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The social utility of science

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Science is often valued by society due to the immediate applicability of scientific knowledge to satisfy certain human needs, mainly in the fields of medicine and technology. Topical examples of this mind-set are the search for a cure for cancer or the discovery of a hypothetical clean and endless form of energy. Another argument commonly used to justify continued investment in science is the belief that scientific knowledge will eventually turn into economic gain. Researchers and research institutions increasingly use this argument to secure project funding and gain social acceptance. In recent decades, an additional goal of science has emerged: a more rational use of natural resources in order to guarantee their continuity (and the ensuing continuity of humanity itself), an endeavour that is currently referred to as "sustainability". Scientists are often challenged by popular questions such as: what is science useful for? Why should we continue to invest in science? Scholars desperately try to justify their work with the above mentioned and similar arguments, currently linked to personal health and longer life expectancies, technological advancement, economic profits, and/or sustainability, a collection of topics that have been summarised by terms like "welfare" (or "wellbeing"), "quality of life" or simply "happiness". It is not uncommon to hear or to read that virtually everything around us is a product or by-product of scientific research, from pens to interplanetary rockets, from aspirin to complicated organ transplant procedures. Another common argument used by scientists in a variety of social contexts is that sooner or later, all scientific knowledge will be useful for humanity, as has been the case historically. A well-written and highly accessible account of the applications of science through history from the discovery of fire until the 20th century was provided by Isaac Asimov in his book *Chronology of science and discovery*, which is highly recommended reading for anyone who wishes to understand how science has shaped the world.

However, other aspects such as social inequality, inadequate uses of scientific discoveries and ethical concerns in scientific research are of paramount importance and should not be overlooked. For example, from an individual's perspective, an increase in welfare and life expectancy is perceived as a positive goal, but its complete attainment would eventually lead to unwanted social consequences. The most obvious sequel would be the failure to secure the food supply for the next generations. On the other hand, as has occurred with many other human needs, the current global socio-economic system has demonstrated its inability to guarantee a fair and equitable distribution of the resources necessary for human life, including access to health services and medicines, which is a situation that has resulted in increasing social injustice and inequality. The same bad practices have been used to manage the more powerful energy sources, as for example oil, which precludes to be optimistic in

relation to the eventual discovery of a never-ending energy source. Problems such as unsuitable uses of scientific discoveries and ethics in research are usually attributed to the pressure of so-called external forces (ideology, politics, economy, moral, religion, etc.) that constitute serious concerns for honest scientists in the face of social demands. These drawbacks are extensively examined elsewhere (Rull, 2010, 2011, 2012, 2014). The purpose of this essay is to evaluate alternative answers to the above questions on the usefulness of science for humanity beyond the cluster of health-economy-technology-sustainability (HETS). The following discussion will focus exclusively on the usefulness of science for humanity, here termed the "utilitarian" approach. The benefits of science for the earth in general and for its biosphere in particular (i.e. the "telluric" approach) are also discussed in other papers (Rull, 2014). Whether science makes sense by itself or should be at the service of human needs has been intensely debated since the publication, in 1939, of the book *The Social Function of Science* by the British physicist John D. Bernal. This scholar considered that science should be targeted to satisfy the material needs of ordinary human life and, influenced by Marxism, defended a central control of science by the state to maximise its utility in this sense. This "Bernalistic" view was further criticized by the zoologist John R. Baker, who defended a "liberal" conception of science according to which "the advancement of knowledge by scientific research has a value as an end in itself". This approach has been called the "free-science" approach and lead to the formation of the *Society for Freedom in Science*, in 1940 (McGuken, 1978). The free or utilitarian science duality has also been discussed elsewhere (Rull, 2012).

First, it should be noted that the utilitarian viewpoint of science in terms of immediate social gains has already adopted an explicit socio-political and economic manifestation, virtually worldwide. Perhaps the most recent and striking example is the outstanding shift in European scientific policy championed by the so-called "Horizon 2020" or "H2020". This is a medium-term programme (2014-2017) openly defined as a "the financial instrument implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness". The word "competitiveness" is used in capitalistic terms, as is manifest and explicit in the following sentence: "Seen as a means to drive economic growth and create jobs, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament" (EC, 2014). It could be argued that this is a common view of science and technology in the modern world, notably in leading countries such as the USA or Japan, where investment in science is high owing to the conviction that resultant economic returns are guaranteed and relatively rapid. It is often said that the world's larger economies are also those with higher public and private investment in science. This phenomenon is generally true, but in the case of the European H2020 programme, economic arguments are explicitly placed in a leading role, ahead of any other reason.

In the USA, for example, the National Science Foundation (NSF) declares that its mission remains the same as when it was founded in the 1950s: "To promote the progress of science; to advance the national health, prosperity and welfare; to secure the national defense; and for other purposes". The NSF adds that it "envisions a nation that capitalizes on new concepts in science and engineering and provides global leadership in advancing research and education" (NSF, 2011). Expressions such as "prosperity", "other purposes" or "global leadership" might be interpreted in economic terms, but this is not explicitly stated and, in either case, these expressions have the same importance as health and welfare, for example. The Japan Science and Technology Agency (JST) is less explicit when proclaiming that its mission is "contributing to the generation of science, technology and innovation". In his President's Message, Michiharu Nakamura is more specific, recognising that Japan is already a major economic power, and states that "Japan seeks to create new value based on innovative science and technology and to contribute to the sustained development of human society ensuring Japan's competitiveness" (JST, 2013). Nakamura also uses the word "competitiveness" but in scientific, rather than economic, terms. The link between science and the economy seems more obvious in sentences such as "…we hope that industry can commit to bold new challenges based on the seeds of scientific research in academia". The obvious difference between the fundamental scientific declarations of these major economies and the European H2020 proclamation is that the latter

prioritises economic competitiveness. It seems that Europe seeks to transform itself into an economic power similar to the USA or Japan and is relying on science to achieve this goal. The relative youth of the European Union's population, together with its socio-political heterogeneity, in comparison to the longer running and more homogeneous American and Japanese economies, seem to be major handicaps for Europe; however, this is a collateral topic that deserves its own individual treatment.

In either case, the result is the total subjugation of EU-funded science, which is at the beck and call of market rules and economic growth (slave science). Curiously, this conception of science, based on capitalistic premises, is analogous to the formerly discussed "Bernalistic" approach, emerged from Marxist rules. It is also worth noting that the slave-science approach is in open contradiction with one of the foundational tenets of the "liberal" *Society for Freedom in Science*, saying that "science can only flourish and therefore can only confer the maximum cultural and practical benefits on society when research is conducted in an atmosphere of freedom" (McGuken, 1978). In a slave-science scenario, where immediacy is a norm, the progressive, long-term and ordered accumulation of knowledge characteristic of free science is at risk of being replaced by a disordered aggregate of short-lived and unconnected developments biased by immediate industrial needs and useless for future generations. Consequently, fundamental science may suffer severe setbacks, owing to its assumed lack of immediate application, which could result in the end of science as we know it. Just as an example, the discovery of laser emissions in 1960 was a strictly scientific venture oriented to demonstrate a physical principle predicted by Einstein in 1917. In industrial terms, the laser was useless at that time and was defined as an "invention in the search for a job" (García Ramos, 2014). The first applications of laser technology came about ten years later with the development of optical fibres and were followed by spectacular and useful medical and technological applications. Under a slave-science system, the invention of laser would hardly have taken place. In such a system, universities and other research institutions would lose their scientific character and turn into consulting companies at the service of industry, which implies the sequestering of public research funds for private purposes. The dismantling of the current science structure—which has taken centuries to build up—and its transformation into a slave-science system with potentially catastrophic consequences for humanity may be just around the corner unless we are able to convince political and scientific managers of the danger of this course as soon as possible. An eventual campaign supporting the continuity of the current free-science system funded with public budgets would likely be popular, as almost three quarters (73%) of the people surveyed in a special Eurobarometer survey dedicated to the social perception of science in Europe agreed with the statement: "Scientists should be free to carry out the research they wish, provided they respect ethical standards", whereas only 10% disagreed. In some countries, positive answers were approximately 90% (EC, 2005).

The mercantilisation of science and scientific research is, explicitly or not, based on the simplistic and undemonstrated idea that economic growth leads to increased quality of life. However, the use of general economic indicators, as for example, Gross Domestic Product (GDP), to measure social wellbeing and happiness, a common practice since the Second World War, has been considered flawed, even by leading economists. This is the case made by Robert Costanza of the Australian National University, who recently published a paper in the journal *Nature* with several collaborators entitled *Time to leave GDP behind*. In this paper, Costanza and his colleagues announce the "dethroning of GDP" and its replacement by more appropriate indicators that consider not only economic growth but also "a high quality of life that is equitably shared and sustainable". A fully satisfactory alternative to GDP is not yet available, but according to Costanza and his collaborators, such a successor "should be a new set of metrics that integrates current knowledge of how ecology, economics, psychology and sociology collectively contribute to establishing and measuring sustainable well-being" (Costanza *et al*., 2014). In such a scenario, Europe could be in danger of taking a step backwards in its compulsion to become a world leader at any cost. In the case discussed here, the cost would be the dismantling of a free science system, which originated in the late 17th century during the Enlightenment (a genuine European movement), which nurtured the roots of modern science. An additional factor promoting the political advocacy for a central planning and

control on scientific research could be the ongoing economic crisis, as it occurred with the emergence of the "Bernalism" that was, in large part, a consequence of the great depression initiated in 1929. It seems that, in situations of economic adversity, "the traditional piety of a pure unworldly science seems at best a phantastic escape, at worst a shameful hypocrisy", in Bernal's words (McGuken, 1978).

In the endeavour to find an answer to the above questions on the utility of science beyond HETS, a mind-set moving from a focus on short-term, restricted and ephemeral needs to long-term, global and more permanent targets is needed. It could be argued that sustainability already considers the long run, but this term is commonly used in economic, rather than humanistic, terms and is usually restricted to the next few generations; therefore, it has been considered useless for long-term ventures (Rull, 2011). In the American NSF declaration (see above), there is a word that is rarely mentioned when dealing with scientific applications; this word is "education". From an academic angle, formal education would simply not be possible without the constant improvement of science and scientific knowledge within in a freedom-based research system. This appears to be so obvious that is often ignored, but it should be emphasised because the need for education is and has been unequivocally recognised as mandatory for the continuity of human values in the past. Education must retain its pivotal role if we have to persist on earth. A glance at the textbooks used by our children and grandchildren is enough to show how knowledge has advanced in a couple of generations and how these advances have been transferred to the daily education of young people. A classic example is the outstanding development of molecular biology, a discipline that was virtually absent from school textbooks a couple of generation ago. These advancements have been possible by a free-science system. On the other hand, the medical, technological and environmental applications of science require the existence of qualified professionals in these fields who acquire their skills through formal education. Therefore, education is a paramount scientific application, because it contributes not only to the continuity of humanity but also to the maintained improvement of its wellbeing.

In a more general sense, education may refer to maintaining the knowledge-based background and identity of humanity and its different cultures, and to upgrading the general cultural level of society. According to Stuart Jordan, a retired senior staff scientist at NASA's Goddard Space Flight Center and currently president of the Institute for Science and Human Values, widespread ignorance and superstition remain "major obstacles to progress to a more humanistic world" (Jordan, 2012). Jordan uses the term "humanistic world" to refer to the pursuit of a world in which prosperity, security, justice, good health and access to culture are equally accessible to all human beings. This author considers that the proliferation of the undesirable consequences of scientific knowledge, such as overpopulation, social inequality, nuclear proliferation and global climate change, resulted from the abandonment of the key principle of the Enlightenment—i.e. the use of reason under a humanistic ethical framework. If global human wellbeing is really our target, we should return as quickly as possible to that principle.

When discussing ignorance, we should consider not only the large part of humanity deprived of access to basic education, but also a large fraction of the population living in so-called developed countries, including global economic leaders. A striking example is provided by the Eurobarometer survey mentioned above. On average, only the half of the surveyed Europeans knows that electrons are smaller than atoms, almost a third believes that the sun goes around the earth, and nearly a quarter of these people affirms that earliest humans coexisted with dinosaurs (EC, 2005). In developed countries, there is still a significant amount of people (often termed "reactionary") whose mental orientation is predominantly toward the past (Jordan, 2012). This population sector is usually dogmatic and/or superstitious, and relies on faith-based moral principles rather than on reason-based knowledge to explain the world and to drive their everyday lives. Another type of ignorance (here called passive ignorance) that is increasing dramatically in the industrialised countries, especially within the younger generations, is not based on any dogmatic morality but on a dull indifference for socio-political affairs beyond their own individual and immediate wellbeing. According to Jordan's definition of "progressive" people—i.e. those whose mentality is predominantly oriented towards the future—dull people also fall within the reactionary category.

Both active and passive ignorance may have a relevant influence on the political scene of their respective countries through democratic elections. This is largely because reactionary people are easily manipulated by their leaders or because they have no (conscious) political preference and their votes may depend on irrelevant details, such as candidates' physical aspects or their performance in public debates, rather than on ideology, social programs or previous experience. As a result, a segment of low-quality political representatives persists and, in several cases, they dominate the scene. Therefore, ignorance not only influences individuals' personal quality of life but also has a significant social impact in that it promotes the continuity of unsuitable political leaders and governments, which can lead to inadequate policies. A high-quality democracy should be based on a well-formed and informed society; otherwise, inadequate representatives may perpetuate in the governments by manipulating the will of the citizens. Education *sensu lato*—including both formal learning and cultural education—is decisive in developing personal freedom of thought and free will, which is projected to society in the form of higher-quality representatives and governments (Rull, 2014). In some sense, democracy could be viewed as an empty pot, where what is important is not the pot itself but its contents. You may have a pot of honey or a pot of dung and so is democracy.

To upgrade the cultural level of human societies is certainly a long-term venture in which science may play a critical role. First, we should admit that scientific reasoning is intimately linked to human nature, as reason is an intrinsic feature of human mind. Humanity did not adopt science, a reason-based system, as the preferred tool for acquiring knowledge after choosing among a set of possibilities; we simply used our own mental functioning to explain the world. Second, reason is a universal feature of all human beings, and therefore, any knowledge generated by reasoning can be easily transmitted and understood by everyone without the need for alien constraints, not unlike art or music. All humans have the capacity to see a picture or hear a song, unless we are ill or have our eyes closed and ears covered, voluntarily or not. All we need to properly grasp scientific knowledge is to maintain an open mind. In contrast, knowledge based on faith and superstition is subjected to fundamental *a priori* "truths" that must be accepted without any explanation. In addition, these faith-based axioms are not shared by mankind as a whole, but change across cultures and time and are largely dependent on the dominant culture in a particular historical time. Consequently, faith-based knowledge systems are neither natural nor common to all of humanity and must be imposed by force or authority and maintained through strict moral rules.

In addition to its natural character for human beings, throughout history, science has demonstrated that it is the better knowledge system to explain the world, to solve usual human problems and to fulfil human needs. A fundamental condition of science is its dynamic nature, based on the constant revision and re-evaluation of the existing knowledge. Every scientific theory is always under scrutiny and is questioned when new evidence seems to challenge its validity. Sometimes, non-scientific or anti-scientific sectors use this dynamic nature to accuse science of being hesitant and insecure, but on the contrary, constant knowledge revision is the best way to progress towards the explanation of natural phenomena using human reasoning. If this were not the case, the eventual declaration of some scientific theory as an "absolute truth" would explicitly adhere to a faith-based system, thus stopping scientific progress in this particular field. We should note that this has occurred historically and continues to occur in some marginal sectors, but this is obviously a non-scientific practice based on authoritarian conceptions of knowledge, rather than on the application of the scientific method itself. Concerning the relevance of science to solve human problems or cover human needs, the more obvious examples are medical and technological applications. Thus far, no other knowledge system has demonstrated this capacity and even the defenders of faith-based systems are common users of medical services and technological facilities that have emerged from scientific knowledge and experimentation. In summary, reason-based scientific knowledge is not only the more natural but also the more useful system to humanity.

In contrast to formal education, which is highly organised through specific institutions and programs, the cultural improvement of human society relies on more diffuse structural and functional

patterns. In the case of science, its diffusion to the general public is commonly called the popularisation of science and its vehicles can be diverse, from scientists themselves to science amateurs (including journalists and others). Usually, the popularisation of science is understood as the downgrading of scientific knowledge to make it intelligible by the general public, but it would be more appropriate to increase the skills of this public in order that science might be understood as is (Rull, 2012). In this endeavour, scientists should be actively and massively involved, as science amateurs are not qualified enough or are constrained by external forces, or both. Scientists, especially those working in public institutions, should leave their labs from time to time and communicate with society as to what science is and what is not, how is it done, what are its main results, and what are they useful for. This would be the best way of demystifying science and scientists, and upgrading society's scientific literacy, as science's contribution to increasing the cultural level.

In summary, in addition to the HETS cluster, there are two more applications of science that must be considered: (1) making formal education possible, and (2) upgrading the cultural level of society. The combination of (1) and (2) is useful for bolstering personal skills and free will, which in the long run will result in a society less pliable to socio-political leaders, and also less susceptible to dogmatic moral systems, developments that would improve global welfare (Rull, 2014). Scientists who prefer to use the HETS approach alone to justify their work should not change their classic arguments. Those who are prone to consider the education-based alternatives have additional arguments capable of convincing—or, at least, creating reasonable doubts in—sceptical but educated people inquiring about the usefulness of science. Whether they are aware of it or not, these inquirers had not reached their position, whatever it is, without science. It is possible that none of the answers discussed here are the best answer, or that any one of them is more important than the others, but they all provide scientists an array of arguments to be used together or carefully selected from according to the inquiring audience. What seems irrefutable is that science is not only useful and necessary for humanity in both the short and the long term, but is also—and this is hardly disputable—an inevitable feature of the human condition derived from the functioning of our mind, as well as the better suited tool to satisfy the unavoidable human passion for knowledge (Rull, 2012).

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