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Evolution and future of the knowledge commons: emerging opportunities and challenges for less developed societies[1]

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This article addresses the emerging field of the knowledge commons in relation to the challenges of international development. It reviews the history of academic knowledge and innovation since the Enlightenment, its evolution and current trends, with the purpose of exploring the future of the knowledge commons. Assuming that knowledge is the most important resource in the twenty-first century, the intention of this article is to map the conditions necessary to take advantage of this resource. What are the barriers to accessing and using the global common pool of knowledge that is currently being generated? The supply and the demand sides of the knowledge sharing equation are reviewed to understand their particularities and trends. Particular attention is given to the demand side of this equation in order to identify the obstacles that prevent people from less developed countries from taking full advantage of this fast-growing resource.

Introduction

After 12,000 years of quasi-stagnation and discontinuity, the knowledge pool of humanity has been growing annually by 3% to 5% at a quite stable rhythm for more than three centuries. From 1650 to the current day, 50 million academic articles have accumulated and more than 1.5 million are written each year. Concomitant with this growing wealth of knowledge is the expanding social outreach of digital technologies and mobile devices that facilitate access to the knowledge pool.

During the last two decades two contradictory trends have become evident. From the enclosure side, governments and private companies in developed countries are expanding the power of enforcing Intellectual Property Rights, thereby limiting the fair use of knowledge. From the disclosure side, a growing percentage of scientists and academics are becoming part of the Open Access movement expanding the number of academic articles that can be accessed through the Internet at no financial cost.

In the literature about the knowledge commons, the supply side of the knowledge sharing equation has received abundant attention. The barriers to knowledge access, from the supply side, such as financial cost, digital divide, language, fragmentation, knowledge and meta-knowledge quality and knowledge structure, have been addressed systematically. The analyses of the factors that affect the demand side of the equation, such as motivation, cognitive awareness (or blindness), absorptive capacity and conditions for application, have not received the same level of attention. This is particularly true for the context of less developed countries.

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This article approaches both sides of the equation, emphasizing the analysis of the demand side. The reason for that emphasis is that the perspectives of the demand side are looking much more challenging for people from less developed countries, and deserves more attention. The social divide respect to knowledge is moving from the supply side toward the barriers for looking for, assimilating, and using productively this growing wealth.

To approach the relationship between knowledge, technological innovation and economic development, the article relies on the historical work and concepts of knowledge developed by Joel Mokyr (2002a 2002b, 2005) and Simon Kuznets (1955). To analyse the institutional components of the knowledge commons, the article relies on the Institutional Analysis and Development framework created by Charlotte Hess and Elinor Ostrom (2007), while the analysis of the absorptive capacity is based on the conceptualization developed by Wesley Cohen and Daniel Levinthal (1990).

To address the challenges of the demand side, the article conceptualizes cognition as a socially distributed phenomenon, analysing the requirements for looking for, absorbing and applying knowledge, and taps into the literature on three types of knowledge communities; such as thought collectives (Fleck 1979; Sady 2001), epistemic communities (Hass 1992), and communities of practice (Wenger *et al*. 2002, Wenger 2006). The intention of visiting these diverse types of knowledge communities is to explore a social fabric that may contribute to reducing the disadvantages encountered by people living in less developed countries.

Conceptual premises

The motivation for approaching the knowledge commons and the logic behind the analyses of this paper come from a set of conceptual premises which I would like to make explicit from the outset: knowledge is the primary driver of economic improvement. This premise is based on the coincidental historical evolution of economic improvement and knowledge generation, particularly after 1750 (Mokyr 2002a, 2002b, 2005; Beinhocker 2007).

The likelihood of success of innovative initiatives is positively related to the knowledge assets that innovators can access, absorb and apply. Using the language of Mokyr, the likelihood of the success of innovation is strongly related to the quality of the epistemic base of innovative intents.

In economic terms, knowledge is a very particular resource: it is non-rivalrous, intangible, and has no inherent limit for its expansion and application. Knowledge needs to be treated differently from tangible resources such as labour, financial assets and natural resources.

Any treatment of international and social inequities is incomplete, if it does not include the role of knowledge in reproducing the differences in wealth generation, particularly in the knowledge-based economy of the twenty-first century.

Access to knowledge requires physical access and cognitive competence or absorptive capacity. The physical access to knowledge artefacts is a condition, but it is not enough to make sense of its meaning and take full advantage of the contents embedded in knowledge artefacts.

Conceptualisation of knowledge

There are many ways of conceptualising knowledge. Philosophers have been reflecting on knowledge for millennia and have developed diverse ways of understanding what knowledge is. The way this paper conceptualizes knowledge is from the point of view of its usefulness for economic growth and social improvement. The concept of knowledge used is 'useful knowledge'. This way of understanding knowledge, as an economic resource, was originally developed by Simon Kuznets (1955) and extensively used by Joel Mokyr in his studies on the role of knowledge in industrial revolutions (Mokyr 2005). According to Mokyr, useful knowledge 'deals with natural phenomena that, potentially, lend themselves to manipulation, such as artefacts, materials, energy and living beings' (Mokyr 2002b, p. 3). Useful knowledge, as Mokyr understands it, is knowledge about any regularity or pattern of nature that, potentially, can be applied to generate economic value or otherwise benefit human beings. This approach does not focus on the origin of knowledge, or how it is generated, but on the application of existing knowledge to something practical.[2]

The original concept of Mokyr refers exclusively to knowledge about nature.[3] It is consistent with his concept of technology which solely includes physical technologies and does not consider social technologies. In this paper, I expand the concept of useful knowledge to include knowledge about society. The purpose of this extension is to go beyond physical technologies. My premise is that when addressing development, social technologies can be as important or even more important than physical artefacts.

Useful knowledge does not refer to truths or falsehoods, nor to any epistemological feature of its origin. The concept of useful knowledge refers to its reliance for practical application. It is assumed that all knowledge is a social construction, with more or less empirical support, more or less logical consistency, and more or less consensual acceptance. It does not matter, for the purposes of this paper, if the origin of the useful knowledge was scientific research, theoretical speculation, experience, reflection, creativeness or traditional beliefs.[4]

According to Mokyr (2002b), useful knowledge has two subcategories: propositional knowledge and prescriptive knowledge. Propositional knowledge is the type of knowledge that catalogues natural and social phenomena, it refers to 'what we know' about nature and society. It explains what things are and how they work. Propositional knowledge is important for making sense of the world. Propositional knowledge includes scientific knowledge but also includes all sets of known patterns, empirical tables, documented experiences, interpretations and beliefs that can be applied to practical uses. Propositional knowledge is said to be tight if the consensus around its reliability is broad. The tightness of propositional knowledge depends on the confidence that people have on the particular rhetoric (research procedures, concept construction, logical deduction, theorem demonstration, etc.) that supports the knowledge claim. There was a time when divine revelation and the opinion of Aristotle were enough to believe in the trustworthiness of a statement. But, after Galileo and the Invisible College, empirical verification, following specific procedures, and processes of peer (critical) review, became a requirement for the academic community to consider reliable a knowledge claim.

Prescriptive knowledge, in the understanding of this paper, is the collection of techniques and instructions for manipulating nature and social institutions for human purposes. Archetypal expressions of prescriptive knowledge are: recipes for taking a drug, instructions for building a bridge, or a manual containing norms for managing a natural resource commons.[5]

Knowledge, both propositional and prescriptive, has tacit and explicit dimensions (Polanyi 2009). The explicit dimension refers to that part of knowledge that can be codified and expressed through words or using any type of symbols. In other words, explicit knowledge is knowledge that can be expressed in the form of information, through symbols. The tacit dimension of knowledge refers to knowledge that can be expressed through actions. It is assumed that knowledge cannot be completely codified, and that the use, by a human agent, of any set of codified descriptions or instructions requires tacit, non-codified, components embedded in the mind of the agent.

According to Mokyr (2002a, p. 4), 'the useful knowledge of a society is defined as the union [sum] of the knowledge of the individuals in that society and whatever is stored in storage devices'. In this definition, Mokyr includes knowledge in the form of information stored in storage devices, such as databases, but does not mention knowledge that is tacit; that is, embedded in social behaviours, implicit social rules, and thinking skills. To work with social technologies, it is convenient to expand the concept of useful knowledge to include this type of non-codified, tacit knowledge to include the type of knowledge that can only be expressed through action. All communities have a huge stock of knowledge, such as lessons learned, practical skills and experience, which is stored in the form of behaviour and social norms, and most of this knowledge is tacit.

The study of the industrial revolution has shown that propositional knowledge and prescriptive knowledge are profoundly intertwined. All techniques require a set of propositional knowledge that, to some degree, 'explains' the phenomenon that is being manipulated by the technique. This set of propositional knowledge is the epistemic base of the technique. Historical evidence (Mokyr 2002a) has shown that the emergence and evolution of techniques depends on the quality of their epistemic base. If the epistemic base of a technique is narrow, the evolution of the technique is limited. Once the epistemic base is broadened the technique can evolve much further. For example, the first steam machine was invented based on a quite limited understanding of thermodynamics. The steam machine was developed relying on empirical knowledge accumulated by engineers. However, the improvement of the efficiency of steam machines, for transportation and industrial uses, required the work of the scientists, such as Sadi Carnot, who went on to develop the laws of thermodynamics. The invention of the internal combustion engine had to wait for more than one century until the scientists were able to make theoretical breakthroughs in thermodynamics. Similarly, knowledge about microbiology (propositional knowledge) had a decisive impact on the development of medicine, an applied field of biology. If we look at the history of medicine, we find that it has to be organised into two phases: before and after the development of microbiology.

Currently, the critical variable for less developed countries is not how broad the epistemic base is that supports innovation locally, but how broad the epistemic base is that local innovators can effectively access. In less developed countries, innovators struggle with problems whose understanding is already part of the global stock of knowledge. The problem they face is that access to, and the absorption of, existing knowledge is limited to a small group of social elites. For people with limited access to knowledge, the cognitive context is similar to that of decades ago, and sometimes, centuries or millennia ago, when that specific knowledge was not yet created. Despite the fact that we are all living in the same time period, when we move across countries and social sectors it is possible to travel back to the past, as if we were in a cognitive time-machine.

Useful knowledge can be analysed from two perspectives: the nature of the knowledge and its context. As already explained earlier, through the lens of its nature, useful knowledge can be classified into propositional and prescriptive. Through the lens of its context, knowledge can be classified as general knowledge and local knowledge (Table 1).

Despite the prestige and importance of scientific knowledge, its use in any activity, such as value generation and innovative initiatives cannot happen without the complement of local knowledge. Hayek (1945) used to refer to local knowledge as 'a body of very important but unorganised knowledge which cannot possibly be called scientific in

Table 1. Knowledge by category and context.

		Context of knowledge	
		General knowledge	Local knowledge
Nature of knowledge	Propositional	(1) Descriptive knowledge that was built upon, and submitted to, scientific scrutiny: scientific knowledge	(1) Sum of knowledge of individuals of a community.
		(2) Sum of interpretative beliefs broadly shared but not submitted to scientific scrutiny.	(2) Sum of non-scrutinized beliefs of individuals of a community, such as health principles, Cosmo vision, social hierarchy, understanding of local economics, etc.
	Prescriptive	(1) Nationally and globally available patented and public domain technologies and methodologies.	(1) Elements of general prescriptive knowledge mastered by members of a particular community such as artistic skills, language, and mechanisms of social interaction.
		(2) Nationally shared practical skills of people such as spoken language, reading skills, computer literacy, cell phone familiarity, and driving a car.	

the sense of knowledge of general rules: the knowledge of the particular circumstances of time and place' (p. III-H9). Institutions, companies, and professionals rely on their local knowledge to contextualize and make use of the general (external) knowledge they may access. However, despite its practical relevance, local knowledge is not enough to capture the systemic nature of the problems that communities face. To lead innovative initiatives and develop sustainable solutions, communities need to combine local and external (general and other local) knowledge. Indeed, the quality of the external knowledge absorbed locally may decisively affect the effectiveness of innovative initiatives.[6]

The systemic nature of local problems can only be fully captured through interpretations that use general (external) knowledge. As Hayek (1945) explained:

> The 'man on the spot' cannot decide solely on the basis of his limited but intimate knowledge of the facts of his immediate surroundings [local knowledge]. There still remains the problem of communicating to him such further information as he needs to fit his decisions into the whole pattern of changes of the larger economic system. (p. III-H17)[7]

Conceptualising the commons

Commons refers to any resource (natural or man-made) whose use is shared by a group of people, but not by everybody. Examples of commons are: rivers, forests, deep sea, fisheries, highways, playgrounds, the Internet, and some types of knowledge, such as local and academic knowledge. Shared use of the commons has the potential to trigger social dilemmas and conflicts resulting from free-riding, overuse, competition, ravage and rivalry among those people who could, in some way, benefit from the resource.

Human societies have thousands of years of experience in managing the challenges of using the commons. For example, the management of the lands in the Nile River valley constitutes a successful story about using a resource commons. The requirements to manage the annual redistribution of the land in the Nile's river valley shaped the Egyptian state and spurred the creation of trigonometry and topography. In this case, the requirements of sustainability of a commons shaped a whole society and triggered their cultural development. A case of unsuccessful management of a commons is Easter Island (Isla de Pascua) in the southern Pacific. The almost total depletion of the island's ecological resources (trees, palm trees, birds, fresh water, and fisheries) and the final anthropophagic war among the diverse clans exemplifies the tragedy that happens to a society when it fails to manage the resources of the commons (Diamond 2005).

Because of the spontaneous tendency of individuals to overuse a shared common pool of natural resources, sustainable use of the commons requires some type of institutional arrangement. Three analytical approaches were developed to understand the challenges of using the commons:

(1) Garrett Hardin (1968), in his influential article about the tragedy of the commons, concluded by advocating the need for some external agent to prevent overuse and free-riding;
(2) The prisoner's dilemma, formalised by Albert Tucker and based on game theory, suggests that two isolated prisoners, applying non-cooperative strategies, harm each other when trying to protect themselves (Cunningham 1986);
(3) An alternative way of approaching the same dilemma was developed by Mancur Olson (1965) when working on the challenges of collective action (as cited by Ostrom 2003). Olson concluded that without coercive mechanisms, most individuals do not give priority to the interests of the collective over their own individual interests. However, local agents can create these mechanisms and achieve control over the use of their resource.

Elinor Ostrom, who was a Nobel Prize-winner for her work on institutional arrangements required for sustainable management of the commons, has found that the users of common-pool resources avoid depletion when they are self-organised to govern the use of the resource through an institutional arrangement that is capable of preventing and correcting overuse and free-riding. Based on successful cases, Ostrom developed a framework to analyse the commons and define rules for a sustainable use of the resources. Later on in this paper, I will present an adapted analytical framework, developed by Charlotte Hess and Elinor Ostrom, for the knowledge commons.

The history of commons and the knowledge commons

Awareness about the importance of the commons has existed since ancient times. A long time before the Neolithic Revolution, human bands and tribes used to dispute access to commons, such as food sources, through local wars. The commons in those times were fishing and hunting areas, firewood sources, drinking water sources, and quartz quarries (to make tools); to list some of the most important ones. For bands and tribes, the knowledge required to take the best from the commons of natural resources was in itself knowledge of strategic relevance. In those ancient times, the fate of human bands and tribes was critically dependent on their access to sources of natural resource commons as well as their knowledge about the use of the natural resource commons.

The assets of knowledge of a community (ancient or modern) can be considered as the sum of the knowledge, both tacit and explicit, that exists in all forms, in human brains, machines and storage devices, and under all types of property. Part of these assets is held privately by individuals, companies and institutions, in the form of intellectual capital and secrets, and another part is held by the community. Patents and the knowledge imbedded in processes and in the machinery of a factory are examples of private knowledge. Shared knowledge assets refers to knowledge that is collectively held by community members or which is in the public domain, theoretically accessible to everyone, such as basic sciences, mathematics, classical literature, demographic information, or the set of skills that is locally shared by social groups such as technical and aesthetic skills collectively cultivated by a community of tool-makers. Knowledge commons refers to this second type of knowledge asset.

Before the development of language, all knowledge had to be acquired exclusively through observation and imitation. The knowledge commons at that time were shared by very small groups of people who used to live, gather food and hunt together. Without direct observation it was impossible to access other people's knowledge. Additionally, the rationales behind the actions (propositional knowledge behind the prescriptive knowledge) belonged exclusively to the individuals who carried out the actions and were not part of the knowledge commons. During those ancient times, there was almost no common pool of propositional knowledge, the epistemic base of techniques was extremely simple and narrow, and innovation was serendipitous. The development of language created the first mechanism to communicate ideas (explicit forms of knowledge), and greatly contributed to the expansion of knowledge assets.

The development of writing, a second revolution in the evolution of language, after the development of oral language, strongly influenced the social segments that could share specific subsets of the knowledge commons. For example, the Sumer cuneiform script and Egyptian hieroglyphs functioned to make knowledge the exclusive privilege of the administrative elite, monarchs and the clergy. The Phoenician alphabet, which was developed for trading, greatly expanded the social frontiers of the knowledge commons, making writing technically available and useful to common people. The Greek civilization started based on oral communication, but developed by having writing as a vehicle for sharing knowledge among creative people.[8]

The Library of Alexandria led the third step in developing the knowledge commons. Before the Library of Alexandria, most knowledge was developed exclusively and in isolation inside specific civilizations: Sumer, Egyptian, Indian, Chinese, Greek and so on. Wars and cross-frontier traders and adventurers were the exceptional carriers of 'external' knowledge, expanding the cognitive limits of those cognitively closed worlds. At that time, the frontiers of the knowledge commons were almost the same as the physical frontiers of the civilization in which the knowledge was developed.

During those millennia, the fate of different civilizations was also the fate of the knowledge commons. Each time a civilization was destroyed, an important part of humanity's knowledge assets were lost. The Library of Alexandria was the first institution to be deliberately set up with the purpose of gathering and protecting a multi-civilization, and thereby in some way a ‘universal’, stock of knowledge commons. The mission of the Library of Alexandria was to create the first universal knowledge pool. Copying documents and ships’ records and gathering brilliant minds were the two core strategies adopted by the Library of Alexandria in order to create the first reservoir of knowledge commons of a multi-civilization scope. However, the Library of Alexandria was a dream before its time. Despite the admirable work of its librarians and scholars, the Library never fully realised its mission.

Gutenberg’s printing revolution was the fourth step. Thanks to the movable typefaces, printing costs fell drastically, thereby increasing the number of sectors in society that could now access books and written texts. Although the methods for creating knowledge did not change much during the first century after Gutenberg, the number of knowledge artefacts, mainly books, increased exponentially and, for the first time in history, reached the middle classes. After millennia of enclosure, literature, academic knowledge and Greek philosophy moved out of the castles, monasteries and a few elite ateliers. Through printing, books became a commodity for the middle classes, and the social space of the knowledge commons expanded dramatically. The enlightenment would be unthinkable without Gutenberg and his movable typefaces.

The Internet and digital technologies, combined, were the fifth step. Through the Internet, the mission of the Library of Alexandria was finally fulfilled; the first reservoir of universal knowledge really emerged, making knowledge accessible in real time and from almost any place. Thanks to these technologies, access to knowledge took a gigantic step forward and became less dependent on geographical location. With the Internet and mobile devices, spatial location started to lose its critical role in limiting access to knowledge. Through digital technologies, copying became almost costless, multiplying the number of copies of knowledge artefacts on the Internet; the distributed universal reservoir.

Hess and Ostrom approach to knowledge as commons

Based on the work of Elinor Ostrom on sustainable ways of managing natural resource commons, Charlotte Hess and Elinor Ostrom (2007) have developed and adapted a model to analyse the knowledge commons (Figure 1). The Institutional Analysis and Development (IAD) framework for the knowledge commons, adapted by Hess and Ostrom (2007), has five components: (a) resource characteristics, (b) action arena, (c) patterns of interaction, (d) outcomes, and (e) evaluative criteria (not shown in the framework).

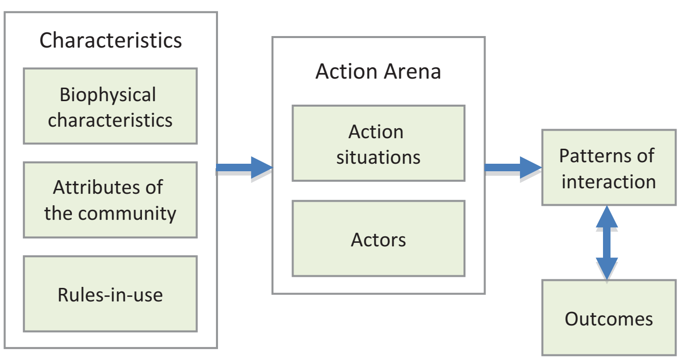

Figure 1. Institutional analysis and development (framework).

Resources characteristics

The characteristics of the resources include: biophysical-technical characteristics, attributes of the community, and rules-in-use. The biophysical-technical characteristics for natural resources have two levels: the resource system and resource units. The biophysical-technical characteristics of the knowledge commons have three levels: facilities, artefacts and ideas. Facilities are libraries and any other type of physical or digital reservoirs containing books, journals, databases and papers. Artefacts are physical or digital discrete objects or flow channels such as books, journals, papers, maps, videos, research notes and blogs. Artefacts contain ideas. Ideas are the artefacts' knowledge content such as concepts, mathematical formulas, theoretical principles, geographical maps, logical maps, and research findings. Examples of ideas are: the Pythagoras theorem, the binary number system, the theory of evolution, the concept of knowledge commons, and human DNA.

Traditional knowledge artefacts such as paper-books are rivalrous, because only one person can read a book at a time. However, digital books and academic articles can be classed as non-rivalrous. This is because multiple copies of digital artefacts can be made at very little cost and two or more people can concurrently read the same copy using different computers or mobile devices with Internet access. This is the fundamental difference between physical objects such as water, trees and fish, and digital knowledge artefacts such as articles in PDF format, blogs, podcasts and eBooks.

Because ideas are non-rivalrous goods, there is no inherent limit to the number of people who can concurrently apply the same ideas. Indeed, ideas are quite the opposite of rivalrous physical objects; if more people are applying the same idea, its value increases for each one of them and also for the whole group. Although ideas are not rivalrous, access to ideas may become rivalrous. It can happen if the access flow is too intense, because the facilities can collapse and, in so doing, restrict access to the artefacts in which the ideas are embedded.

Communities that use a knowledge commons are more complex than communities that share an irrigation system or a fishery. Producers who are cultivating pieces of land inside the area of the irrigation system constitute the community of an irrigation system. Owners of fishing ships and of fishing equipment constitute the community of a fishery. These two types of communities have very well-defined borders. Communities of a knowledge commons have a fuzzier border.

Similar to natural resource commons, the individual elements of knowledge communities are users, providers and policy-makers. Users in a knowledge community are those who access to the knowledge artefacts and knowledge flow, and, in some way, process the ideas accessed. Providers are those who generate content, make content available, develop software to enable the knowledge system to function, and contribute to preserving the stock of knowledge. Policy-makers are those who are in charge of the governance of the knowledge commons.

Although the types of members of communities of knowledge commons are similar to those of natural resource commons, two features of knowledge systems add complexity to the communities of the knowledge commons. (1) Who the users and non-users are may be a question of voluntary affiliation or frequency of use, thereby making it difficult to define membership and establish the size of the community. (2) In knowledge resource systems an important part of the resources (ideas) can be embedded in the brains of the providers and users, so new participants may add knowledge to the resource pool without adding any artefact to the facility.[9]

Hess and Ostrom (2007, p. 50) defined rules in a knowledge commons as 'shared normative understanding about what a participant in a position must, must not, or may do in a particular action situation, backed by at least a minimal sanctioning ability for noncompliance'. Those rules can be formally stated, or can be applied in practice, as rules-in-use. Part of these rules-in-use can be explicitly formulated and another part may be tacitly defined. For the purpose of understanding how a community functions, tacit rules-in-use are particularly important. Rules-in-use in knowledge commons may have three levels: operational, collective-choice and constitutional. Operational rules establish how the participants should interact on a daily base: in other words, what users and providers can or cannot do. Collective-choice rules define how operational rules should be defined. Constitutional rules define who should participate in the definition of the collective-choice rules, and how collective-choice decisions should be made.

The rules of a knowledge commons are not defined abstractly; they have to respond to the biophysical-technical characteristics of the knowledge system and of the community. When technology goes through a qualitative change, such as the emergence of the Internet and digital technologies, the rules defined in the old context no longer match the new characteristics of the resource, and so new rules have be designed in order to fit in with the new characteristics of the resource. For example, the Digital Millennium Copyright Act 1998 (DMCA 1998), an adjustment of intellectual property rights to the Internet era, has strongly affected the possibilities of fair use of copies that were accepted under the old legislation.

The action arena, patterns and outcomes

The action arena is the place where situations emerge on a day-to-day basis. To use the resources, conflicts have to be solved and agreements have to be reached inside the action arena. The action arena has two main components: action situations and actors. Action situations are problems and solutions, conflict and cooperation, disagreements and agreements; they are the concrete situations that users, and providers, face when managing the commons. Actors are users, providers and policy-makers who act at each level of the rules: operational, collective-choice and constitutional.

Particularly important are the incentives that influence the patterns of interaction among users and providers. Incentives may stimulate conflicts or cooperation among them, may help the actors to solve problems or may conspire against possible solutions. In any resource system, it is always a challenge to uncover the unintended effects of incentives; knowledge commons is not an exception in this respect.

The outcomes for knowledge commons refer to the stock of knowledge and the conditions to access this knowledge. Some examples of outcomes for the knowledge commons

Table 2. Outcomes for knowledge commons.

Negative outcomes	Positive outcomes
Proprietary scientific databases (enclosure)	Gold and Green Open Access of academic articles
Digital divide and information inequity	Global and multi-language access
Erosion of the knowledge stock, degradation	Standardised digital information, interoperability
Non-compliance of standards, dispersed resources	Well-populated and interconnected repositories
Span, digital pollution, lack of reliability	Trustful scholarly blogs and podcasts

Note: Synthesis based on Hess and Ostrom (2009, p. 61, Table 3.1).

are the pace of knowledge generation for different fields and disciplines, the cost of access, the technical requirements for access, the quality of the searching metadata, and the languages of the knowledge artefacts. Hess and Ostrom (2007) list some negative and positive outcomes that are currently taking place in the knowledge commons (Table 2).

Evaluative criteria are required to govern a knowledge commons. By applying the set of criteria, policy-makers can evaluate the performance of the knowledge commons and adjust policies. Hess and Ostrom (2007) suggest a set of criteria that applies to academic knowledge commons: '(1) increasing scientific knowledge, (2) sustainability and preservation, (3) participation standards, (4) economic efficiency, (5) equity through fiscal equivalence, and (6) re-distributional equity' (p. 62).[10]

The growth of knowledge assets

The invention of methods for empirically testing hypotheses and submitting ideas to critical scrutiny, which was achieved in the seventeenth century, triggered an exponential growth of knowledge. The production of knowledge, both propositional and prescriptive, developed mutual synergy and gained momentum, opening a new intellectual and productive era.

Estimating the growth of useful knowledge is a difficult task. Indeed, quantifying the stock of all types of useful knowledge held by entire societies (propositional and prescriptive, explicit and tacit, private and public, general and local) is an impossible mission. For that reason, most researchers work with proxy indicators about existing knowledge assets. For propositional knowledge the most used proxy is the number of academic articles published in peer-reviewed journals. For prescriptive knowledge the most used proxy is the sum of patents granted.[11]

In 1650, academic journals emerged in France (*Le Journal des Sçavans*) and England (*Philosophical Transactions*) and the Enlightenment movement spread throughout most of Europe. Supported by the new wealth of propositional knowledge, innovation became less serendipitous and triggered the first Industrial Revolution. Within a couple of centuries, the living standards of the European middle classes surpassed the level of kings and queens living five to eight generations earlier. For three continued centuries, from 1650 to 1950, the number of academic journals, a proxy for the amount of academic knowledge, increased at an annual pace of 5.6%, doubling every 13 years (Larsen and von Ins 2010). Within three centuries, academic knowledge increased over 200,000 times.

The pace of growth in academic knowledge in recent times, which is measured in terms of the number of academic articles produced, is a contested issue. Depending on the sources of information consulted and the methodology applied, the figures may vary. The classical study by Derek de Solla Price (1961), which counted the cumulative number of abstracts of academic articles in chemistry, biology and physics between 1900 and 1960, found an annual pace of 4.7% and a doubling period of 15 years. Larsen and von Ins (2010), applying the same methodology of Price, in a very comprehensive work that counted the abstracts of academic articles from 1907 to 2007, arrived at a growth rate of 4.2% and a doubling period of 17 years. Mabe and Amin (2001), based on Ulrich's Periodical Directory, by filtering academic journals, have estimated the annual growth rates for six countries, from 1981 to 1995, as 3.25%, with a doubling period of 22 years, and suggest that worldwide this indicator should be found somewhere between the range of 3% and 3.5%.

Independent of these discrepancies among sources and methods, the figures suggest that the exponential growth of knowledge is slowing down gradually, changing from around 5.6% (between 1650 to 1950) to 3.2% (by the end of the twentieth century). However, as the base of the growth rate was doubling each 17 years, it is possible to estimate that, from 1907 to 2007, the number of academic articles increased approximately 60 times (Larsen von Ins 2010). So, despite this slowing down process of exponential growth, the amount of knowledge produced each year is growing.[12]

Based on ISI and Ulrich's databases, Bjork *et al*. (2008) have found that, in 2006, approximately 1,350,000 articles were published by 23,750 academic journals. According to Larsen and von Ins (2008, p. 594), 'In 1981 it was reported that there were about 43,000 scientific periodicals [registered] in the British Library Lending Division'. However, the estimation of Bjork *et al*. (2008), of 23,750 academic journals, has reliable sources and solid methodology and their figures are closer to the estimation of other authors. Jinha (2010a), for example, has estimated that 26,406 journal titles existed in 2008.

Based on the work of Bjork *et al*. (2008) and on his own research, Jinha (2010b) has estimated that approximately 1.5 million articles were published in 2009 and, summing up all academic articles published from 1655 to 2008, has estimated 50 million as the total number of academic articles published throughout these 343 years.

One possible explanation for the exponential slowing-down in the growth rate of knowledge is the increasing complexity of generating new knowledge, expressed in the increasing need of cooperation among scientists to write one article. During the second half of the twentieth century, the number of authors per article has doubled, moving from 1.8 to 3.7 co-authors. The requirement of interdisciplinary approaches and the scope of the literature reviewed are also growing (Mabe and Amin 2001, Mabe 2003). An implication of the increasing complexity is the growing importance of open access to academic articles for coming up with new knowledge and innovations.

Patenting

Although the role of patents in economic growth is disputed, patenting is still the most recognized proxy to technological development, and an important component of prescriptive knowledge. The number of patents granted annually can give a reference to the increment of prescriptive knowledge.

When analysing patents, it is necessary to be aware that they refer almost exclusively to physical technologies such as machinery, industrial processes, and drugs, and to software. Most social technologies, such as management processes, hospital management systems, electoral systems, universities, and pedagogies, cannot be fully patented.[13]

Unlike academic articles, whose exponential annual pace is slowing down slightly, patenting has accelerated exponentially during the last two decades, outpacing the generation of academic knowledge. According to the World Intellectual Property Organisation (WIPO), 'between 1995 and 2007, [patent] filings grew by 5.2 percent a year, compared to 3.7 percent for the 1983–1990 period' (WIPO 2011, p. 8).

One possible explanation for these differences in growth pace between academic knowledge and patenting is the orientation of the global economy toward a knowledge-based one. According to the USA National Science Board (NSB), knowledge- and technology-intensive sectors have had an annual growth rate of 5.8% during the last 12 years (NSB 2010). This fast growth of knowledge- and technology-intensive sectors has happened despite the fact that, during the same period, the global economy was only growing by 3.7% per year (IMF 2011). The emergence of China, India and other Asian countries as leading actors in the global economy may be an additional explanation for the fast growth of patents and technology.

An implication of these trends is that the economic importance of knowledge, both propositional and prescriptive, is growing and increasingly impacting the potential of value generation and competitiveness of entire nations in the global economy, thereby increasing its importance in defining who will, and who will not, benefit from the opportunities that are emerging in this new century.

The open access movement

The increased economic importance of knowledge and the development of digital technologies have generated two opposing trends: (1) private companies and the government of developed countries have made strong moves to increase the enforcement power of intellectual rights and patents worldwide, thereby increasing the barriers to, and financial costs of, accessing knowledge, and (2) an open access movement has emerged. I am going to briefly review the evolution of the open access movement.

As a global phenomenon, the open access movement emerged in the early 1990s (OAD 2011), rescuing the collaborative nature of academic work, software design and artistic creation, and arguing the importance of having access to knowledge for innovation and development. In two decades, the open access movement has unleashed a dramatic change on the three-centuries-old landscape of accessing academic knowledge, increasing knowledge accessibility as never before.

With respect to academic articles, the open access movement took two main forms: Gold Open Access and Green Open Access. Gold Open Access consists of making the academic articles published by journals free of charge. It can be done from the date of publishing the journal or after a brief time, such as six months or one year after publication. Green Open Access consists of archiving the academic article in an open access repository. Once archived in those repositories the articles are free to be read and downloaded. Both forms of open access have been growing since the 1900s.[14]

One possible explanation of this growth is that authors have incentives for favouring the open access option. The citation likelihood of open access articles is superior to non-open access ones. Hajjem *et al*. (2005), working with reference metadata of open access and non-open access peer-reviewed academic articles, have found that open access articles have a 77% median advantage of being more cited than non-open access articles.[15]

Similar results were found by other studies. Analysing a cohort of 1492 articles of the Proceedings of the National Academy of Sciences, and having done the careful work of eliminating confounders, Eysenbach (2006) found that open access articles had an average of 5.9 citations, and that non-open access or self-archived articles had 4.4 citations, meaning a 34% advantage for open access articles. Through complementary analysis, Eysenbach also found that open access publishing (Gold Open Access) is more effective than self-archiving (Green Open Access). Swan (2010) has reviewed 37 articles analysing the advantages and disadvantages of open access for the likelihood of being cited, and confirmed the advantage of being open access.

Considering the twenty most prestigious publication venues in computer sciences, Lawrence (2001) has found that the median of citations of free online articles is 284% higher than for offline articles. His conclusion is that open access (free online) publishing contributes more to the development of scientific knowledge than traditional, paper-printed, publishing. Evans and Reimer (2009), using metadata citations from Thomson SCI, SSCI and AHCI, have found that the most relevant impact of open access articles refers to the increased use of these articles by scientists from less developed countries.

The number of open access academic articles is already relevant. Exploring the accessibility of academic articles, Bjork *et al*. (2008) have found that 8.1% of the articles were openly accessible up to one year after their publication (Gold Open Access), and an additional 11.3% were accessible in homepages e-print and repositories (Green Open Access). These figures combined means that, by the end of the first decade of the twenty-first century, around 20% of new academic articles were, in some way, accessible on the web.

According to the Directory of Open Access Repositories (2011), the annual growth of repositories from 2007 to 2011 is 25.5%. By 7 June 2011, there were already 1970 open access repositories. According to the Directory of Open Access Journals (2011), the number of open access journals has been growing still faster, reaching an impressive annual pace of 32.5%, from 2004 to 2011, duplicating the number of open access journals in less than three years. Considering that the pace of growth for academic knowledge is around 3%, open access journals are growing 10 times faster than the pace of academic knowledge in general. This difference means that the accessibility to academic literature is going through a process of qualitative change. If this trend goes on for two or three decades, which is a very likely scenario, open access journals will dispute the current predominance of non-open access articles in academic literature.

The recent emergence of blogs and podcasts in physics, economics and a variety of other fields is increasing the accessibility to cutting-edge ideas. A reason for the growth of blogs in the scientific community is their impact on interaction among scientists, and the reduction of the time between conceiving new ideas and receiving intelligent feedback from peers. Blogs also have the power of identifying peers with similar interests, increasing the likelihood of positive synergy. Some academic blogs are a new version of open access to academic knowledge. Podcasts and online versions of newspapers are increasing free access to general information through the Internet.

Despite the development of the open access movement and the emergence of academic blogs, practitioners and scholars from the South still have important disadvantages in accessing and using knowledge in this new century. Investigating this issue, Jinha (2010a, pp. 8–9) found that: ‘These price and technology barriers are felt especially where access to knowledge is most needed, in parts of the world where the burden of social, economic and ecological problems are felt the most’. Researchers who work in the global South do not share the privileges of the northern scholars such as language domain, technology or connectivity, cognitive skills, and opportunity to participating of local clusters of intellectual collaborators.

Richard Florida (2002), after analysing the spatial distribution of creative and knowledge-intensive economic activities, has concluded that synergy and collaboration, critical components of knowledge creation, are concentrated in the metropolitan centres of developed countries. This is not good news for less developed countries. The findings of Florida indicate the importance of the spatial and social aspects of the knowledge generation processes. Although physical access to knowledge is becoming independent of geographical location, the application of knowledge for value generation is highly centralized in a few dozen metropolitan centres.[16]

Supply-side barriers to knowledge

Although technological developments, open access movement and Internet are greatly contributing to reducing the financial cost and permission to use the knowledge commons, other barriers (Suber 2007) such as the digital divide, language, power, and non-digitisation still remain important.

Digital divide

Cell phones are covering the world and the prices of digital technologies are falling systematically. However, for the inhabitants of poor countries and rural areas, communicational divide is still important. Three billion people live in rural areas worldwide and more than one billion are not walking out of poverty (Collier 2007).

Language barrier

Although the existence of a language standard, English, for knowledge sharing has many positive aspects, for those who do not master that particular language, it constitutes a cognitive barrier which is difficult to overcome. Over 50% of academic articles are written in English, and those articles written in languages other than English, or without abstracts in English, are hard to find on the Internet and, in most cases, are unsearchable (OpenDOAR 2011). The implication of the predominance of one single language is that American and European science is much more visible than the Asian and African scientific contribution.[17]

Power

Power (particularly political power) influences the channels and spaces where knowledge flows, the knowledge contents and architectures, the topics around which knowledge is built or not, and the norms that regulate access to knowledge. In those countries lacking democratic systems, government censorship prevents people from knowing the existence of divergent ideas, from accessing them, and from exchanging their ideas with others. Although democracy is expanding throughout the continents, almost two billion people (China and many African countries) still live under dictatorial systems.

Non-digitisation

Libraries and museums are analogous to natural resource commons. Access to them is limited to people living close enough to physically visit the museum or library, or to get books mailed to them. Most twentieth-century literature, academic and non-academic, and an important part of the artistic heritage of ancient civilizations, are stored in libraries and museums in developed countries, such as the American Library of the Congress, and the Smithsonian Museum. In its traditional form, that wealth of knowledge is unreachable to most of the world's population.[18]

In addition to these four main barriers, other factors also operate which limit access to the knowledge commons. These additional factors are scarcity, fragmentation and structural complexity:

(1) Scarcity: problems with strong constituencies, such as corporations and the aging populations of developed countries, receive much more attention than problems that affect economically weak or politically marginalized populations of less developed countries.
(2) Fragmentation: ecologists have found that the fragmentation of knowledge limits their ability to address problems of contamination in international ecosystems, and the same can be said about many development and poverty-overcome challenges.
(3) Complexity: Gapminder.org, using graphical tools, has shown that information stored in databases under numerical tables can become much more understandable and useful if their structure is modified. However, most information about

systemic problems is still in the abstract form of numerical tables, which are hard to manipulate by people if they are not statisticians.

The demand side of the knowledge commons

There is a lot of experience available to work on the supply side of knowledge sharing. The first generation of knowledge management, during the 1990s, focused on taking advantage of digital technologies and increased the assets of knowledge stored in databases. In addition, the open access movement is advancing significantly, expanding geometrically the wealth of knowledge accessible with almost zero financial cost. However, the demand side of the equation has not received the same level of attention.[19,20,21,22]

The demand side of the knowledge commons has to do with the awareness of the need and importance of external knowledge, knowledge about the existence of knowledge, the capacity to assimilate and contextualize external knowledge, and the conditions to apply new knowledge to develop innovative solutions. These four elements work as a chain. If a single link is not present, the demand will not be fully realized. For example: if a group of people who are addressing a problem are not aware of the need of enriching their knowledge, they will not look for external knowledge and, despite their real needs, no demand for external knowledge will emerge at all. If the group is aware of the need for external knowledge, but nobody is able to find or absorb the pieces of knowledge the group needs, the process will get stuck and the initial demand will quickly die out. If the group can absorb and contextualize external knowledge, but has not the conditions to apply it adequately, the demand will, in most cases, become unstable and gradually shrink.[23]

Awareness

Awareness of the need for external knowledge depends on the way in which reality is conceptualized and on epistemic beliefs. For those people who interpret local problems as the exclusive result of local factors, understanding systemic conditions is not relevant, and information and knowledge about the macro-context becomes irrelevant. Those who see no value in the knowledge that is being currently generated will not search or try to understand these different ways of understanding. The particular way in which we conceptualize reality becomes a kind of filter for looking for external knowledge, defining which type of external knowledge we value as being relevant to be incorporated.[24] Beyond our own awareness, we tend to eliminate entire fields of knowledge because we believe that they are not relevant or trustworthy.[25]

Knowledge about knowledge

In less developed countries, the wheel is reinvented every day. It is not always bad to reinvent the wheel; many local problems require fresh approaches in order to be solved adequately under the particularities of the local conditions but, more often than not, reinventing the wheel is a waste of time and resources. For example, searching in Google scholar for 'articles only' (11 July 2011) about 'manglar' (which means 'mangrove' in Spanish), I found 9160 results (in Spanish), and when searching for academic articles about 'mangrove' I found 193,000 articles (in English). These figures mean that, on the Internet, 21 academic articles exist about 'mangrove' which are written in English, for each article written in Spanish. If I were in Peru doing a research about mangroves without knowing the existence of those 193,000 articles that have already been written about the same subject that I was researching, it would be very likely that my study could not incorporate or, at best, would repeat the discoveries already made by someone else a few decades ago in Bangladesh or in Peru.[26]

Absorptive capacity

Absorptive capacity is another determinant of the demand for knowledge. Without absorptive capacity, external knowledge becomes meaningless and useless. After some initial intent, if a knowledge piece cannot be understood, the interest for searching that knowledge will vanish.[27] Cohen and Levinthal (1990) developed the concept of absorptive capacity for studying knowledge transfer among firms. These authors have defined absorptive capacity as 'the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends' (p. 128), and stress the importance of prior related knowledge to firms' absorptive capacity. The rationale behind their approach is the importance of innovation for competitiveness and the importance of external knowledge for innovation. This same rationale can be applied to professionals and communities in less developed countries: innovation is important for solving development problems and external knowledge is important for innovation. Studying how organisations assimilate new knowledge, Cohen and Levinthal (1990) have found that prior related knowledge is a precondition to identify the importance and to absorb new knowledge. It is important because prior related knowledge works as a reference to assimilate new knowledge. Indeed, they found that the complexity and sophistication of prior knowledge should be similar to those features of the new external knowledge. They found, for example, that firms with R&D experience in a specific field can take full advantage of external scientific knowledge and technologies in that particular field, and that firms without that same level of expertise may have their absorptive capacity affected, and may need support from people who could play the role of a cognitive interface to complex external knowledge.

The lack of knowledge in a given field also may prevent people and organisations from seeing the importance of acquiring related knowledge, and may lead to a kind of cognitive blindness in that field. As new knowledge is generated, and the organisations do not assimilate that knowledge in a timely manner, the cognitive distance increases and becomes a barrier to the assimilation of new knowledge, opening up a reinforcing cycle of cognitive distance and cognitive blindness. As time goes on, whole fields of knowledge may become inaccessible to these organisations for the lack of absorptive capacity.[28] Additionally, as new knowledge is generated, old knowledge becomes obsolete and loses economic value.[29]

A lack of absorptive capacity is not the only single barrier to assimilating external knowledge. Other factors may increase the difficulty of its absorption. For example: the level of abstraction, in the use of concepts or math, may require more sophisticated cognitive skills and complementary information to assimilate a piece of knowledge. Sometimes it is because the understanding of a piece of knowledge requires knowledge from other fields, but sometimes it is simply a question of language and structure. This issue of the level of abstraction is particularly important with respect to academic knowledge, an area where the knowledge commons is growing faster.[30]

Application conditions

The application of knowledge has different requirements from those needed to access knowledge. Digital and mobile technologies and the Internet are making location less important in order to access knowledge. However, this is not the case for applying new knowledge. Coming up with new solutions is not a question of isolated individuals, but of communities or clusters of people and firms. The research of Florida (2002) shows that geography matters. Creativeness is concentrated in a few hundreds of places worldwide, most of them metropolises in developed countries. Innovation requires combining pieces of knowledge from diverse fields and also diversity of conceptualizations. The gathering of these elements can only be reached through social interaction.

Evidence of the concentration of creativeness and the need for social interaction are abundant, but the reasons behind these phenomena are not so well understood. What combination of factors made possible the development of the software industry in Bangalore, the textile industry in Sri Lanka, and the film industry in Nigeria? Knowledge generates value when it is applied to solving problems, developing new knowledge, coming up with innovations, or spurring on new economic activities. Access to knowledge is not an end in itself; knowledge application is what improves the economy and quality of life.

If communities are important for the absorptive capacity, they are critical for applying new knowledge. The invention of the laboratory of Research and Development (R&D) gave birth to the second industrial revolution. The added value of the R&D lab made the processes of knowledge generation and use systematic.

Before the industrial revolution, there were creative minds. Leonard da Vinci was one of these minds. However, their creativeness could not become innovation because of the lack of knowledge (epistemic base) and partners. The expression of this barrier in less developed countries is that most innovators there either cannot connect to, or connect badly with, the knowledge communities that could enable and leverage their creative work.

Knowledge communities

To approach the demand side of the knowledge commons, I will explore three closely related concepts of knowledge communities: (a) thought collectives (Fleck 1979), (b) epistemic community (Haas 1992) and (c) communities of practice (Wenger 1989).[31] I also will look at a concept of knowledge network that goes beyond knowledge communities and connects individuals and communities with the society as a whole. My premise is that each one of these concepts has contributions that illuminate the factors which shape the demand and use of the knowledge commons.[32]

Thought collectives

While reconstructing the history of the evolution of medical thinking during the process of identifying the bacterium Treponema Pallidum as the cause of syphilis, Ludwik Fleck (1979) came up with the idea that scientific discovery happens inside social groups, and that the group has the power to influence the evolution of the thinking of its individual members. As a condition for understanding that process, Fleck put forward the notion of the social nature of knowledge, stating that cognition is 'not an individual process of any theoretical "particular [individual] consciousness." Rather it is the result of a social activity, since the existing stock of knowledge exceeds the range available to any one individual' (p. 38). He named these groups 'thought collectives'.

For Fleck, thought collectives were 'a community of persons mutually exchanging ideas or maintaining intellectual interaction . . . [that] provides the special "carrier" for the historical development of any field of thought, as well as for the given stock of knowledge and level of culture' (p. 39). The main thesis of Fleck is that thought collectives shape the way individual members interact with any stock or piece of knowledge. In their reasoning, all individuals are members of thought collectives and their interaction with external knowledge, such as the knowledge of the knowledge commons, is shaped by the epistemic beliefs of their thought collectives. [33] For Fleck, the absorptive capacity of individuals depends on the thought collective they belong to.

Each thought collective has its own thought style. The thought style refers to a set of epistemic preferences and beliefs, both explicit and tacit, shared by the members of the thought collective, a set of 'common features in the problems of interest to a thought collective, by the judgment which the thought collective considers evident, and by the methods which it applies as a means of cognition' (as cited in Sady 2001, para. 7). According to his understanding, the thought collective constitutes the social cognitive near-context or environment of any individual thinking or discovery, functioning as a kind of scaffold to support the inquiry process of the members of the collective, but also working as an invisible filter and frontier for acceptable thoughts. Any idea or fact that is beyond those frontiers is rejected, not noticed or modified by the thought collective. Despite the important role of epistemic beliefs in filtering possible thoughts, the members of the thought collective, frequently, do not recognize most of the epistemic beliefs that shape their inquiry.

Communities of practice

The concept of 'community of practice', coined by Jean Lave and Etienne Wenger (Wenger 2006), refers to 'groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly' (p. 1). For any group of people to become a community of practice (CoP) three features are necessary: (a) domain: 'a shared competence that distinguishes members from other people' (p. 1), (b) community: a set of 'relationships that enable them to learn from each other' (p. 1), and (c) practice: 'a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems' (p. 2).

Communities of practice are based on the idea that cognition is situated and distributed; that for learning and for making sense of external knowledge, people need to collectively contextualize the information they receive. Brown *et al.* (1989) supported this approach by suggesting that cognition is not an isolated process of an individual, but a distributed process. 'Communities of practice enable practitioners to take collective responsibility for managing the knowledge they need, recognizing that, given the proper structure, they are in the best position to do this' (Wenger 2006, p. 3). Communities of practice are social mechanisms to build and share contextualized knowledge.

Epistemic communities

Haas (1992, p. 3) defined epistemic communities as 'a network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area'. Epistemic communities were conceptualized by Haas as an institutional actor inside the institutional framework of international relations, acting in the intersection between research and action, such as policy-making and advocacy.

Because of the complexity and relevance of the problems in the international arena, the concurrence of experts as part of a single knowledge community was seen as a way of raising the cognitive level of the institutions responsible of addressing those problems. Epistemic communities have emerged as an answer to the demand of specialized knowledge for the increasing complexity of the problems of the international arena.[34,35]

According to Haas, members of epistemic communities share four attributes: (1) a set of principles or value-based rationale that govern the community functioning, (2) a set of beliefs about the interpretative or causal framework, (3) a notion of validity or an epistemology for knowing, and (4) a set of practices and common policies for working together on concrete problems. These four principles together generate the conditions for a shared effort of creating reliable knowledge for addressing relevant problems. 'The causal logic of epistemic policy coordination is simple. The major dynamics are uncertainty, interpretation and institutionalization' (1992, p. 3).[36]

The epistemic communities, related to international issues, congregate scientists and professionals with recognised expertise. Collectively, they work as an interface between the needs of international policymakers and existing knowledge and information, generating knowledge ground for decision-making. Haas sees the emergence of epistemic communities as an expression of the expanding role of expert knowledge and highly qualified professionals in problem-solving and policy-making.[37]

Applying the concept of 'thought collectives' of Fleck (1979) and his understanding of the social nature of knowledge acquisition and generation to the concept of knowledge communities, we can conclude that the absorption and processing of knowledge is not a work of individuals but a collective effort of knowledge communities. The implication of this assertion is that the agency in knowledge absorption and processing should not be seen as a role of individuals, but as a collective role of knowledge communities. Although individuals interact with the knowledge stored in databases or embedded in academic articles, or any other knowledge artefact, individuals should not be considered as isolated entities, disconnected from the knowledge communities to which they belong. As Fleck explained, the work of developing knowledge is beyond the scope of individuals. Individuals make their contributions by building upon the epistemic cultures and knowledge assets of the knowledge communities they are part of.

The research of Joel Mokyr (2002b) on the role of the social movement known as the British Industrial Enlightenment in supporting the Industrial Revolution exemplifies the collective and collaborative nature of the work of those innovators who drove the development of industrial machinery and institutions. Although Mokyr does not use the concept of knowledge community, he emphasizes the social nature of the work of those innovative individuals. Indeed, he attributes to the Industrial Enlightenment a crucial role for explaining why the Industrial Revolution happened in England in the eighteenth century. According to Mokyr, a complex intellectual network of around 200,000 people supported the initiatives of innovators in England during the period of the industrial revolution.

Conclusions

The history of knowledge creation has shown that since the Enlightenment, knowledge has been generated at a very stable pace, generating a growing amount of knowledge each year. Currently, over 1.5 million academic articles are produced annually. It is not only a question of quantity, but also of the tightness of knowledge. A set of procedures for evaluating knowledge trustfulness has become commonly accepted in the academic community, enabling cross-cultural knowledge sharing, expanding the wealth of the knowledge commons, and enriching the universal knowledge pool.[38]

Digital and communication technologies are bringing down the costs of knowledge reproduction and sharing, reaching almost zero, and the spread of computers and mobile devices in most countries is reducing the impact of the technological or digital divide. However, rural communities are still out of these processes.

The open access movement in growing faster than the production of academic articles, suggesting that in a couple of decades the impact of intellectual property rights as a barrier to knowledge will decrease qualitatively. The growing use of blogs and podcasts about scientific subjects is also amplifying access to front-line and high quality scientific knowledge.

Despite the improvement of mechanical translation, language remains an important barrier to knowledge access, particularly for those who do not speak English. The existence of a standard language for scientific knowledge makes mastering many different languages in order to tap into the universal knowledge pool unnecessary. However, multilingual versions of academic articles, additional to a standard language, like English, would contribute towards expanding access to the knowledge commons in less developed countries.

Although there are still barriers, the situation of access to knowledge is improving. It is on the demand side of the knowledge sharing equation where the barriers are challenging. Limitations in the absorptive capacity, and social isolation, are the two main factors that conspire against people in less developed countries taking advantage of the universal pool of knowledge. These two areas should receive attention if we want to democratize worldwide the impact of the growing wealth of knowledge.

I am aware that this article is an initial exploration of the knowledge commons and opens up more questions than answers. The conditions for knowledge absorption and use by people in less developed countries are still blurred, and the work for paving the way towards a globally fair access to the knowledge commons in the twenty-first century is in its initial phases.

Notes

1. An initial version of the article was presented in 2011 as an essay in the ELC doctorate program of Fielding Graduate University
2. Although it is very frequent to understand knowledge and information as different levels of complexity, I will assume that explicit knowledge, when it is outside the human brain, is expressed through information. So, the idea is that information can have different levels of complexity. It may express data or sets of data, and also more complex subjects such as knowledge and ideas. The conceptualisation behind this definition is that tacit knowledge expresses itself through action, as an operational skill, and explicit knowledge, knowledge that was codified, is expressed through information.
3. Simon Kuznets, originally, used the term 'tested knowledge'. Mokyr coined the term 'useful knowledge', referring to the same concept of tested knowledge, developed by Kuznets.
4. I am not suggesting here that all types of knowledge or epistemologies are equivalent. It is impossible to understand modernity without the development of the methods for submitting hypotheses to empirical tests, and for evaluating logical consistency, and the social institutions of knowledge creation such as journals, peer review, academic research, and scientific societies. I am saying that for the economic and social usefulness of knowledge, features of knowledge as an object have more relevance than its epistemology.
5. Mokyr defines prescriptive knowledge as the set of techniques related exclusively to manipulating nature. However, I am expanding the concept of prescriptive knowledge to include the manipulation of social institutions. The reason behind this conceptual expansion is that, for less developed countries that are far from the edge of scientific and technological advancements, social technologies are critical areas of innovation. Social technologies are required to assimilate the new (physical) technologies that are being created in developed countries. To work with social technologies, it is necessary to have a concept of prescriptive knowledge that includes the manipulation of social institutions.
6. Analysing the challenges of ecosystem conservation, Hammond *et al*. (2008) have concluded that the fragmentation of knowledge undermines ecologists' efforts, and explains an important

part of the failures of their conservational efforts. The knowledge that is accessible to some ecological groups is incomplete and fragmented, and this limitation conspires against the effectiveness of their efforts.

7. My experience of working with communities in the highlands of Peru confirms the importance of general, mostly external, knowledge to grasp the systemic nature of the problems they were facing.
8. Reading and writing still remained a privilege of a small social segment for over five thousand years. It was the expansion of public education (an admirable social technology), in the nineteenth century, that made reading and writing a general human attribute, including millions and billions of people into the formerly exclusive club of readers and writers.
9. In communities of practice (Wenger *et al*. 2002), most of the knowledge deployed by the community of practice is embedded in the brains of their members.
10. Thinking of the conditions of the global South, this set of criteria may deserve further analysis. For example: are they sufficient, or are some critical aspects of the knowledge commons being missed? Under which conditions, are these criteria adequate? Which criteria should receive priority, in which situation? Which actors could become, unintentionally, excluded from having access to the knowledge commons by this set of criteria?
11. Another way to estimate the increase in prescriptive knowledge is the improvement in total factor productivity (TFP). However, the total factor productivity, TFP, measures the impact of innovation in the productivity of an economy, not only the generation of new technologies.

    As Mokyr (2002a) has explained, non-academic knowledge plays an important role in supporting economic activities and innovation. One part of this knowledge is tacit or barely externalized in the form of lessons learned, dispersed and invisible inside people's minds. Another part of this knowledge may be documented in private documents of companies and institutions, which are not so accessible to external people.
12. In 1907, there were roughly 800,000 academic articles (accumulated from 1650 to that date), and in 2008 this number had increased to roughly 50,000,000 (Jinha 2010b). The growth of academic articles in 1907 was approximately 45,000 (800,000*5.6%), and in 2008, it was 1.6 million (50,000,000*3.2%). Although, these rough estimations may have errors of 20% or 30%, they do not change the magnitude of the figures.
13. The importance of social technologies is hard to overestimate. The second industrial revolution would not be possible without social technologies such as the research lab, the industrial factory and the production line.
14. In an early phase of the movement, the mathematician Andrew Michael Odlysko (1994) envisioned the emergence of online, through Internet, alternative ways of diffusing academic works. Odlysko imagined a future when online publishing of academic articles has become mainstream, displacing old-fashioned paper printing. Although Internet publishing evolved differently from the vision of Odlysko, his idea of open access has become more and more important.
15. The metadata research of Hajjem *et al.* (2005) was comprehensive, covering 1,307,038 articles for the time-span of 12 years: 1992 to 2003, exploring the citation impact over 10 disciplines such as biology, health, education, psychology, economics, sociology, business, administration, law and sociology.
16. The findings of Florida do not mean that people living in less developed countries lack creativity. Staying alive, free, safe and healthy in some countries, requires a huge amount of creativeness. However, the economic value generated by that creativeness is not the same as in developed countries.
17. Most of the existing metadata refers to academic articles that are published in English, or with an abstract in English. Particularly underestimated in current metadata are publications from Asia. The annual growth rate of academic journals on science and engineering in China can be estimated between 12% and 16% (NSB 2010) but its representation in English written articles is still invisible using current searching tools.

    According to OpenDOAR (2011) in the Open Access segments of academic articles, 54% of all articles are written in English, and only six other languages have more than 2.0% of participation in the academic global pie. They are Spanish, 7.2%, German, 6.4%, Japanese, 4.9%, French, 4.3%, Portuguese, 3.6%, and Chinese, 2.6%. All together, these six languages total 29% of open access academic production. So, English and the following six languages total 83% of the open access academic articles worldwide, and all the other languages account for only 17%. In open access academic literature, power law is the pattern of language concentration.

Considering that the open access movement is an emergent phenomenon that concentrates mostly on open-minded and innovative researchers, it is likely that the state of language distributions in traditional academic literature is more concentrated than these figures of OpenDOAR. Indeed, with respect to academic articles in general, not only open access articles, the concentration in English is higher than in the open access movement. Clarke *et al*. (2007) have found that in the subject of health 96.5% of the academic literature was in English and only 3.5% in other idioms, with German being the second one. Larsen *et al*. (2010) concludes: 'western science were over-represented; whereas small countries, non-western countries, and journals published in non-Roman scripts were under-represented' (p. 596). Although, the coverage of the Thomson ISI Index may include articles in other languages, it covers exclusively those articles whose abstract is in English. Because English is so dominant in academic literature, those who do not master English and its use in academic literature are excluded from the global flow of scientific knowledge.

18. Although knowledge is non-rival, physical artefacts containing knowledge, such as books, tapes and CDs, are rival. Museums and libraries are full of these types of artefacts.
19. The Institutional Analysis and Development (IAD) framework of Hess and Ostrom (2007) for the knowledge commons approaches is an adaptation of the IAD framework developed by Ostrom (2003) with the purpose creating governance and management systems effective for avoiding the depletion of a natural resource commons. It approaches, predominantly, the supply side of the knowledge commons equation. The open access movement is successfully addressing the access barriers that come from the supply side such as quality, preservation, costs, and metadata.
20. Donald Waters (2007) raised the concern about the low level of endurance of digital sources of scholarly articles. Reviewing literature in the field, he has found that the percentage of inactive Internet references two years after citation was 23%, and seven years after citation, the percentage of inactive ones was over 50%. These findings evidence a real problem of instability of digital sources on the Internet. However, Clay Shirky (2008) has found that, once a document is uploaded on the Internet, it is almost impossible to eliminate all its copies.
21. The destruction of the Library of Alexandria by Julius Ceasar in 48 BC and the fall of Constantinople by the Ottomans in 1453 have meant the definitive destruction of single copies of important Greek cultural heritage. At those times, to make copies were quite expensive and to protect them from the obscurantism was a real challenge. The increase in the number of copies of documents, enabled by movable type printing and now by digital technologies, has become a kind of insurance against knowledge destruction.
22. Demand for the knowledge commons is quite different from the natural resource commons. For the natural resources commons, the primary purpose of management is the preservation of the resource system, via a controlled use. In the supply-demand equation of natural resources, the protection of the supply side of the equation commands management. The leading objective, when managing natural resources commons, such as fish, water, and timber, is to guarantee the continuity of the supply over time, it is the sustainability of the resource pools for current and future generations.

Who can be granted access to a natural resources commons? For the rivalrous condition of natural resources, there are a limited number of users who can appropriate the resource units. That number is limited by the capacity of nature to restore the original conditions of the resource pool. Technology may influence the number of potential users that can appropriate resource units, but beyond a threshold, nature cannot restore the resource pool. So, before the system reaches that threshold, the extraction of resource units has to be reduced. Indeed, an important policy is the definition, identification and quantification of the quantity of resource units that users can extract from of a natural resource pool.

For digital knowledge commons, the issues are quite different. Knowledge is a non-rivalrous commodity so there is no intrinsic limit to the number of ideas that can be extracted from a knowledge pool, or for the number of potential users of those ideas. The access and use of the knowledge stored in digital artefacts does not generate erosion, and the risk of the total depletion of artefacts in the knowledge pool on the Internet is quite low. As the Internet has already proved, as more copies are made of a digital document, the greater the likelihood becomes of its preservation.

The limit for accessing a digital knowledge commons is given by the technical features of the facilities, not by the features of the resource pool in itself. Although a digital knowledge pool may suffer from free-riding, from people who want to appropriate or give unfair use to other people's creativity, in most cases that opportunistic behaviour does not exclude others from using the same artefact or idea.

These are important differences of the knowledge commons from natural resources commons: non-rivalrous, continuing growth, unlikely to be depleted, decreasing access cost, and expanding outreach of access facilities. As technology evolves, the number of people who can access a knowledge reservoir will become higher and higher. In addition to this trend, the access costs to the facilities, artefacts and ideas are decreasing every day. Assuming that knowledge will keep on growing with no foreseeable limit, and that the open access movement is going to succeed, the supply side of the (digital) knowledge commons equation has a great future.

23. Motivation is a precondition for engaging in any process of knowledge building. The sources of motivation to engage in knowledge building may be diverse. Awareness about the need of external knowledge is one of them. Foreseeable positive outcomes, self-confidence in local capacities, and possible alliances to expand access to knowledge and improve local capacities are other sources of motivation.
24. For those cultures and set of religious beliefs that do not feel adequately represented by modern knowledge, the situation is particularly difficult. They feel that most external knowledge is framed in a way that threatens their cultural heritage. However, they also feel that the aspirations of their new generations cannot be fulfilled exclusively relying in their traditional knowledge. Finding positive synergies between these diverse ways of conceptualising reality and knowledge is a challenge for anyone interested in protecting and developing the cultural heritage of humanity.
25. In Latin America, I could observe important segments of professionals who have strong ideological beliefs (about political, social and economic subjects) that induce them to underestimate the relevance of becoming well informed about new interpretations and conceptual approaches that are being generated in those fields. When they feel the need to become informed, they are not inclined to read the original authors, preferring to read interpretations that were developed by authors with whom they share ideological inclinations.
26. I treated the issue of language in the supply side of knowledge sharing. However, it also greatly influences the demand side. People who do not feel comfortable reading in English will not look for information in that language. Socially or cognitively isolated people will not look for information they need only because they do not know of its existence. Indeed cognitive isolation may be a more important variable preventing knowledge access than the digital and language divides. I will come back to this topic below.
27. Firms have been studying absorptive capacity with the purpose of increasing their innovative capacity. Firms have found that absorptive capacity is key for innovation and that innovation is key for competitiveness. This same causal chain is valid for professionals and communities, both in developed and in less developed countries. As Mokyr (2002b) has explained in detail, if the epistemic base for innovation is too narrow the innovative capacity becomes undermined. The absorptive capacity is necessary to enhance the epistemic base of innovative initiatives.
28. The improvement of local absorptive capacity is critical for development, but falls beyond the scope of this article.
29. In situations of complexity and uncertainty, it is better to have more than one person playing the role of an interface to capture the diverse dimensions of the complexity of external knowledge.
30. The terminology and the structure of academic knowledge make it more complex for those who are not familiar with that type of presentation. This is an area where interfaces may play an important role. Gapminder.org has shown how the graphical presentation of data can make relevant patterns much easier to see and analyse than a simple matrix of numbers.
31. There are other types of knowledge communities. However, these three ones are enough to illustrate the issues related to the social nature of knowledge generation.
32. When analysing the demand for knowledge, it is possible to look at individuals, communities and the whole society and their access, assimilation and application of knowledge. In this paper I gave priority to the perspective of communities. The premise for this decision is that currently only communities can hold the knowledge required to develop any theoretical or technical field.

33. Outliers, people endowed with extraordinary intellects and deep feeling of independence can get beyond their cognitive context and generate breakthroughs that change the way a field is understood. Thales, using theorems, strongly influenced the future of mathematics; Galileo, using the scientific method, transformed the future of science; Newton started the systematic development of in physics; Darwin re-conceptualized evolution, etc.
34. Originally, I felt tempted to generalise the concept of epistemic communities toward the concept of thought collective of Fleck. But, considering that epistemic communities already have a traditional definition, developed by Haas, I concluded that the use of the same term for two notions could generate confusion. Then, I decided to use the term 'knowledge community' as a generic notion of any group of people whose main purpose is to work together to generate knowledge, and do some precisions on how this term should be understood. In this sense, thought collectives, epistemic communities and communities of practice are particular forms of knowledge communities.
35. Originally, John Ruggie (1975) started using the concept of epistemic community for international issues. Ruggie conceptualised epistemic communities based on the concept of 'episteme' of Michel Foucault as a particular way of understanding reality, and defined epistemic communities as 'interrelated roles which grow up around an episteme' (as cited by Haas 1992, p. 27). Operationally, episteme can be understood as the set of beliefs about reality and knowledge that underlies a particular way of knowing, a particular way of generating reliable knowledge. Building upon Ruggie's ideas, Haas (1992) developed the concept of epistemic communities to apply to groups of experts in international issues such as financial stability, wars, conflicts, nuclear threats and ecological problems.
36. Comparing the patterns of the research work of physicists in high-energy physics and biologists in molecular biology, Knorr-Cetina (1999) came up with the notion of epistemic cultures. She defined epistemic cultures as 'those amalgams of arrangements and mechanisms – bonded through affinity, necessity and historical coincidence – which, in a given field, make up how we know what we know' (as cited by Mork *et al*. 2008, p. 15). The set of epistemic beliefs, methods, techniques, equipment and tools should be considered as part of the mechanisms for knowing of those communities of scientists.

    Although Knorr-Cetina developed the concept of epistemic culture specifically for scientific-research communities, carried out under laboratory conditions, her notion can be expanded to include the work of knowledge generation carried out by experts in any knowledge community. Combining the Knorr-Cetina concept of epistemic culture, the Ruggie and Haas notion of epistemic communities, we can infer that epistemic communities share common epistemic cultures, and those epistemic cultures shape their particular way of acquiring and generating knowledge.
37. The Delphi Method also draws on expert knowledge to address complex subjects, but takes expert knowledge as an input inside another methodological approach.
38. This universal knowledge pool is not free from controversy. Many social groups do not feel that their conceptions and epistemic beliefs are represented by the current standard procedures for generating trustworthy knowledge. Most indigenous communities do not agree with the predominant procedures of scientists and academics, and feel their wealth of knowledge to be misinterpreted and undervalued. Some schools of thought, stressing the social character of knowledge construction, call for a more open dialogue among people with diverse epistemic beliefs. Pseudo-science is also abundant in the media and Internet, and shows no signal that it will be less ubiquitous in the coming decades.

Notes on contributor

Sebastiao Mendonça Ferreira (1949) is a Brazilian consultant, author and researcher, settled in Peru. His first passion was physics, but in the early 1970s he turned his professional life towards social subjects. He has facilitated over 300 processes of social learning in the field of strategy design, local planning, micro-finance and innovation. He is author and co-author of six books in these fields. Between 2006 and 2011 he has been at Massachusetts Institute of Technology as visiting scholar. Currently, he is an associated researcher at the Community Innovators Lab of MIT and independent consultant. Addressing the cognitive divide is his personal priority.

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