Reconciling Open Science with Technological Sovereignty: Can the European Union do it?

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Abstract. Openness has emerged over the last decades as a core European value and an explicit policy ambition of the European Commission, in its science and research policy. Since 2016 the EU became a formal leader in open science and with its "plan S" it championed open access. Quite recently, a need for a more "realistic" approach has emerged with Europe positioning itself now as striving towards "technological sovereignty". The question addressed in this paper is how the notion of "openness" can be maintained as a core characteristic of European values in a world in which the geo-political tensions following the Russian invasion of Ukraine in 2022, have taken their toll. Particularly with respect to the global sustainability challenge, the question can be raised how "technological sovereignty" as opposed to "open science" is likely to contribute to tackling the global climate and biodiversity crises.

Keywords: open science, strategic autonomy, industrial policy, data protection, technological sovereignty

1. Introduction

On June 3rd, 1769, some 250 astronomers across the world looked for the second time in eight years through their respective telescopes at the sun to observe the moment that the planet Venus would once again "transit" between the Earth and the Sun[1], a situation that occurs only pairwise every Century[2]. The extraordinary story of this first, large-scale scientific collaboration is being told by Andrea Wulf in her book Chasing Venus: the race to measure the heavens (Wulf, 2012). Ultimately some 150 observations of the transit were made from different locations across the earth ranging from Paris to Saint Petersburg, from California to Tahiti, from India to Mexico. The large-scale collection of measurement data from Venus' passage were essential for the measurement of distances between the planets in our solar system. When the

[1] The next time would be in 1874 and 1882. The most recent occurrence was in 2004 and 2012.
[2] See amongst others Hirschfeld (2002) and Wulf (2012).

results were analysed, the distance from Earth to Sun was found to be about 94 million English miles[3]. This first estimation of distances in our solar system was regarded in the period, known and subsequently described as the Enlightenment, as a unique achievement, providing answers to one of the most important scientific questions at that time. But solving it had also a practical side. With this knowledge, better maps could now be made; these improved maps would make navigation at sea easier and safer, which in turn would promote international trade.

We start with this, in astronomy circles, well-known story because this first, large-scale scientific collaboration took place at a time of great political tensions between the different European countries to which the scientist astronomers belonged. It was also a time in which it was sheer impossible to communicate internationally fast and hence an organisational nightmare to have astronomers at different locations across the globe observe each within a very small time slot the Venus transit. And yet it became also the moment in history in which a successful common "open access" pool effort was made bringing together individual observations ("data") from hundreds of different locations in a standardized fashion (according to current "FAIR" principles) allowing the scientific community to carry out for decades the collective comparison and analysis of these observations, advancing humanity's knowledge about the earth's place in the universe.

In short, an illustration of the fact that regardless of any geo-politics, "open science" is science done better and faster, providing an essential input as a global "common good" for the development and enhancement of humanity, in this case its international trade and travel under safer conditions. The recent COVID-19 pandemic and the ensuing world-wide search for a vaccine, is in comparison still a too recent example to draw similar conclusions from, but here too "open science" saved ultimately lives[4].

From this perspective, it is no surprise that it was the European Union: the institution that received 10 years ago the Nobel Peace prize for having illustrated how "openness" in trade amongst European nations would not just bring about economic growth and welfare but also peace that became the initiator and the strongest defender of the notion

[3] "Using the solar parallax values obtained from the 1769 transit, Hornsby wrote in Philosophical Transitions December 1771 that "the mean distance from the Earth to the Sun (is) 93,726,900 English miles." The radar-based value used today for the astronomical unit is 92,955,000 miles (149,597,000 km). This is only a difference of eight-tenths of one percent... These results have been described as "absolutely remarkable" considering what the astronomers had to work with". See https://en.wikipedia.org/wiki/1769_transit_of_Venus_observed_from_Tahiti.

[4] See amongst others Burgelman (2020).

of “open science”. The EU, illustrating Thomas Paine’s old statement that:

> “If commerce were permitted to act to the universal extent it is capable, it would extirpate the system of war” (Paine, 1791).

It was and still is one of the central contributions of international economics: how starting from relatively simple notions of nations’ comparative advantage as David Ricardo described in his famous example of two countries: Portugal and the UK, trading two commodities: wine for cloth, one could prove that ultimately both trading countries would be better off. The welfare gains of free trade became the example of a non-obvious economics insight given by Paul Samuelson to his Nobel Prize colleague Ken Arrow. A free and open market for goods and services, capital and labour, and ultimately for knowledge became the basis of intra-European integration. It has been the categorical imperative of the EU’s internal policies for the last 70 years and became also an intrinsic part of European values of democracy and transparency towards the outside world; also in science with the EU becoming a champion of open access, data and open science since 2016 (Burgelman et al. 2019).

Without much fuss and rather unannounced, this European “openness” vision[5] is today being challenged. A need for a different, more “realistic” approach has emerged recognizing the changing geopolitical situation with Europe positioning itself now no longer as one of a “strategic rival” towards the US and China (Mettler, 2023), but as one of striving towards “open strategic autonomy”. The latter notion, introduced well before the Russian invasion of Ukraine, could be said to result from the acknowledgement that the EU had been confronted, more than other regions in the world with the consequences of both the financial subprime crisis in 2008 starting in the US but leading nearly to the collapse of the EU’s common currency and pushing most European countries into a “great recession”, and the global pandemic health crisis starting in China and bringing to the fore Europe’s critical dependency on foreign medical and other essential materials’ supplies.

At the same time and less documented but well known to EU policy watchers, there has also been a growing frustration that after decades of support, Europe (still) has no champions in the high-tech, Information and Communication Technology (ICT) sector. In fact, it lost its few champions like Nokia, Ericson, etc. in the telecommunication

[5] A vision which was probably most explicitly formulated in Commissioner Carlos Moedas’ publication: Open Science, Open Innovation and Open to the World (European Commission, 2016) and the subsequent experts’ publication (European Commission, 2017) to which both of us contributed.

sector and is today more or less absent in most digital platforms. It undoubtedly also explains why the European lawmaker, in the sector of data protection, provided for the General Data Protection Regulation (GDPR)[6] to have a territorial scope that goes beyond the borders of the European Union. Article 3 of the GDPR sets out that it applies "regardless of whether the processing takes place in the Union or not", thus necessarily involving also non-European actors (platforms, companies, etc.).

The question we wish to address in this paper is how the notion of "openness" can be maintained as a core characteristic of European values in a world in which the geo-political tensions following the Russian invasion of Ukraine in 2022, have taken their toll. To what extent does the latter represent in first instance a military/security crisis highlighting both Europe's military and digital technologies' dependency on the US and Europe's energy dependency on Russian fossil fuels, and an economic, industrial dependency on China as in the case of solar panels, forcing Europe into a stronger domestic focus on strategic autonomy and technological sovereignty? Or rather the opposite way, to what extent does the outbreak of war on Europe's eastern borders illustrate the invisible civic strength of "open values" forcing autocratic regimes to invade neighbouring countries to crush the democratic outbursts of such openness values?

From an economic perspective, science and technology are of course conceptually rather different activities. This appears evident with respect to the particular role of intellectual property[7], and also considering the data protection legal framework[8]. However, these distinctions are becoming blurred particularly in response to both the current security crisis as in the case of technologies subject to dual use, the sustainability crisis as in the case of open access to data, and at individual level as in the case of the use of personal data. We focus here (in a final section), primarily on the implications with respect to current out-of-control climate change and declining biodiversity. To

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[6] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) (Text with EEA relevance) ELI: http://data.europa.eu/eli/reg/2016/679/oj.

[7] See Scotchmer (2014), with as a result science being primarily based on public funding and technology based primarily on private funding.

[8] The EU legal framework for processing personal data for scientific research purposes are very specific compared to any other purpose. The paper focuses on technological sovereignty in relation to the EU open science policies, referring also to the more specific debate between technological sovereignty and European data protection policies. (See: Floridi 2020; Celeste 2021; Pagallo 2022)

what extent will strategic autonomy and technological sovereignty as opposed to open science contribute to tackling these global climate and biodiversity crises?

We start with some further reflections on the notion of strategic autonomy and technological sovereignty.

2. From strategic rivalry to strategic autonomy

The notion of "open strategic autonomy" emerged rather implicitly in the slipstream of the financial and health crisis of the last decade. Each of these crises brought to the fore the external dependency of specific European Member States, whether in terms of capital imbalances as in the case of the financial crisis or of global value chains as in the case of COVID-19, each one of which translated itself into an increase in overall EU vulnerability. Initially the focus was on the word "open":

> Open strategic autonomy emphasizes the EU's ability to make its own choices and shape the world around it through leadership and engagement, reflecting its strategic interests and values. It reflects the EU's fundamental belief that addressing today's challenges requires more rather than less global cooperation. It further signifies that the EU continues to reap the benefits of international opportunities, while assertively defending its interests, protecting the EU's economy from unfair trade practices and ensuring a level playing field. Finally, it implies supporting domestic policies to strengthen the EU's economy and to help position it as a global leader in pursuit of a reformed rules-based system of global trade governance.[9]

Following the Russian invasion of Ukraine, the concept became now also politically endorsed. Awareness of the total dependency in many European countries on Russian fossil fuel supplies including their distribution brought about a radical shift in policy reflections on Europe's international dependency predicament. Not just its external dependency on Russian gas and oil: fossil fuel energy sources which Europe wanted in any case to replace with renewables, but also its growing foreign dependency on rare earth materials, essential medical goods and equipment, microchips, cloud computing and other technologically advanced equipment. In short, questioning many of the advantages of open international trade on which the EU itself had been built and from which it had benefited most over the last seventy years or so within the

[9] See https:eur-lex.europa.eu/legal-content.

framework first of the General Agreement on Tariffs and Trade (GATT) and subsequently the World Trade Organisation (WTO).

The most explicit critique on the way economics, and in particular international economics has relied on open, international trade as policy tool to achieve global welfare, came most recently from David Singh Grewal. Grewal (2022) describes the "world without walls" of the international economist as a world-historical "gamble": a "combination of liberal hopes for an international order of peaceable and cooperating states... the United Federation of Planets from Star Trek." Assigning "a market-led order pride of place in setting the terms of international relations", whereby "states are supposed to defer to and enforce the private cross-border orderings of the global market, which mainly means letting a transnational price system determine where production goes globally, and thus who gets what in globalization" is, for Grewal from a political perspective unsustainable.

The underlying basis of the comments made by Gerwal are of course well-known to international trade economists. The old traditional neoclassical, Grewal would call them today neo-liberal, assumptions behind the welfare gains of international trade have been the subject of numerous theoretical and empirical contributions filling many international economics journals. One of us wrote with two colleagues: Giovanni Dosi and Keith Pavitt a textbook about it back in the late 80's: The Economics of Technical Change and International Trade (Dosi et al. 1990). The narrative the book starts with is worth requoting here:

> Once upon a time, international trade theorists like to tell each other, there was a paradise where everybody lived efficiently, producing and trading whatever was demanded in the most efficient combination. Then an angel came and stamped on each person's forehead a different colour, you could say a national flag, allowing him or her to produce and trade only with capital and land with the same colour. The diaspora which followed led to large differences in efficiency across the world... Since that unhappy moment, international trade theorists – by definition, economists with a world rather than national welfare vision – have been trying to show how to get back to this paradisiacal situation... In terms of our parable, it could be said that trade theory established how, through Gods's invisible hand, free trade would undo the angel's ill-doings and re-establish paradise all over the world.[10]

Unfortunately, and as argued in more detail in this 1990 textbook, the story does not really hold once the dynamics of technology and innovation are taken into account. Basically, there is no return possible

[10] Dosi et al. (1990).

to paradise. Place matters: "it does matter whether a region or country is specialized in mushroom production or silicon chips". Viewed in retrospect, and here we would follow Grewal's argumentation, it is indeed surprising that so little attention has been paid over the last thirty years to the particular strategic role of "place" in international economics.

3. The EU as we knew it: open science, open innovation and open to the world

The new policy emphasis on the need for "strategic" investments in Europe as a "place based" response to the current geopolitical tensions, is, in other words, not that surprising. What is much more surprising, is the way the broader notion of "openness" has now more or less disappeared from the European policy language. For sure, officially the word "open" is still there in the concept of "open strategic autonomy" but no effort is made anymore to explain the implicit policy oxymoron in the concept. Less than a decade ago, we were both involved in the report of the Research, Innovation and Science Expert (RISE) group who produced at the request of the then Commissioner for Research and Innovation, Carlos Moedas, the report: Europe's Future: Open Science, Open Innovation and Open to the World (EC, 2017). Again, it seems worthwhile to quote from this report:

> "This new 3 O's doctrine provides us with three perspectives on openness. Openness as tool addressing the grand societal challenges of our time with Europe as central player in addressing those challenges with applications at the global level and at the local (city) level, enabling new firms to emerge in newly constructed markets and the scaling-up of existing firms. Second, openness as inclusive tool: as "commons". Openness started here from within the scientific community – the community for whom the production of knowledge is to quote Jean-Claude Guédon "the most noble thing human beings can do" or "the place where we feel most human" – with the initiatives on open access and open data, but which became quickly broadened to many other networks and communities building on trust as a precondition to reach higher levels of community thinking and focusing on people as actors of change, rather than institutions. And finally, openness for experimentation, for enabling radical change, for the emergence of, now and then disrupting innovations in new areas, with European and local procurement as open but effective leverage tools using innovation-friendly regulation and a regulatory sandbox providing additional degrees of freedom for

testing, for local co-creation, for living labs; for market creation mechanisms to emerge and flourish."

While it might seem that the addition of the word "open" to the new policy of "strategic autonomy", has been the only remembrance for policy makers of that RISE report, it highlights the need to combine notions of openness with the newfound need for strategic industrial support[11]. In many ways, the new belief in Europe in "technological sovereignty" is reminiscent of the many old ideas at creating through the Research Framework Programmes European industrial champions as in the 80's and 90's of the previous Century. Very few of those succeeded, most failed particularly in some of the most technologically advanced areas such as digital technologies. One can, in other words, only hope that the recent new calls for strategic autonomy and technological sovereignty learn from past experiences and become, as Edler et al. (2023) have argued, a new objective of innovation policy[12] rather than of industrial policy.

The starting factor for pushing research and innovation policy in the direction[13] of strategic autonomy and technological sovereignty is the military notion of security. And indeed, there is little doubt that the fragmented European defence markets have not contributed to the overall competitiveness of Europe's defence and security industries. The advantages of European scale were never realized[14]. From making a case to strengthen defence security, it is only a small step towards making

[11] For a further elaboration see Soete and Stierna (2023).

[12] "In this paper, we propose and justify a concise yet nuanced concept of technology sovereignty to contribute to and clarify this debate. In particular, we argue that technology sovereignty should be conceived as state-level agency within the international system, i.e. as sovereignty of governmental action, rather than (territorial) sovereignty over something. Against this background, we define technology sovereignty not as an end in itself, but as a means to achieving the central objectives of innovation policy - sustaining national competitiveness and building capacities for transformative policies. By doing so, we position ourselves between a naive globalist position which largely neglects the risks of collaboration and the promotion of near autarky which disregards the inevitable costs of creating national redundancies and reducing cooperative interdependencies. We finish by providing a set of policy suggestions to support technology sovereignty in line with our conceptual approach." (Edler et al., 2023).

[13] As pointed out by (Csernatoni 2021) in a Carnegie Mellon position paper "The EU's rise as a defense technological power: from strategic autonomy to technological sovereignity".

[14] As highlighted in the official Consilium document: "To ensure the long-term competitiveness of the European defence industry and secure the modern capabilities needed, it is essential to retain defence Research & Technology (R&T) expertise, especially in critical defence technologies. The European Council invites the Member States to increase investment in cooperative research programmes, in particular collaborative investments, and to maximise synergies between national

the case for strengthening technological security given the large number of so-called dual-use technologies open to either civilian or military applications. The lack of scale is, however, here not so much the issue than the desire to keep the knowledge "secure" and not accessible to foreign "rival" nations.

"Knowledge security", just like the need for technological sovereignty as argued by Edler et al. (2023) are now being introduced as new competitive features in science and higher education policy. There are several questions raised by this European policy shift towards autonomy, sovereignty and security in the area of science, research and innovation.

Broad philosophical ones such as the extent to which such "autonomy", sovereignty or security notions can ever become fully part of Europe's value scheme. Open science, open access and open data clearly were. They fitted Europe's vision and support for human rights, for open debate between scientists, for independence in research, scientific integrity based on common standards, etc. In many international scientific collaborations in which the EU took the lead, "trust" was a basic characteristic. It explained the success of European involvement in many multilateral UN research programmes such as the IPCC. Introducing notions of technological sovereignty or knowledge security do not contribute to such values, on the contrary.

Pragmatic ones such as is it feasible and/or realistic? While it might at first sight appear defendable and in Europe's immediate interest to develop policies in support of "technological sovereignty" or "strategic autonomy", the implicit danger is that it trickles down to a "fortress Europe" vision rather than become a boost for domestic innovation. Europe does not have a particularly successful history in making its industry championing, even in areas in which it had a strategic interest.

Furthermore, in many areas such as nuclear energy[15] , neither Europe nor the US for that matter, is any longer in a position of technological leadership but rather dependent on foreign knowledge from China. It is important within this context, to realize that there is nothing surprising about this. Technological catching-up and/or leapfrogging is ultimately an intrinsic part of global development. One may remember the old Krugman North-South trade model (1979) in which ultimately

and EU research. Civilian and defence research reinforce each other, including in key enabling technologies and on energy efficiency technology."

[15] E.g. in small modular nuclear reactors China is leading in the thorium molten salt reactor (TMSR) nuclear energy system which is designed for thorium-based nuclear energy utilization and hybrid nuclear energy application based on the liquid-fuelled thorium molten salt reactor (TMSR-LF) and solid-fuelled thorium salt reactor (TMSR-SF).

technological catching-up was the driving force of global development[16]. "Like Alice and the Red Queen, the North must keep running to stay in the same place", as Paul Krugman put it.

In this sense, such processes of catching-up offer now also to the old North opportunities for learning, for catching up itself e.g. with respect to attracting more students into Science, Technology, Engineering and Mathematics (STEM) fields. As argued in a recent opinion piece by an ASML researcher, Simon Van Gorp (2023):

> The role of geography in scientific progress is also beyond dispute. Over time, certain areas have emerged as hubs for scientific research and innovation. Silicon Valley in California is well known, but Shenzhen in China is also a textbook example of stimulating innovation and science. In the space of forty years, Shenzhen has grown from a fishing village into a city of millions that carries the 'Silicon Valley of hardware' as a roaring honorary title. Of course, this was no coincidence. In 1980, Shenzhen was given a special status that was constructed economically, socially and legally to facilitate and stimulate investment. Our governments and universities should also get started with targeted mini-Shenzhen experiments. This is where the science of progress can come into play. By studying the history of science, where it has thrived best, why it was (enhancing factors), and experimenting with local initiatives, this new field of science could identify the most effective ways to tackle society's toughest problems. to solve. Just think of the many inspiring stories, exciting career opportunities and world-renowned start-ups this could produce. Our STEM directions would soon fill up again.[17]

It brings us quite logically to the next section of this paper.

4. Addressing sustainability though strategic autonomy or through open science?

In a recent speech, the EC's President Ursula Von der Leyen identified a number of areas in which more funding would be required to promote the EU's Strategic Autonomy. To quote her: "I am speaking of beefing up the resources available for upstream research, innovation and strategic projects at EU level. Just think of hydrogen, semiconductors,

[16] See also Keun Lee book (2022) about China's technological leapfrogging and economic catching-up, illustrating this process on the basis of the earlier processes of Korea and Taiwan.

[17] See: Van Gorp (2023), see https://www.tijd.be/opinie/algemeen/chinese-experimenten-kunnen-stem-lokaal-weer-doen-vollopen/10460450.html.

quantum computing, AI, biotechnologies – that is where we have to invest now"[18]. A logical choice given that this Century "clean" technologies as well as "data" or AI-based technologies are, or will be, the basis for any nation or continent to be relevant. In this scenario, regulatory choices that led the European institutions to enact the GDPR in 2016 and that are currently even more leading to the enactment of the Artificial Intelligence Act are likely to acquire great relevance from an economic point of view. In particular the need to balance protection with innovation in a global economy.

The focus is therefore now on strengthening Europe's ability not only to develop but also to retain a number of critical technologies considered essential for European businesses and citizens' future growth and welfare, strengthening at the same time at the policy level the EU's ability to act and decide independently in a globalised environment[19]. It translated so far into a Strategic Autonomy agenda focusing on building and strengthening economic and industrial capacities with amongst others a Chips Act[20], a Hydrogen Bank[21], and Twinning the Green and Digital transitions[22]. At the same time, one also acknowledges, as also highlighted in the quote above from the ASML researcher, that all this will require despite the declining population in a rapid growth in a well-educated STEM workforce. The need for "open" global access is in other words acknowledged but limited to human capital: youngsters' brains.

This approach to "strategic autonomy" fits, one could argue, the competitive use of European values. These values make Europe in a certain sense a more attractive place in the "war for talent" than less open, and more autocratic regimes. But do they also fit the sustainability challenge? The latter is, as recognized in the ICCP reporting, more than ever dependent on "open science", "open access" and "open data" to speed up the deep and urgent transformations needed both

[18] European Commission, Speech by President von der Leyen at the European Parliament Plenary on the preparation of the European Council meeting of 15 December 2022, available at: https://ec.europa.eu/commission/presscorner

[19] See: EPRS — European Parliamentary Research Service, Key enabling technologies for Europe's technological sovereignty, September 2021.

[20] Proposal for a Regulation of the European Parliament and of the Council establishing a framework of measures for strengthening Europe's semiconductor ecosystem (Chips Act), COM/2022/46 final.

[21] Directorate-General for Energy, Commission outlines European Hydrogen Bank to boost renewable hydrogen, 16 March 2023, available at:https://energy.ec.europa.eu/news.

[22] Joint Research Centre,The twin green & digital transition: How sustainable digital technologies could enable a carbon-neutral EU by 2050, 29 June 2022, available at: https://joint-research-centre.ec.europa.eu.

at the industrial production and distribution side and at the individual consumption side. The looming danger for climate change to become out-of-control in a business-as-usual scenario illustrates well what happens when science itself remains "closed" from public attention. Remember the so-called 'Climategate' case when the emails at the Climatic Research Unit at the University of East Anglia were hacked and climate-change denial groups took excerpts from these emails to portray climate scientists as activists. The result was a further delay in global policy making with respect to climate change despite the broad consensus in the scientific community on the urgency of the situation.

The evidence on immanent climate change and on a rapidly declining biodiversity is itself in need of continuous actualisation. Past evidence appears no longer to fit the simple linear relationships on the basis of which predictions were made. New feedback loops emerge that intensify interdependencies to a scale where observations deviate from predictions (See Lenton et al., 2019). A good example, highlighted by Sir David King, the former Chief Scientific Adviser to the UK (2000 to 2007) is the modelling of Arctic Circle ice. To quote King:

> "Past models predicted that ice cover would reflect sunlight away from the North Pole until the end of the 22nd century, but observations have diverged from these forecasts as the ice has melted, and nearly half the Arctic Ocean is now exposed to sunlight in the summer. Blue seawater is less reflective than white ice, so it heats more rapidly as more of it is exposed, accelerating the melting of the remaining ice. In addition, as the ice melts, it forms lakes that become bluer as they get deeper – creating more pockets of heat, which melt more ice."

There is, in other words, a need for continuous improvements in modelling climate change, in suggesting possible policy solutions requiring new, global, open, out-of-the-box input of scientists coming from different areas and from all over the world. There is very little place for prioritizing technological sovereignty.

5. Conclusions

Open science rather than technological sovereignty remains a crucial input for addressing Europe's and the world's sustainability challenges. We need new, open out of the box reflections on how to address the urgency of out-of-control climate change and declining biodiversity. Let us conclude with two such out-of-the-box ideas, proposed by David King (2023) that in this particular case could help protect icecaps in the Artic and restore ocean biodiversity but that need massive data collection and open data sharing: 'artificial whale poo' and 'marine cloud brightening'. As we are neither a scientific expert in the field, let us just quote from an interview with King:

> "Large whales feed and swim at depths of 300m–500m, where they are unable to excrete faeces due to the extreme water pressure. When whales periodically rise to the surface to breathe, they also expel great clouds of part-digested waste into the ocean. Within days, this excretion has spread across thousands of kilometres of ocean, leaving in its wake a green forest of phytoplankton. The whales behave like a farmer spreading fertiliser in the sunlit areas of the ocean."

This provides the basis of an ocean-wide food chain that helps to lock carbon within living animals. This process is operating at a fraction of what it once was, because of the declining whale populations: only at around 5% of their historic numbers. This is the global "open science" challenge: can scientists find a natural source of minerals with a similar composition to whale poo which could replicate this process? Following David King's research, volcanic ash appears to be the right type of substance with its high levels of iron, silica, phosphates and nitrates. But for sure there are others. Strategic autonomy or technological sovereignty will not help, on the contrary...

The second example given by King deals with marine cloud brightening:

> "Marine cloud brightening is another technology that could save the Arctic. When a wave crashes against a rock, a small amount of salt spray is sent into the air, where it is caught by the wind. The water evaporates off the spray, leaving behind microscopic salt crystals, which begin to fall under the influence of gravity and collect water, forming clouds. The larger the crystal, the bigger the drops of water collected and the darker the cloud. If the crystals can be made the right size, they will collect tiny droplets of water, making bright white clouds."

Resembling some sort of limited, small scale geo-engineering exercise, King proposes that some 500 to 1,000 remotely operated ships surrounding the Arctic Circle would be told to spray salt crystals into the sky to form clouds that would drift over the Arctic Circle protecting it during the midnight sun period from the sun's rays. Again, not an exercise whose success will depend on "technological sovereignty" but rather one which will be crucially dependent on open access to data, on the FAIR collection of scientific and engineering evidence following try-outs and experiments. A story, which is in many ways reminiscent of the story of Venus's transit with which we started this paper. It is politically probably as challenging with Russia possessing more than half of the Arctic Ocean coastline, being at war in Ukraine, and at cold war with the seven other members of the Artic council building or re-activating 50 military installations and bases in the Arctic. And all this within a context whereby the war in Ukraine further adds to the challenge of climate change with the fighting itself having released so far some 200 million tonnes of carbon into the atmosphere.

So, time for scientists across the globe to make their voice heard. Technological sovereignty will not solve the climate crisis. Open science is more needed than ever: one needs the help and support of all scientists. Let Europe hence take again the lead in open science and make the latter the core ingredient of our planet's survival.

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