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Beyond Open Science

Really Understanding 'Open Science'

-Its Beneficial Potentials, Its Fragility, Its Functional Performance Problems, and How NOT to Try to Fix Them-

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Abstract

My presentation advances three connected points about what is properly meant by "Open Science", its potential functionality for sustaining economic growth, the nature and sources of this social system's contemporary disappointing performance, and how we should not undertake to remedy those problems. These understandings, I contend provide a necessary foundation for contemporary discussions and decisions about science and technology policies.

First, "open science" is best understood as multi-dimensional dynamical process involving the behavioral interactions of functionally differentiated sub-communities: educators, theoretical and empirical researchers, readers, authors, reviewers, research funding public institutions and private business organizations, publishers, archivists, a journal and book editors, and referees and reviewers. Each of these sub-communities, local and international as they may be, has an associated normative structure that that is neither externally imposed nor perfectly self-enforcing. Being most universal in its scope, or at least in its international reach, the "open science norms" have become those that are most fully articulated and familiar. Consequently, it is necessary to proceed from a brief review the functional performance implications of adherence to the individual norms, and the interaction consequences of norm-adherence that should be more widely grasped and appreciated.

Second, "open science" processes can be expected to function at the macro-dynamical level so that scientific resources are allocated at the micro-level in a manner that is in accord with its operating norms, and produce allocative effects that are complementary to the beneficial micro-level workings of competitive market-based efficiencies in resource allocation. Were the coupled subsystems not plagued by "negative externalities" that they may generate (such as global warming), their interdependent actions could be relied upon to yield sustainable economic growth. An understanding of this is the foundation upon which science and technology policy strategies and the selection of instrumental tactics should be based.

Third, it is to be expected that, like all human social systems, deviant individual conduct is to be expected where-ever norms have been sharply articulated, and hence in research laboratories and corporate offices. Institutional and organization design failures, similarly, will strain the normative guidelines that leaders of those socio-legal organizational entities promulgate. They therefore call for continuous corrective efforts to counteract costly market failures on the one hand, and, on the other hand, to contain the extent of individual scientific misconduct so that it does not undermine the basis for reciprocal collegial trust, or overwhelm the internal corrective capacity of the subsystem's knowledge-generating and -disseminating institutions. Open science's structural features have evolved historically and the persistence of institutionalize legacies from its past is a potential source of dysfunctional modern outcomes. The later, institutionalized survivals, however, should not be hastily discarded on the dubious grounds that that the successful introduction, and popular acceptance of "free and open source software" - especially in educational and scientific research activities—has rendered them obsolete and readily replaceable by software-implemented "openness" in all aspects of scientific activity. Understanding the ineluctably human social nature of open science processes, and the limitations of algorithmic information processes quickly dispels the mistaken notion that the vexing performance problems that we encounter in the workings of the open science system are not of a nature that permits them to be readily "fixed" by substituting an integrated array of "open" computer algorithms for communicative, knowledge-sharing human actors.

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I am very pleased to be here, and I want to thank the National Institute of Informatics, the able staff, Kei Kurakawa, Hayashi-san, and other people with whom I have had several days of very stimulating conversation to prepare me so that I might be more informed of the context in which you are going to attempt to receive what I want to talk about.

I think the title and subtitle of my talk are pretty descriptive of my intention, which is to talk about what I understand the term 'open science' is about, and what others who have preceded me and who came after me have also come to understand what open science is. I will talk about why it is important because of its beneficial potentials for the advancement of knowledge, and for the benefits that flow from greater knowledge, both in terms of human welfare and wellbeing, and the processes of economic growth that are driven by the advancement of knowledge. I also want to talk about open science as a social economic knowledge system, which takes institutionalized forms for some very important aspects of it. However, it is a fragile system because it is not guided by market forces in a direct way. It is not producing a product that is sold. Knowledge is not to be treated as property in a private market system within the open science system. Once we understand what the system is, I want to talk about the problems that arise and the system's functional performance. Almost no systems are perfect, and some problems are more serious than others. That means that people who observe and are part of system think that perhaps the system could be remedied or fixed. I will not tell you how to fix the system and provide remedies, but I want to talk about how not to fix the problems.

Open Science as a System

Instead of an outline or an agenda, I offer a menu with three courses that correspond to parts one, two, and three. The first important part is understanding the open science system. It is not a state of the world. The system exists, but it is dynamic. It is changing, and it has evolved. It is a peculiar system, especially in modern societies. The penetration of a market moves an organization and incentives are tied up with market valuations of people's services and their abilities to purchase other things using money. This is not a system in which market transactions are central to motivate people or to evaluate what their contributions are. It is peculiar for that reason, and yet it is vitally important. It has evolved and has deep historical roots. Talking about the system's historical legacy, it is a gift from an earlier epoch, one which was characterized in the West by feudal organization of society. This is not in the sense that Marx used it of a superior property-owning class and then landless proletariat who worked for them, but it is a system that historian Marc Bloch saw as peculiarly European, but was not everywhere in Europe. It is a system of vassalage in which there are strong people who claim control of the land resources and then give to followers who are useful to them (first in the military sense) a right to exploit the resources of a particular part of the land. Therefore, these people get estates. For this, they have to provide services to the person who gives it. This arrangement is a very old one in pre-feudal history in Europe. This system structured the relationships among the elite, and the elite had needs in a more modern setting for people with special knowledge of various kinds to be in their court to perform services that could not be done by just anyone. The origin of the word 'feudalism' is the old French *féodal*. It had to do with things concerning the fief. The fief was the holding of someone who could perform a special service. It started with special military service, and then it went on to a scribe, a person who could write and could send messages to other people for the lord of this estate because the lords were not always literate. In fact, few of them were.

Therefore, this system was entangled with the knowledge domain through the incorporation of Arabic and Indo-European mathematics, which gave as powerful tool for investigation of physical systems such as the universe, the planets, the solar system, and phenomena that are evident on our terrestrial globe. The knowledge domain working with mathematics formed this system because of its beneficial uses for scientific organizations, and communication. It became entangled with and was important in the Scientific Revolution in the 17th century, which was not the same as the Scientific Revolution. It was an organizational form for creating networks through which information about the discoveries of the new sciences at that time could be propagated and could be the basis for further advances. Those are the characteristics of this social system. This is another thing that I want to impress upon you, which is the complexity of the system, like many other social systems.

In part two, I will talk about three significant performance problems in the open science system. They occur at three levels. First is at the level of individual behavior. Second is at the level of organizational coherence and the lack of internal conflicts within organizations that affect and degrade its performance. Third is at the system level where other aspects of knowledge and its applications are adversely affected by mal-allocation of scientific resources, which is misdirection of scientific resources either too much in one direction, or other structural things that tend to degrade the system.

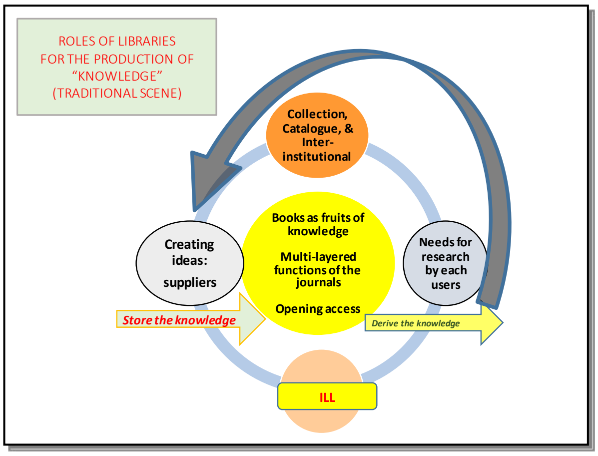
Part three is very brief because I do not have solutions for all of these problems. I have thought about the three that I have talked about, and I have a policy message that is the same in all cases. It is the message that doctors are asked to follow when they enter the profession, which is 'do no harm'. In other words, when treating the patients, the most important thing is not to kill, cripple, or damage the patient in any way that is not absolutely necessary to save their patient's life. Therefore, I will provide some cautionary message about how not to go about fixing the three types of problems that I have mentioned.

The Role of Repositories in the Open Science Mode

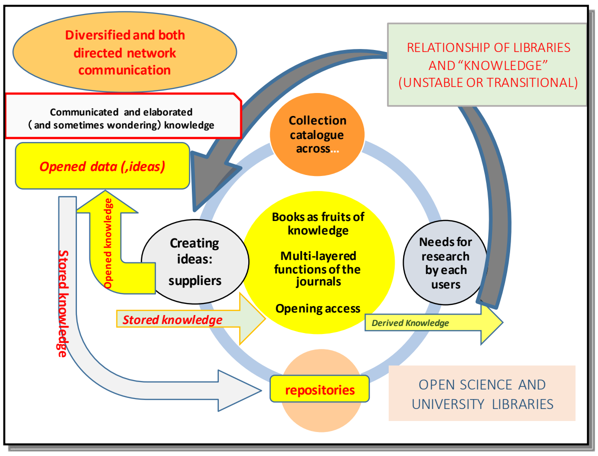
I have been told that many people here today work in conventional libraries or repositories for digital materials, and work on the curation of those materials and how those materials can be searched. This means they are working on how internal information can be structured so that it is accessible through search for particular topics. Also, I received some helpful insights that the framework that I am going to talk about may not be recognized by the people in attendance. However, the central problem is depicted in this very nice graphic at the beginning of the slides by Professor Fukagai on the 'Open Basis of Scientific Knowledge: Transactions of Ideas via the Repository, and the Possible Roles of University Libraries', which he presented at the 18th Library Fair two years ago (Figure 1, 2). The point is to say that this is a system that is now in transition. It is a complicated system. It is a system that links activities of individual actors, groups of actors, and institutions that have the roles of libraries that you can visit, and repositories in which you can extract things because they are in digital form. The extraction is very easy and can be highly targeted and selective.

The role of libraries in the production of knowledge is tradition, and is shown on Figure1. It is quite linear in its needs. We have needs for research by users. There are needs for them to use the resources that they require for research such as previous documentation of research. Data that are generated by researchers are now storable. You can access that data and use it for your own purposes. Therefore, there is a need to have structured collections of this data. In the model, essentially, the suppliers of the function of storing and retrieving are librarians. The knowledge satisfies some of the needs of the researchers, and it goes around in a nice linear way.

On Figure 2 is a schematic of the system you



(Figure 1)



(Figure 2)

are coping with, which is evolving and having new functions. Some functions are created by the advances in digital information technologies and the discovery of things that can be done with this digital material. Some functions quite new, and they require adaptation by those who provide repositories in order to make them useful. Therefore, we have not discovered all the things that can come out of the use of these techniques, nor have we discovered all the ways of utilizing them, creating them, and distributing them.

Once you give open access to digital resources and structure the way resources can be distributed, used, curated, their use recorded, as well as the patents of resource use, now resources can be useful to those in the public. The role of repositories is quite central, and the collections contained in repositories play into resource allocation and the conduct of research in the open science mode.

Understanding Open Science

To understand this system, it is easier to start with the idea that they inquire important reinforcement through the emergence of a shared normative structure. Norms are the way of telling people what is proper and appropriate behavior in the company of other people who are a part of a particular social system. If you go into another culture, people may have to tell you how to behave, so these are behavioral norms. Behavioral norms in turn become both constraints and developments that improve the functioning of the formalized institutions that are needed to organize, reinforce, and transmit the modes of operation to successive generations of people who work within this system.

I have told you that there is a strange system called ‘open science’, which is not the market system. There is a market system, enterprises conduct research in their laboratories. They patent and license their discoveries. They commercialize the products by licensing them and interacting with users. Users learning becomes a source of learning and understanding for the producers of new devices and services, which support research.

Why do we have two distinct systems of open science and commercialized science? They are in conflict at many points since they give rise to different motivations that affect the behavior of individuals and organizations that have different goals. You have the goal of increasing the net worth of a business corporation, or a startup firm on one hand, and on the other hand you have the goal of advancing the career of the researchers to enable them to mobilize resources from society that cannot be obtained by selling because that would involve the transfer of property, and what they have are ideas/knowledge. Knowledge is a very difficult thing to transact in for money. If I come and tell you, “I have a fantastic idea for a soft drink. It will make you a lot of money.” The person then says, “Well, what is it?” I say, “Well, if I tell you what it is, then you will have it. How do I tell you what it is without giving it away?” Therefore, we have complicated ways of transacting in new knowledge. How can you be rewarded for giving it away? That is the germ of the idea that, in order to get some benefit for researchers to allow them to continue doing what they want to do in the knowledge domain, they had to give it away, disclose, and allow others to verify that what was being done was not a fraud, and that having such knowledge would allow someone to do something that they could not otherwise do.

Why do most modern societies have both systems that seem to be in conflict with one another? The reason is that they are also complement each other. Together, if kept in proper balance, the two systems produce things that neither subsystems can on their own. How did we get such a system? We need to understand this often the roots of a new system reveal the central purposes of a system and why people came to adhere to such a system.

The History of Open Science

I would like to elaborate the puzzling phenomenon of open science. In a world characterized by secrecy about such a dangerous and disruptive thing as knowledge, how did it come about that people publish knowledge and make it available and understood by everybody so that others can try it for themselves and find out whether something works or not?

When you have a phenomenon in the social sciences, you can try to explain it in two fundamentally different ways. One is to try to find out how it came about, which covers the logical origins. If it did not exist logically, why would people want to create it? For that, people would have to understand what is missing and say, "This is the logical answer to the question of why we cannot do this, or why we do not have that." So that, to take essentially functional explanation, people ask, "What does the process of this system do for us? What is its function?" Without a function, people will not continue doing something unless it is for entertainment or for symbolic purposes. However, at a functional level, there is a need for knowledge to operate in the world by transforming other things and generating energy, controlling it, manipulating physical goods, and trying to discover new things to be explained, how these new things can be applied, and so forth. Those are functional reasons. However, logical origins are based on people saying, "We need this, and we would invent it today." It must be the case in the past at some point where they needed it and logically that is why they created it.

But this does not explain why things did not begin. *Ab initio.* When the first person said, "We need something like this," why did many centuries pass, and why did people live within the opposite system, which means that they did not need to share things, that they do not need to cooperate, that they do not need to make things available to as many people as could understand it, and that they do not need to educate people so that they are able to understand it. Not before the 16th century in Europe, did we get the set conditions in sufficient to motivate people within the dominant system of vassalage? There were people who had lots of resources. There were people of lesser or greater nobility. There were people need things to be performed in their court and on their estates. They wanted the knowledge of the people about things like armaments and defense. They needed to be able to calculate the trajectory of arrows, cannon balls, and so forth. They needed to be able to design a castle that could resist cannon balls and other kinds of projectiles once gunpowder was invented.

There is a story about old motivations for patronage and then the problems caused by new mathematics. Noble people were interested to have someone in their court that knew about the heavily mathematized new source of knowledge. Very few of the nobles could follow what these people were doing mathematically. Therefore, the problem was that you needed these people, but you did not know for yourself whether they were a good knowledgeable person. For example, if someone said that they could make fine lutes, you could look at what they make and could determine for yourself whether or not it was true. However, nobles could not determine on their own whether someone with mathematical knowledge is actually knowledgeable. The nobles needed people with expertise that they could not understand themselves. Nobles would have to be become experts themselves in order to understand.

This is called 'informational asymmetry'. It exists as a major problem today in government contracting. For example, contractors can say that they can build a new transport system, a modern airport design, or a new armament system, but how do you know to trust them? This is a problem that exists in all specialized services. Your doctor understands things and could try to explain to you, but if you are not trained as a doctor, this would take him a lot of time. If you do not understand, then you do not know whether he is telling you is true. Therefore, you need to have a basis for trusting a person, some way of certifying them. You need to have other people who have never met the person tell you, "His or her reputation has preceded her. She is well known in the domain that she is talking about. Yes, this is the person you should trust. If they tell you to do something, you should accept that because they have the esteem of their peers." You can also have people who know what they are talking about say, "Yes, this is a person whose work I know. I trust it because I have access to it and have seen for myself that it works," or, "Somebody else who I know has tried it." Therefore, it became important that people could demonstrate that they had knowledge to solve this informational asymmetry.

The Normative Structure of Institutionalized Open Science

Regarding grasping the institutionalized norms, Robert K. Merton wrote about the correct way to do modern science first in 1938, and was motivated to publish it in his theses and articles before making a book in the 1970s. He published a thesis in 1942 during the war, and it had a strong political animus to it. It was, in a sense, an attack or critique of Nazi science and of the destruction of what was generally recognized as a leadership position in the physical sciences, chemistry, and physics in Germany in the early part of the 19th century. He emphasized cooperation, not authoritarian control. Cooperation is voluntary. Universalism means that science is open to everyone, although there are some ascriptive limitations on who could practice science based on their birthplace, culture, or religion. The entry to it was on the basis of demonstrative merit, that people should be, in a specialized sense, disinterested in whether knowledge would benefit them personally. That is to say that those practicing science should be interested in the truth, a passionate interest that was personally disinterested. They are interested in the problem and finding the solution.

There are two senses of openness. One is the openness of the pursuit and then skepticism, which is the ability to freely challenge somebody and to exercise affirmative skepticism. This is the ability to say, "I have followed you thus far, but what about this? This part does not seem to follow logically." In other words, it is the freedom to question. That gives rise to idealized socialized norms. The full disclosure of findings and methods are one part of it which is necessary, as well as the expectation of verification by replication by one's peers. Those are the conditions. Those are social norms that people cannot be personally offended by people who question them, want to see the evidence, and so on.

Procedural arrangements depend upon rewards which are based on the things that come when you have reputational status, when your peers say, "Yes, this person has done very good work." That tends to increase the rewards of your university in seeking to have you teach, and seeking to have you do research there. Similarly, it might lead to business firms wanting to consult with you, not necessarily employ you, but to seek your knowledge in some way. Reputation is based on peer-appraisal of your scientific contribution, not your politics or anything else. Your eligibility for evaluation is on non-ascriptive characteristics of the author and their contributions, which involve valid claims to priority in discovery or invention. The last arises from the problem how to determine whether someone is working. You cannot monitor what they are doing. The physicist sitting in a nice warm bath is thinking very hard about the problem, but you cannot find that out by watching them in the bath, as entertaining as that might be.

You can only give something to somebody who claims to have been the first to discover it if they show it first. Therefore, disclosure is an important way in which you claim to have been not copying what somebody else has done, but to have done it yourself. Therefore, the priority of claims becomes important. It becomes something which is disputed sometimes with priority conflicts and claims, so this is the aspect of rivalry for the reputation that is present in this system, which makes for non-cooperative behavior. You would like to slow down your rivals, but on the other hand, you will have to disclose what you are doing. You just want to disclose it before they do, so there is an aspect of an inner-tension within the system.

Regarding the system's relationship to the Scientific Revolution, leaders grasp this system in their scientific work who are also still engaged in the world of secret knowledge, of alchemy. In his notebooks, Isaac Newton wrote 1.2 million words about alchemy and chemical alchemy, more than anything else that he published about his scientific discoveries. He belonged to circles of alchemists that included people like Robert Boyle. This is in the late 1600s, and they were in the world of secret knowledge. They believed that it was a bad thing to release something prematurely because such knowledge could be very dangerous.

The problem I have mentioned before was initially solved by people demonstrating what they knew. Mathematicians who had algorithms would challenge people who were skilled abacuses to who could do calculations faster to solve well-established problems. Or, they would pose a new problem, and say, "Let the abacuses try to do that." There were other kinds of open challenges. Reputational competition gave rise to priority disputes, and people found other ways to get direct confirmation.

Regarding Scientific Misconduct

I would now like to focus on the problem of scientific misconduct at the level of individual behavior. Misconduct does not include honest errors, sexual harassment, scientific discourtesies, and so forth. There are three forms of scientific misconduct, which are fabrication, falsification of data, and plagiary. In most investigated cases where we have data, plagiary does not figure centrally. It is a problem likely in one domain only, which is where plagiary corrupts the value of certification through education. If people could get their twin brother to come in and sit the examination because their twin brother is much smarter than they are, then we have certified somebody who really should not be certified. That corrupts the idea of educational system that produces a measure of confidence, and so forth.

Otherwise, plagiary from my viewpoint is a victimless crime. Nobody is hurt by it. This is because plagiarists take something that is little known, has been published someplace in an obscure journal, and republishes it maybe in a slightly different form. Plagiarists bring something back to the notice of people who have overlooked it because anything worth plagiarizing is better than something which is allowed to go on indefinitely. Who is hurt by this? The original author is not hurt because people pay attention. It is a fact that the true author published something that was ignored and could not be published in an important journal. It was published someplace just to make sure it was published on the person's CV, so now it has been rescued from obscurity. For plagiarists, if attention is called to the value of the piece, it usually awakens people who remember that it was somebody else who worked on it first, and so the plagiarist does not benefit greatly for very long.

Usually, good plagiarists are also publishing good work on their own in some kind of pathological cases. They think, "I could have written this paper better because I have published all of these other papers, which is what I did." This is another problem. We have spectacular cases involving well-known established famous people. Before Marc Hauser, there were others in environmental medical science and cloning who used fabricated images and presented the same image as representing many instances of cloned organisms. There was a physicist who wrote a spectacular number of papers in physics working at the IBM lab in Geneva, which all turned out to have been fabricated. The results did not work.

People think about this in one of two ways. In the model of open science, if you violate one of the norms, then you get punished by the loss of peer respect. Alternatively, you have the crime and punishment approach. For the approach, the economist Gary Becker says, "What are the probable benefits that you get, and what value do you get from having successfully claimed this fame?" If something attracts attention and you are not caught, that is a benefit. Then, on the other hand, what happens if you are detected? How large is the punishment that you suffer? People approach this by saying that the problem is that you have not made the detection system strong enough and you have not made the punishment severe enough. If you do so, we could reduce the frequency with which this happens. That is one approach. The other approach is, "You have to educate people so that they do not do this because it is wrong. It is a violation of the norms, and your colleagues will eventually detect it or the young people working in your lab will see it. If they have been properly educated, they will know that this is inappropriate behavior, and somebody should report it to somebody who is overseeing their work and funding them."

Very little data is available on misconduct. Data from 1996 onward from what became the Office of Research Integrity is available in cases where there were allegations of misconduct. They started to try to investigate themselves, but they got out of that very quickly by 1995. They just supervised the investigations conducted by institutions that received research. Since this organization was part of the Public Health Service, it focused on the domain of biomedical procedures, drugs, and devices. There are many people in this domain due to its close connection with application. The biomedical sciences were growing very rapidly in this period, so maybe there was much rivalry. There was an intensity of allegations, but also opportunities for people to enhance their careers. The relative importance of biomedical sciences has been maintained. You see that there is a distribution of young people such as postdocs and then other researchers. The share of postdocs is higher in the biomedical sciences. Lab sizes have increased. The scale of the conduct of sciences is no longer the solo scientist or a very small group working together. It is large teams, and the teams have other researchers in addition to the post-docs, some of whom are not scientists in the literal sense. They may be technical or administrative. They are supporting, such as nurses who monitor patients in field trials who are neither researchers nor technical people.

The interesting thing about this is, when you look at the positions held by people who are involved, the main thing that is interesting is that the open science model cannot account for behavior because these people are violating norms. The basic crime and punishment model does not help because there are a lot of people who are very brilliant and slightly crazy. They believe that they will not be a detected, and they will go on doing misconduct. That is not rational. Therefore, making punishment greater does not affect those people who think they will not be caught. Also, for people who are very early-stage or who are only marginally entering the field, the typical punishment was to prevent them from getting grants. For most of them, they are more or less alienated from the area because they cannot even get a second year as a post-doc, much less a tenure position. They do not think that being prevented from getting a grant is really going to be an incremental problem for them. They cannot get the grant anyhow, so people are picking the wrong things.

Who gets charged and who is found guilty in misconduct? The people who are charged most frequently are the young. Graduate students and postdoctoral students are in this group. Of all cases, about two thirds of them in this field. Associate professors, assistant professors, and research assistants are in the liminal state. Full professors are at an even lower probability of being charged and found responsible. The anomaly here is that the industrialization of research in the biomedical sciences has led to the same kinds of problems of alienation and anomie on the part of the people who work on the assembly line, not the designers. They are not mentored. They are not made to feel that they are part of what the lab is doing, and that is important. In socialization of open scientists, if you do not do your job properly, you are hurting a good cause, so that is a failure of the system. It lies in the organizational failure to respond to increasing specialization of function and the need to do research on a different scale. It is most evident in this area in biomedical research, and it needs to be addressed in different ways. That is a kind of paradigm.