPROACH

To us it is obvious that we should both (a) learn from history, build upon knowledge and experience gained from adjacent cross-disciplinary fields, such as the Trustworthy AI and nano-ethics paradigms, declassification of uranium isotopes[67], know-how sharing in the semiconductor industry, as well as biotechnology, with its similarly long hi risk investments and uncertain returns, and (b) treat quantum technology as something unique and unprecedented, developing regulation and governance methods that are tailored to the distinct physical characteristics of its underlying principles of quantum mechanics.

This means that we should put controls in place that address identified risks, threats and vulnerabilities in a proportional manner. Controls that fit into a risk-based approach based on the pyramid of criticality (adjusted to quantum), with low risks at the bottom and existential, unacceptable risks for humanity at the top. In many cases, the benefits will outweigh the risks and open research and innovation can take place, unhindered by legislative controls.

Enforcing this risk-based approach, which includes attributing responsibility, requires a clear definition of hi-risk quantum systems. Creating an accurate, satisfactory definition in this early stage, however, is a challenge without a crystal ball, since the use cases necessary to draw on do not yet exist. This loophole demands for new forms of transformative tech governance, such as an agile legislative system, that can quickly respond to changing circumstances and societal needs in the field of applied quantum technology. To make certain benefits will be maximized and distributed equally and equitably across the population, and undesired ramifications of quantum infused products and services will be mitigated as much as possible without hindering progress, pivotal work must be done in the areas of quantum ethics[68], regulation, standardization and certification.[69]

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[66] *See* Mauritz Kop, *Quantum ELSPI: Ethical, Legal, Social and Policy Implications of Quantum Technology*, Digital Society (Springer Nature) (2021), https://law.stanford.edu/publications/quantum-elspi-ethical-legal-social-and-policy-implications-of-quantum-technology/.

[67] AMOLF, *supra* note ....

[68] By ethics we mean for humans [and machines] to act virtuously, and to make sure these actions have desirable consequences, *see* Mauritz Kop*, Ethics in the Quantum Age*, Physics World (2021), https://physicsworld.com/a/why-we-need-to-consider-the-ethical-implications-of-quantum-technologies/. *See also* Vincent Muller, Andrea Bertolini, Emilie Rademakers, *Position Paper: Ethical, Legal and Socio-economic Issues in Robotics,* euRobotics topics group on 'ethical, legal and socioeconomic issues' (ELS) (2017), http://www.pt-ai.org/TG-ELS/; and Elija Perrier, *Ethical Quantum Computing: A Roadmap*, (2021), arXiv:2102.00759.

[69] See also Kop, *supra* note .... (Berkeley)

An effective method to manage the identified risks of applied quantum technologies, might be to integrate bespoke IP regimes into national security policy[70], as part of a quantum-specific innovation strategy tailored to the unique physics of the very small.

X. ADDING A NEW SECURITY EXCEPTION FOR QUANTUM TO TRIPS

One plausible explanation for the Fermi paradox is the evolutionary theory predicting that it is the nature of intelligent life to destroy itself before reaching the stars. This could happen to humanity as well. Not being able to manage our own inventions, our civilization might eradicate itself before getting the chance to colonize space.

For example, a civilization could be destroyed by an all-destructive nuclear conflict. To prevent this, an array of guardrails is used such as non-proliferation, dual use rules, the Wassenaar agreement and TRIPS art 73, mirrored by WTO's General Agreement on Tariffs and Trade (GATT) in article XXI.[71] Article 73 (b) (i) contains a security exception for fissionable materials and thus integrates an adapted IP regime for the nuclear industry into national security laws.[72] In certain cases, countries may invoke this exception to the normal rules for IP in the interest of national security.[73] For nuclear, this means, for example, that the atomic bomb cannot be patented.[74] The theory behind withholding publication of nuclear patents was to prevent disclosure and dissemination of game changing technology.[75] Because of the described similarities between nuclear and quantum, we hereby propose to add this mechanism to Article 73 for quantum. In the form of a new paragraph to article 73 (b) (iv) TRIPS en GATT XXI (b) (iv), stating: "relating to quantum technology'', which should include quantum-AI hybrids.[76]

This novel security exception results either in exclusion of patentability, secret patent procedures or suspension of the enforcement of patents and other IP rights such as trade secrets, design rights, trademarks and copyright. What remains is either classified information governed by state secret regimes[77], or public domain creations and inventions in the territory of the country that invokes Article 73 TRIPS.

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[70] National Security Commission on Artificial Intelligence's (NSCAI), *supra* note ....

[71] *See* WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) article 73, https://www.wto.org/english/docs_e/legal_e/27-trips_09_e.htm and WTO's General Agreement on Tariffs and Trade (GATT) article XXI, https://www.wto.org/english/docs_e/legal_e/gatt47_02_e.htm#articleXXI

[72] Alexander Matveev & Vladimir Martynov, *Intellectual property challenges to nuclear energy*, (2016), https://www.academia.edu/30222182/INTELLECTUAL_PROPERTY_CHALLENGES_TO_NUCLEAR_ENERGY

[73] *Cf.* National Nuclear Security Administration, 10 CFR Part 810, https://www.energy.gov/nnsa/10-cfr-part-810 and U.S. Nuclear Regulatory Commission, Information Security, https://www.nrc.gov/security/info-security.html

[74] *Cf.* Alex Wellerstein, *Patenting the Bomb: Nuclear Weapons, Intellectual Property, and Technological Control*, Isis 2008 99:1, 57-87, https://www.journals.uchicago.edu/doi/pdf/10.1086/587556

[75] Please note that art. 73 (b) (i) (connected by us to quantum technologies) has a different rationale than art. 73 (b) (iii) (connected to the pandemic/IP waiver by several commentators), the latter being invoked during the COVID-19 pandemic. Art. 73 (b) (i) aims to prevent disclosure and dissemination of knowledge by suspending IP, whereas (iii) aims to encourage disclosure and dissemination of knowledge by suspending IP. Therefore, the article 73 national security exception can [in theory] be invoked for both widely disclosing crucial information, and for keeping it secret.

[76] Instead of adding a novel paragraph (iv), ''relating to quantum technology'' could also be added to art. 73 (b) 1 as follows: ''relating to fissionable materials or the materials from which they are derived, and relating to quantum technology''.

[77] Alexander Matveev & Vladimir Martynov, *supra* note ...

It is different from the US Defense Production Act of 1950, that authorizes the President to requisition, or involuntarily seize, any property. The DPA also permits the President to institute regulatory mechanisms such as an executive order[78] to allocate resources, materials, production lines, and services to secure national defense.

The practical consequences of invoking the security exception are no technology transfer, no commodification, no market entrance, no monopolization and no disclosure. [Please note that the state trying to monopolize quantum technology itself via patents probably has no effect.] So the end result of baking in controls into the design of our innovation architecture -either for political, economic or safety reasons- is certain information remaining secret (like the German 'poison cabinet' during WWII) or not eligible for vesting exclusive rights.

In practice however, it may be harder to exclude state of the art quantum materials from IP protection as compared to fissionable materials as in that case most of the breakthroughs came directly from National Labs that are funded in a different way, often by governments spending public money. On the other hand, it might be easier to block disclosure and dissemination of future game changing discoveries since the Trump administration set up the US funding through the National Labs.[79] Therefore, we may have a repeat play with basic science innovations emerging in secrecy rather than in the private sector.[80] And with that, we can distinguish cycles of disclosed and secret development of transformative technologies, with history repeating itself under the influence of global power shifts. Put differently, we are witnessing historic recurrence of cycles of open en closed innovation. Similarly, IP history shows a pendulum swing between stages of underprotection and overprotection. This means that for applied quantum technologies we are currently heading towards a scenario of overly stretched IP rights (overprotection) in combination with progress made in secrecy (undisclosed information), which both interfere with the innovation process.

One fundamental question is whether we want technological information disseminated widely or want it hidden.[81] Ironically, while patents are supposed to disclose information, withholding or breaking patents has been suggested in the service of both goals.[82] Similarly, article 73 TRIPS can be invoked to both encourage and prevent disclosure and dissemination of knowledge by suspending IP rights.

A novel article 73 (b) (iv) TRIPS exception will give countries like the US, China and The Netherlands the opportunity to integrate handcrafted IP regimes for quantum technology into their national security policy. These measures can be seen as a risk-based restriction - in the public interest - of IP incentivized innovation. The next step is identifying use cases, including a dynamic list of quantum-

[78] National Security Commission on Artificial Intelligence's (NSCAI), *supra* note ....
[79] *Cf.* Hoofnagle & Garfinkel, *supra* note ...
[80] *See for example* Steve Blank on groundbreaking work on semiconductors done in classified university research labs, The Secret History of Silicon Valley, https://youtu.be/ZTC_RxWN_xo?t=2099 Last visited November 14, 2021
[81] The upcoming U.S. Chips Act (Creating Helpful Incentives to Produce Semiconductors for America) contains a national security part as well, giving the U.S. government the opportunity to prevent disclosure and dissemination of semiconductor and transistor technology information. *See e.g.* David Isaacs, *Momentum Builds in Congress for CHIPS Act Funding, FABS Act*, Semiconductor Industry Association (SIA), Oct. 25, 2021, https://www.semiconductors.org/momentum-builds-in-congress-for-chips-act-funding-fabs-act/
[82] *Cf.* note 75.

specific risks beyond cybersecurity, where open innovation is not the preferred option.[83] To manage our own inventions, rules need to evolve with technology.

XI. CALL FOR FURTHER RESEARCH

In this contribution, we searched for [open] innovation mechanisms tailored to the unprecedented challenges of the quantum era. In our view, incentivizing a sustainable quantum ecosystem asks for a set of cohesive government innovation policy interventions that are adapted to the specific, counterintuitive characteristics of quantum mechanics.

While there is no 'innovation theory of everything', we think it is wise to integrate bespoke innovation mechanisms into other disciplines, and learn from the past. On a distant horizon, we envisage a unified holistic governance framework for quantum technology that combines insights from law, economics, labor mobility, sociology, ethics, philosophy of science, quantum information science, and national security policy.

Our journey so far has been very interesting. It has been surprising to see how much opinions on quantum differ among innovation scholars, whereas a lot of agreement and common ground exists on how to regulate adjacent 4IR tech such as AI, bio & data. Some examples of viewpoints received thus far from colleagues, differing widely, are:

1. We need an open innovation policy toward quantum tech that contains proper market-incentives.
2. A quantum-specific IP policy is not needed, nothing new under the sun that would justify it.
3. The risks are too great for an open policy; we need more controls to prevent unsettling scenarios.

We argue that we cannot leave these matters to the market, due to the anthropogenic risks associated with quantum technology. We advocate an agile, sustainable innovation mechanism in the form of a suite of unified government innovation policy interventions on IP, beyond IP pluralism and fair competition. We recommend building an innovation architecture that mixes freedom, openness and control, integrated into national security policy via article 73 TRIPS. An architecture that searches for an accelerated sustainable innovation optimum. In this vision, standardization, certification and impact assessments play an important role. Anno 2021, the antitrust route seems difficult because the market for quantum driven systems, products and services is incomplete, in particular vis-a-vis quantum computation, quantum sensing, quantum communication and quantum-AI hybrids, and no company owns more than 50% market share.

Please note that in this contribution, we are just scratching the surface. It might be better to first reach consensus about the questions to be asked, raising awareness and snapshotting problems, instead of attempting to provide immediate answers. The field is just too complex and unexplored for that.

We hope to have inspired more innovation scholars to focus on balancing the societal effects of applied quantum technology, so we can create a diverse, inclusive and supportive community together. A positive sum innovation climate requires an open mindset towards other academic fields. Multidisciplinary efforts that break down research silos might add weight to high-level directions set

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[83] *Cf.* Johnson, Walter G., Governance Tools for the Second Quantum Revolution (February 28, 2019). 59 Jurimetrics J. 487-521 (2019), Available at SSRN: https://ssrn.com/abstract=3350830, warning for a siloed approach and proposing specific techniques for overcoming multilateral security concerns.

forth in this uncharted territory. The goal of these efforts should be to provide informed suggestions on how and when to apply variations on traditional interventions, when to be cautious and when to be firm. Lawmakers can then translate these ideas into evidence-based policies. In this spirit, we end with an urgent call for action for further cross-disciplinary qualitative and quantitative research on the issues raised.

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