Evolution and Future of the Knowledge Commons: Emerging Opportunities and Challenges for Less Developed Societies

Sebastiao Darlan Mendonça Ferreira

Abstract

This article addresses the emerging field of the knowledge commons in relation with the challenges of international development. It reviews the history of academic knowledge 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 mapping the conditions for taking advantage of this resource. Which are the barriers to access and use common pool of knowledge that is being generated currently? 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 to identify the barriers that are preventing people from less developed countries taking full advantage of this fast growing resource.

Introduction

After 12 thousand years of quasi-stagnation and discontinuity, the knowledge pool of humanity started growing at 3.2% to 5.6% annually (Larsen & Ins, 2010), a quite stable pace, for more than three centuries. From 1650 to the current days, 50 million of academic articles have accumulated and more than 1.5 million are being written each year (Jinha, 2010a). Simultaneously with the growing wealth of knowledge, it is the expanding social outreach of digital technologies and mobile devises that facilitate the access to the knowledge pool. However, new challenges are emerging.

During the last two decades two contradictory trends have made evident. From the enclosure side, governments and private companies of developed countries are increasing the enforcement power of Intellectual Property Rights, 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 article that can be accessed through Internet without 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 cognitive awareness (or blindness), absorptive capacity and conditions for application, have not received the same level of attention. This is particularly true for less developed countries.

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 the people from less developed countries, and deserves a better understanding. The social divide respect to the knowledge commons is moving toward the barriers for assimilating and using productively the growing wealth of knowledge.

To approach the relation between knowledge, technological innovation and economic development, the article relies on the historical work and on the concepts of knowledge developed by Joel Mokyr (2002a; 2002b; 2005) and Simon Kuznets (1955). To analyze 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), and 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, analyzing the requirements for absorbing and applying knowledge, and taps on the literature about three types of knowledge communities, such as thought collectives (Fleck, 1979; Sady, 2001), epistemic communities (Hass, 1992) and communities of practice (Wenger, 2006; Wenger, McDermott & Snyder, 2002). The intention of visiting the diverse types of knowledge communities is to explore the social fabric that may contribute to reducing the disadvantage of people of 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 I would like to make explicit from the outset:

(a) 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 (Beinhocker, 2007; Mokyr, 2002a; 2002b; 2005).

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

(c) In economic terms, knowledge is a very particular recourse: it is intangible, and non-rivalrous, and has no inherent limit for its expansion and application. Knowledge requires be treated differently from tangible and rivalrous resources such as human (labor), financial and natural resources.

(d) 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 21st century.

(e) The physical access to knowledge artifacts is a condition, but it is not enough to make sense of its meaning and to take full advantage of the contents embedded in knowledge artifacts. Effective access to knowledge requires physical access and

cognitive competence or absorptive capacity.

Conceptualization of Knowledge

There are many ways of conceptualizing 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 here 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 about 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 artifacts, materials, energy and living beings" (Mokyr, 2002, 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 benefit human beings.[i] This approach does not focus on the origin of knowledge, how it is generated, but on the application of existing knowledge to do something practical.[ii]

The original concept of Mokyr refers exclusively to knowledge about nature. It is consistent with his concept of technology that includes exclusively physical technologies and do not consider social technologies. In this paper, I am expanding 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 for addressing development, social arrangements can be so important or even more important than physical artifacts.

Useful knowledge does not refer to truth or false, or 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 o 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, or traditional beliefs.[iii]

According to Mokyr (2002b), useful knowledge has two subcategories: propositional knowledge and prescriptive knowledge. Propositional knowledge, or Ω (omega) knowledge, is the type of knowledge that catalogs natural and social phenomena, it refers to 'know what' about nature and society. It explains what things are and how they work. Propositional or Ω knowledge is important for making sense of the world. Propositional knowledge includes scientific knowledge but also include 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 its verifiability; it depends on the confidence that people have on the particular rhetoric (research procedures, concept construction, logical deduction, theorem demonstration, reflection procedures, analogies, etc.) that support the knowledge claim. There was a time when divine revelation and the opinion of Aristotle were enough reason to believe in the trustfulness of a statement. But, after Galileo and the Invisible College, empirical verification, following a

replicable set of procedures, and processes of peer (critical) review became a requirement for the academic community considers a knowledge claim as reliable.

Prescriptive knowledge, or λ (lambda) 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 doing a drug, instructions for building a bridge or a manual containing norms for managing a natural resource commons.[iv]

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 under the form of information. The tacit dimension of knowledge refers to that knowledge that cannot be expressed through symbols, but becomes visible only through actions. It is assumed that knowledge cannot be completely codified. I am also assuming that the use, by a human agent, of any set of codified descriptions or instructions require tacit components embedded in the mind of the agent.

According to Mokyr (2002a), "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" (p. 4). In this definition, Mokyr includes knowledge under the form of information stored in storage devices, such as databases, but does not refer explicitly to the knowledge that is tacit, embedded in social behaviors, 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 only can be expressed through action. All communities have huge stock of knowledge, such as lessons learned, practical skills and experience, that is stored under the form of behavior 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 technique requires a set of propositional knowledge that, in 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, 2002) 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 has broadened the technique can evolve much further. For example: The first steam machine was invented based on a limited understanding of thermodynamics. It was developed relying on practical 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, developing the laws of thermodynamics. The invention of internal combustion engine, had to wait for more than one century, until those theoretical breakthroughs of thermodynamics were available to engine engineers. Similarly, knowledge about microbiology (propositional knowledge) had a decisive impact in the development of medicine, an applied field of biology. If we look at the history of medicine, particularly related to infectious diseases, we find that it has to be

organized into two phases: before and after the development of microbiology.

Currently, the critical variable for less developed countries is not how broad is the epistemic base that supports innovation locally, but how broad is the epistemic base that local innovators can effectively access and assimilate. In less developed countries, innovators struggle with problems whose understanding is already part of the scientific stock of knowledge. The problem they face is that the access to and absorption of existing knowledge is limited to some social elites. For people with limited access to knowledge, the cognitive context is similar to that of decades ago, and some times, centuries or millennia ago, when that knowledge was not yet created. Despite that we all share the contemporary times, moving across countries and social sectors, it is possible to travel to the past, like in a cognitive time-machine.

Useful knowledge can be analyzed through two perspectives: nature of knowledge and context. As it was already explained, through the lens of its nature, useful knowledge can be classified into propositional and prescriptive. Through the lens of the context, it can be classified as general knowledge and local knowledge.

Useful Knowledge Structure: examples		
	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 2. Sum of interpretative beliefs broadly shared but not submitted to scientific scrutiny.	1. Sum of knowledge of individuals of a community. 2. Sum of non-scrutinized beliefs of individuals of a community, such as health principles, Cosmo vision, social hierarchy, understanding of local of economics, etc.
Nature of knowledge — Prescriptive	1. Nationally and globally available patented and public domain technologies and methodologies. 2. Nationally shared practical skills of people such as spoken language, reading skills, computer literacy, cellphone familiarity, and car driving.	1. Elements of general prescriptive knowledge mastered by members of a particular community such as artistic skills, language, and mechanisms of social interaction.

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 unorganized knowledge which cannot possibly be called scientific in 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 require combining local and general (external) knowledge. Indeed the quality of the external knowledge may affect decisively the effectiveness of innovative initiatives of communities.[v]

The systemic nature of local problems can only be fully captured through interpretations that make use of 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).[vi]

Conceptualizing the commons

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

Human societies have thousands of years of experience managing the challenges of the use of the commons. For example: The management of the lands of the Nile River valley constitutes a successful story of the use of a resource commons. The requirements to manage the annual redistribution of the land in the Nile's 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. Another case, of unsuccessful management of a commons, is the collapse of the Eastern Island (Isla de Pascua) in the southern Pacific. The almost total depletion of the ecological resources of the island (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 managing their 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 the use of the commons: (a) Garrett Hardin (1968), in his influential article on the tragedy of the commons, concluded on the need of some external agent to prevent overuse and free riding. (b) The prisoner's dilemma formalized by Albert Tucker, based on game theory, suggest that two isolated prisoners, applying non-cooperative strategies, harm each other when trying to protect themselves (Cunningham, 1986). (c) 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 collective interests over their individual interests. However, local agents can create these mechanisms of coercion and cohesion, and achieve control over the use of their commons.

Elinor Ostrom, 2009 Nobel Prize winner for her work on institutional arrangements required for sustainable management of the commons, has found that users of a common-pool resources avoid depletion, when they are self-organized to govern the use of the resource through an institutional arrangement capable of preventing and correcting overuse and free riding. Based on successful cases, Ostrom developed a framework to analyze the commons and define rules for a sustainable of the resources. Later on in this paper, I will present and discuss the analytical framework, developed by Charlotte Hess and Elinor Ostrom, for the knowledge commons.

The history of commons and the knowledge commons

The awareness of the importance of the commons exists from ancient times. Much before the Neolithic Revolution, human bands and tribes used to dispute the access to commons, as food sources, through local wars. The commons in those times were fishing and hunting areas, firewood sources, drinking water sources, quartz quarries (to make tools), among the most important. 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 of their access to sources of natural resource commons and also of their knowledge about the use of those (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 and storage devices, and under all types of property: (a) Part of these assets is hold privately by individuals, companies and institutions under the form of intellectual capital, and secrets, and another part is hold by the community. Patents and the knowledge imbedded in processes and in the machinery of a factory are examples of private knowledge. (b) Shared knowledge assets is the knowledge collectively hold by the members of communities or under public domain, theoretically accessible to everyone, such as basic sciences, math, and classical literature, demographic information, or the set of skills that is shared by social groups such as technical and aesthetic skills collectively cultivated and shared by a community of tool makers. Knowledge commons refers to this second type of knowledge assets.

Before the development of language, all knowledge had to be acquired exclusively through observation and imitation. The knowledge commons at that time was small, fragmented and 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 (Ω knowledge behind the λ knowledge) belonged exclusively to the individuals who carried out the actions and were not part of the knowledge commons. Indeed, almost no Ω knowledge was part of the knowledge commons. During those ancient times, there was almost no common pool of Ω knowledge, the epistemic base of techniques was extremely simple and narrow, and innovation was serendipitous. Moving from the early stone axes to the Clovis technology took over one million years to humanity. The development of language created the first mechanism to

communicate ideas (explicit forms of Ω and λ knowledge), and greatly contributed to the expansion of knowledge assets of the human groups of those times.

The development of writing, a second revolution in the evolution of language, after the development of oral language, strongly influenced which social segments could or could not share particular subsets of the knowledge commons. For example: the Sumer cuneiform script and the Egyptian hieroglyphs were functional to make written knowledge an exclusive privilege of the administrative elite, kings and priesthood. The Phoenician alphabet, 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 having writing as a vehicle for sharing knowledge among creative people.[vii]

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

During those millennia, the fate of the civilizations was also the fate of the knowledge commons. Each time a civilization were destroyed, an important part of the knowledge assets of humanity were lost. The Library of Alexandria was the first institution intentionally created with the purpose of gathering and protecting multi-civilization, in some way "universal," stock of the knowledge commons. The mission of the Library of Alexandria was the creation of the first universal knowledge pool. Copying documents and records of ships and gathering brilliant minds were the two core strategies of the Library of Alexandria to create the first reservoir of knowledge commons of 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 could fully realize its mission.

The printing revolution of Gutenberg was the fourth step. Thanks to the movable types, printing costs fell, expanding the social sectors with access to books and written texts. Although the methods for creating knowledge did not change much during the first century after Gutenberg, the number of knowledge artifacts, mainly books, increased massively reaching the middle classes for first time in history. After millennia of enclosure, literature, academic knowledge and Greek philosophy moved out of castles, monasteries and a few elite ateliers. Through printing, books became 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 types.

The Internet and digital technologies were, together, the fifth step. Through Internet, the mission of the Library of Alexandria got finally fulfilled, and the first reservoir of universal knowledge really emerged, making knowledge accessible at real time from almost anywhere. Thanks to these technologies, access to knowledge did a gigantic step, becoming
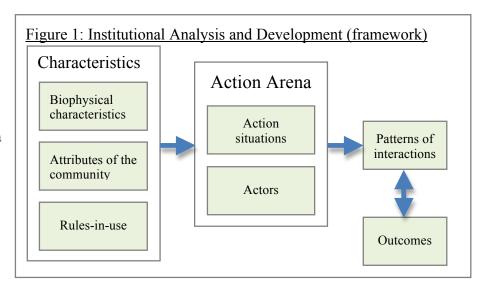
less dependent of geography. With Internet and mobile devices, spatial location started losing its critical role in limiting the access to knowledge. Through digital technologies, copying became almost priceless, multiplying the number of copies of knowledge artifacts in the Internet, the distributed universal reservoir.

Hess and Ostrom's Approach to the Knowledge Commons

Based on the work of Elinor Ostrom on sustainable ways of managing natural resource commons, Charlotte Hess and Elinor Ostrom (2007) have adapted and developed a model to analyze the knowledge commons. 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).

Resources characteristics: The resources characteristics 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, artifacts and ideas. Facilities are libraries and any other type of physical or digital reservoirs containing books, journals, databases and papers. Artifacts are physical or digital discrete objects or flow channels such as books, journals, papers, maps, videos, research notes and blogs. Artifacts contain ideas. Ideas are the artifacts' knowledge content such as concepts, mathematical formula, 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 artifacts 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 characterized as nonrivalrous. It is so because multiple copies of digital artifacts can be done almost costless and two or more people can concurrently read the same copy using different computers or mobile devices with Internet access. This is a fundamental distinction of physical objects such as water, trees and fishes, from digital knowledge artifacts such as articles in PDF, blogs, podcasts and eBooks.

Figure 1: Institutional Analysis and Development (framework)

Characteristics
- Biophysical characteristics
- Attributes of the community
- Rules-in-use

Action Arena
- Action situations
- Actors

Patterns of interactions

Outcomes

Because ideas are nonrivalrous goods, there is no inherent limit to the number of people that can concurrently apply the same set of 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 group as a whole. Although ideas are not rivalrous, access to ideas may become rivalrous. It can happen that the access flow is too intense, causing the collapse of the facilities, restricting the access to the artifacts where the ideas are embedded.

The 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 an irrigation system constitute the community of the system. Owners of fishing ships and of fishing equipment constitute the community of a fishery. These two types of communities have very well defined frontiers. There is no major difficulty to define who is and who is not a member. Communities of a knowledge commons have fuzzier frontiers.

Individual elements of knowledge communities are users, providers and policymakers. Users, in a knowledge community, are those who access to the knowledge artifacts and knowledge flow, and, in some way, process the ideas accessed. Providers are those who generate content, make content available, develop software for the knowledge system functioning, and contribute to preserving the stock of knowledge. Policymakers 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. (a) Who are users and non-users may be a question of voluntary affiliation or of the frequency of use, making difficult to define membership and establish the size of the community. (b) 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 artifact to the facility.[viii]

Hess and Ostrom (2010) 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" (p. 50). 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 at a daily base: 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 in abstract; they have to respond to the biophysical-technical characteristics of the knowledge system and of the community. When technology suffers a qualitative change, such as the emergence of the Internet and of digital

technologies, the rules defined in the old context do not fit to the new characteristics of the resource, and new rules have be designed to fit the new characteristics of the resource. For example: The Digital Millennium Copyright Act (DMCA, 1998), an adjustment of intellectual property rights to the Internet era, is an example of such an adjustment that 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 at a daily base. For the use of 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 policymakers that 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 systems, to uncover unintended effects of incentives is always challenging; 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 knowledge. Some examples of outcomes for the knowledge commons are the pace of knowledge generation for different fields and disciplines, the cost of access, the technical requirements of access, the quality of the searching metadata and the languages of the knowledge artifacts. Hess and Ostrom (2007) list some negative and positive outcomes that are currently taking place in the knowledge commons:

Negative outcomes	Positive outcomes
Proprietary scientific databases (enclosure)	Gold and Green Open Access of academic articles (disclosure)
Digital divide and information inequity	Global and multi-language access
Erosion of the knowledge stock, degradation	Standardized 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
Synthesis based on Hess and Ostrom (2009, p. 61, Table 3.1)	

Evaluative criteria are required to govern a knowledge commons. By applying the set of criteria, policymakers can evaluate the performance of the knowledge commons and adjust policies. Hess and Ostrom (2007) suggest a set of criteria that apply 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).[ix]

The Growth of the Knowledge assets

The invention of the methods for empirically testing hypotheses and submitting ideas to critical scrutiny, achieved in the seventeenth century, triggered 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. Currently, we live in this era of exponential growth of knowledge.

To estimate the growth of useful knowledge is a difficult task. Indeed, quantifying the stock of all types of useful knowledge hold 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 a proxy is the number of academic articles published by peer-reviewed journals. For prescriptive knowledge the proxy is the sum of patents granted.[x, xi]

In 1650, academic journals emerged in France (Le Journal des Sçavans) and England (Philosophical Transactions), and the movement of the Enlightenment spread out through most of Europe. Supported by new wealth of propositional knowledge, innovation became less serendipitous and triggered the Industrial Revolution. In a couple of centuries, the living standards of European middle classes surpassed the level of kings and queens from 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 each 13 years. In three centuries, academic knowledge increased over 200,000 times.

The pace of academic knowledge growth in recent times, measured in terms of number of academic articles, is a question of dispute. Depending on the sources of information and the methodology applied, the precise number may vary. The classical study of Derek de Solla Price (1965) counting cumulative number of abstracts of academic articles in chemistry, biology and physics, between 1900 and 1960, arrived to an annual pace of 4.7% and a doubling period of 15 years. Larsen and Ins (2010), applying the same methodology of Price, in a very comprehensive work, counting abstracts of academic articles from 1907 to 2007, arrived to 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 3% and 3.5%.

Independent of these discrepancies among sources and methods, the figures suggest that exponential grow of knowledge is slowing down gradually, changing from around 5.6% (between 1650 to 1950) to 3.2% (by the end of the 20th 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 & Ins, 2010). So, despite this slowing down process of exponential growth, the amount of knowledge produced each year is continually growing[xii].

Based on ISI and Ulrich's databases, Bjork, Roos and Lauri (2008) have found that, in 2006, approximately 1.350.000 articles were published by 23.750 academic journals. According to Larsen and Ins (2008), "In 1981 it was reported that there were about 43,000 scientific periodicals [registered] in the British Library Lending Division" (p. 594). 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 26,406 journal titles existing 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 all academic articles published from 1655 to 2008, he has estimated 50 million as the total number of academic articles published throughout these 343 years.

A possible explanation for the exponential slowing down of the growth rate of academic 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 literature review are also growing (Mabe & Amin, 2001; Mabe, 2003). An implication of the increasing complexity and need of cooperation is the growing importance of open access to academic articles for creating new knowledge and for coming up with 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 analyzing patents, it is necessary to be aware that they refer almost exclusively to physical technologies such as machinery, industrial processes, software and drugs. Most social technologies, such as management processes, hospital management systems, electoral systems, business models, universities, and pedagogies, cannot be fully patented.[xiii]

Differently from academic articles, whose exponential annual pace is slightly slowing down, patenting is exponentially accelerating in the last two decades, outpacing the academic knowledge. According to the World Intellectual Property Organization (WIPO, 2011), "between 1995 and 2007, [patent] filings grew by 5.2 percent a year, compared to 3.7 percent for the 1983-1990 period" (p. 8).

A 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, knowledge and technology intensive sectors have had an annual growth rate of 5.8% during the last 12 years (NSB, 2011). This fast

growth of knowledge and technology intensive sectors has happened despite that the global economy, in the same period, was growing only 3.7% a year (IMF, 2011). The emergence of China, India and other Asian countries as leading actors of 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 in the potential of value generation and competitiveness of entire nations in the global economy, 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 opposite trends: (a) Private companies and government of developed countries have done strong moves to increase the enforcement power of intellectual rights and patents worldwide, increasing the barriers and financial costs to access knowledge, and (b) an open access movement has emerged. I am going to review briefly 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 on the importance of the access to knowledge for innovation and development promotion. In two decades, the open access movement has started a dramatic change on the three-centuries-old landscape of the access to academic knowledge, increasing knowledge accessibility as never before.

Respect to academic articles, the open access movement took two main forms: Gold Open Access and Green Open Access. The Gold Open Access consists in making free of costs the academic articles published by Journals. It can be done from the publishing date of the journal or after a brief time, such as six months or one year. The Green Open Access consists of archiving the academic article in an open access repository. Once archived in those repositories, the articles are free for reading and for downloading. Both forms of open access have been growing since the 1900s.[xiv]

A possible explanation of the fast growth of Open Access movement is that authors have incentives for favoring the open access option. The citation likelihood of open access articles is superior to non-open access ones. Hajjem, Harnad, and Gingras (2005), working with reference meta data 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.[xv]

Similar results were found by other studies. Analyzing a cohort of 1,492 articles of the Proceedings of the National Academy of Sciences, and having done a careful work of eliminating confounders, Eysenbach (2006) have found that open access articles had on average of 5.9 citations, and that non-open access or self-archived articles had 4.4 citations,

meaning 34% advantage for open access articles. Through complementary analysis, Eysenbach also has found that open access publishing (Gold open access) is more effective than self-archiving (Green open access). Swan (2010) has reviewed 37 articles analyzing the advantages and disadvantages of open access for the likelihood of being cited, and confirmed the advantage of being open access.

Considering the twenty more 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 increase 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 through one year after their publication (Gold Open Access), and an additional of 11,3% were accessible in homepages e-print and repositories (Green Open Access). These figures combined means that, by end of the first decade of the twenty-first century, around 20% of 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 of 25.5%. By June 7, 2011, there were already 1,970 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 3.2%, open access journals are growing ten 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 five more years, a very likely scenario, open access journals will be the predominant form of academic literature.

The recent emergence of blogs and podcasts in physics, economics and diverse other fields is increasing the accessibility to cutting edge ideas. The main reason for the growth of blogs in the scientific community is their impact in interaction among scientist; it is the reduction of the time between the moment of conceiving and publishing new ideas and the moment of receiving intelligent feedbacks from peers. Blogs also have the power of identifying peers with similar interests, increasing the likelihood of positive synergy. Blogs are a new expression of open access to academic knowledge. Podcasts and online versions of newspapers are increasing free access to general information through 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) 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" (pp. 8-9). 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), analyzing 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 centers of developed countries. The findings of Florida are 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 geography, the economic application of that knowledge is highly centralized in a few dozens of metropolitan centers.[xvi]

Supply side barriers to knowledge

Although technological development and the open access movement and Internet are greatly contributing to reducing the financial costs and the need of permission to access to the knowledge commons, other barriers (Suber, 2007) such as digital divide, language, censorship, and non-digitization still remain important.

Digital divide. Cell phones are covering the world and the prices of digital technologies are falling systematically, however, for a meaningful percentage of inhabitants of poor countries and rural areas, the digital divide is still important. Three billion people live in rural areas worldwide and more than one billion are getting behind or simply not walking out of poverty (Collier, 2007).

Language barrier. Although the existence of a standard language, English, for knowledge sharing has many positive aspects, for those who do not master that particular language, it constitutes a cognitive barrier difficult to overcome. Over 50% of academic articles are written in English, and those articles written in other languages than English or without abstracts in English are hard to find in the Internet and, in most cases, 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. [xvii]

Censorship. Although democracy is expanding throughout the continents, almost two billion people still live under dictatorial regimes. In those areas of the world where democracy is not the political regime, such as China and many African countries, official censorship prevent people from knowing the existence of divergent ideas, from accessing to them, and from exchanging their ideas with others.

Non-digitization. Libraries and museums are analogous to natural resource commons. Access to them is limited to people living close enough to go physically to the museum or library, or to get books mailed. Most of the twenty-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. Under traditional form, that wealth of knowledge is unreachable to over 90% of the world population.

Additional to these four main barriers, other factors also operate limiting the access to the knowledge commons. These additional factors are scarcity, fragmentation and structural complexity. (a) Problems with strong constituencies, such as corporations and aging populations of developed countries, receive a much better attention than those problems that affect economically weak or politically marginalized population of less developed countries. (b) Ecologists have found that fragmentation of knowledge limits their ability to address problems of contamination in international ecosystems, and the same can be said about many of the poverty challenges. (c) 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 under the abstract form of numerical tables, hard to manipulate by other people than statisticians.

The demand side of the knowledge commons

There is great experience working on the supply-side of knowledge sharing. The first generation of knowledge management, during the 1990s, focused on taking advantage of digital technologies, increased the assets of knowledge stored in databases, and 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. [xviii, xix, xx, xxi]

The demand side of the knowledge commons has to do with the awareness of the need of external knowledge, the set of skills to find, select, absorb, and contextualize external knowledge, and the conditions to successfully apply the new assets of knowledge to concrete problem-solving situations. It is possible to group these elements into four categories:

(a) The awareness of the need and importance of external knowledge,
(b) Knowledge about existence of knowledge,
(c) The capacity to assimilate and contextualize external knowledge, and
(d) 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 fully realize. 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 of external knowledge will emerge at all. If the group is aware of the need of 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 die out shortly. 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 shrinking.

<u>Awareness</u>: The awareness of the need of external knowledge depends on the way reality is conceptualized and on the epistemic beliefs. For those who interpret local problems as exclusive result of local factors, understanding the systemic conditions is not relevant, and information and knowledge about the macro context becomes irrelevant. Those who see no value on the knowledge that is being generated currently will not search or try to understand these different ways of understanding. The particular way we conceptualize reality becomes a kind of filter for looking for external knowledge, defining which type of external knowledge we value as relevant of being incorporated.[xxii] Special attention should we give to the fact that, beyond our awareness, we tend to eliminate entire fields of knowledge because we are in love of our old beliefs or because we believe that external knowledge is not relevant or trustable.[xxiii]

<u>Knowledge about knowledge</u>: In less developed countries, the wheel is reinvented everyday. It is not always bad to reinvent the wheel, many local problems require fresh approaches to adequately get solved under the particularities of the local conditions, but frequently, wheel reinvention is a waste of time and resources. For example, searching in Google scholar for 'articles only' (July 11, 2011) about "manglar" (which means mangrove in Spanish), I found 9,160 results (in Spanish), and searching for academic articles about "mangrove" I found 193,000 articles (in English). These figures show that in Internet exist 21 academic articles about mangrove, written in English, for each article written in Spanish. If I were in Peru, doing a research on mangroves without knowing the existence of those 193,000 articles already written about the same subject I were researching, it would be very likely that my studies could not incorporate the discoveries already done by someone else, a few decades ago, in Bangladesh or in Peru.[xxiv]

<u>Absorptive capacity</u>: The 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.[xxv]

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 to 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 organizations 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. This is relevant because prior related knowledge works as reference to assimilate new knowledge. Indeed, Cohen and Levinthal found that the complexity and sophistication of prior knowledge should be similar of those features of the new external knowledge. They found, for example, that firms with R&D experience in a field can take full

advantage of external scientific knowledge and technologies in that field, and 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 cognitive interface to complex external knowledge.

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

Lack of absorptive capacity is not the only one barrier to assimilating external knowledge. Other factors may increase the difficulty of its absorption. For example: a high level of abstraction of external knowledge 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 knowing other fields, but some times it is a question of language and structure. This issue of level of abstraction is particularly important in respect to academic knowledge, the area where the knowledge commons is growing faster.[xxvii]

Application conditions: Application of knowledge has different requirements from accessing to knowledge. Digital and mobile technologies, and Internet are making location less important to knowledge access. However, it 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. Creativity is concentrated in a few hundred 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.

Evidences of the concentration of creativity and the need of 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 applied solving problems, developing new knowledge, coming up with innovation, or spurring new economic activities. Access to knowledge is not an end in itself; knowledge application is what improves economy and quality of life.

If communities are important for the absorptive capacity, it is critical for applying new knowledge. The invention of the laboratory of research and development, based on teamwork, greatly increased productivity of ideas generation, and gave birth to the second industrial revolution. The value added of the lab of R&D made systematic the processes of knowledge generation, knowledge application and practical innovation.

Leonard da Vinci failed in doing any innovation beyond painting techniques because of his

isolation as individual. Instead of the "tragedy of the commons," for knowledge pools we have the "tragedy of isolation." The expression of this tragedy in less developed countries is that most innovators there cannot connect to the knowledge communities that could enable and leverage their creative work. Brain drain is just one of the many effects of this tragedy.

Knowledge communities

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

Thought collectives: Reconstructing the history of the evolution of the medical thinking during the process of the identification of 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 of influencing the evolution of the thinking of its individual members. As a condition for understanding that history, Fleck claimed for 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. 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, paragraph 7). In his understanding, the thought collective constitute the social cognitive near-context or environment of any individual thinking or discovery, functioning as a kind of scaffold to support and shape the inquiry process of the members of the collective, but also working as invisible filter and frontier for acceptable thoughts. Any idea or fact that is beyond those frontiers are rejected, not noticed or modified by the thought collective. Despite the important role of epistemic beliefs 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 collectively to contextualize the information they receive. Brown, Collins and Duguid (1989) did support 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 create and share contextualized knowledge.

Epistemic communities: Hass (1992) 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" (p. 3). Epistemic communities were conceptualized by Hass as an institutional actor inside the institutional framework of international relations, acting in the intersection between research and action, such as policymaking 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.[xxix,xxx]

According to Hass, members of epistemic communities share four attributes: (a) a set of principles or value-based rationale that govern the community functioning, (b) a set of beliefs about the interpretative or causal framework, (c) a notion of validity or an epistemology for knowing, and (d) 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" (p. 3).[xxxi]

The epistemic communities, related to international issues, congregate scientists and

professionals with recognized expertise. Collectively, they work as an interface between the needs of international policymakers and existing knowledge and information, generating knowledge grounds for decision-making. Hass sees the emergence of epistemic communities as expression of the expanding role of expert knowledge and highly qualified professionals in problem solving and policymaking.[xxxii]

Applying the concept of "thought collectives" of Fleck 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 a collective role of knowledge communities. Although individuals interact with the knowledge stored in databases or embedded in academic articles, or any other knowledge artifact, individuals should not be considered as isolated entities, disconnected of the knowledge communities they belong to. As Fleck explained, the work of developing knowledge is beyond the scope of individuals. Individuals do their contributions building upon the epistemic cultures and knowledge assets of the knowledge communities they are part of.

The research of Joel Mokyr (2002) on the role of British Industrial Enlightenment 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 do 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 18th 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 of academic articles are annually produced. It is not only a question of quantity, but also of tightness of knowledge. Procedures for evaluating knowledge trustfulness have become commonly accepted, enabling cross-cultural knowledge sharing, expanding the wealth of the knowledge commons, and enriching the universal knowledge pool.[xxxiii]

Digital and communication technologies are moving down the costs of knowledge reproduction and sharing, 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 tenfold faster than the production of academic articles, suggesting that in less than a decade the importance 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 the access to front line 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 unnecessary mastering many different languages to tap on the universal knowledge pool. However, multilingual versions of academic articles, additional to a standard language, like English, would contribute to expand access to the knowledge commons in less developed countries.

Although there are still barriers, the situation of the access to knowledge is improving. It is in the demand side of the knowledge sharing equation that 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 of 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 opens much 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 for a globally fair access to the knowledge commons in the twenty-first century is in its initial phases.

References

Beinhocker, E. (2007). *Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics*. Cambridge, MA: Harvard Business Press

Björk B. C., Roos, A., & Lauri M. (2008). Global annual volume of peer reviewed scholarly articles and the share available via different Open Access options. *Proceedings of the ELPUB2008 Conference*. Toronto, Canada.

Brown, J., Collins, A. & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher, 18*(1), 32-42.

Cohen, W. & Levinthal, D. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), 128-152. Cornell University

Collier, P. (2007). *The bottom billion: hay the poorest countries are failing and what can be done about it*. Oxford, UK: Oxford University Press.

Cunningham, R. (1986). Ethics and game theory: The prisoner's dilemma. Public Choice, 2, 11-27, ABI/INFORM Global.

Diamond, J. (2005). *Collapse: How societies choose to fail or succeed*. New York, NY: Penguin Group.

Directory of Open Access Journals. (2011). *DOAJ statistics*. Retrieved June 7, 2011, from http://www.doaj.org/doaj?func=newTitles&uiLanguage=en

Directory of Open Access Repositories. (2011). *Growth of the OpenDOAR database-Worldwide*. Retrieved June 7, 2011, from: http://www.opendoar.org/onechart-legacy.php?cID=&ctID=&rtID=&clID=&lID=&potID=&rSoftWareName=&search

=&groupby=l.lName&orderby=Tally%20DESC&charttype=bar&width=600&caption=Most%20Frequent%20Languages%20in%20OpenDOAR%20-%20Worldwide

Evans, J., & Reimer, J. (2009). Open Access and global participation in science. *Science 323*, 1025. Retrieved from: www.sciencemag.org

Eysenbach, G. (2006). Citation advantage of open access articles. *PLoS Biol 4*(5), 692-98. DOI: 10.1371/journal.pbio.0040157

Fleck, L. (1979). *Genesis and development of a scientific fact*. Chicago, IL: The University of Chicago Press.

Florida, R. (2002). *The rise of the creative class, and how it is transforming work, leisure, community and everyday life*. New York, NY: Basic Books.

Hajjem C., Harnad, S., & Gingras, Y. (2005, December). Ten-year cross-disciplinary Comparison of the growth of open access and how it increases research citation impact. *Data Engineering Bulletin, 28*(4). Montréal, Canada: Institute of Cognitive Sciences, Université du Québec

Haas, P. (1992). Introduction: Epistemic Communities and International Policy Coordination. *International Organization*, Vol. 46, No. 1, Knowledge, Power, and International Policy Coordination. (Winter, 1992), 1-35. Retrieved from: http://links.jstor.org/sici?sici=0020-8183%28199224%2946%3A1%3C1%3AIECAIP%3E2.0.CO%3B2-%23

Hammond, T., Moritz , T. & Agosti, D. (2008). The conservation knowledge commons: Putting biodiversity data and information to work for conservation. Proceeding of the IASC Conference, July 14-18, 2008. Retrieved from: http://iasc2008.glos.ac.uk/conference%20papers/papers/M/Moritz_129701.pdf

Hayek, F. (1945). The Use of Knowledge in Society. *American Economic Review 35*(4), 519-30. Retrieved from: http://www.econlib.org/library/Essays/hykKnwCover.html

Hess, C. & Ostrom, E. (2007). A framework for analyzing the knowledge commons. In C. Hess & E. Ostrom (Eds.), *Understanding knowledge as common: from theory to practice* (pp. 41-81). Cambridge, MA: MIT Press.

IMF. (2011). *2011World Economic Outlook*. Retrieved from International Monetary Fund official webpage: http://www.google.com/publicdata/explore?ds=k3s92bru78li6_&ctype=l&strail=false&nselm=h&met_y=ngdp_rpch&hl=es&dl=es#ctype=l&strail=false&nselm=h&met_y=ngdp_rpch&scale_y=lin&ind_y=false&rdim=country_group&idim=country_group:001&hl=es&dl=es

Jinha, A. E. (2010a). Article 50 million: An estimate of the number of scholarly articles in existence (Pre-print version). Retrieved from: http://www.stratongina.net/files/50millionArifJinhaFinal.pdf

Jinha, A. E. (2010b). Article 50 million: An estimate of the number of scholarly articles in existence (Post-print version). *Learned Publishing*, *23*(3), 258-263. doi:10.1087/20100308.

Knorr-Cetina, K. (1999). *Epistemic Cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.

Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review*, Vol. 45(1), 1-28. Retrieved from: http://links.jstor.org/sici?sici=0002-8282%28195503%2945%3A1%3C1%3AEGAII%3E2.0.CO%3B2-Y

Larsen, M. & von Ins, M. (2010). The rate growth in scientific publication and the decline in coverage provided by Science Citation Index. *Scientometrics 84*, 575–603. DOI

10.1007/s11192-010-0202-z

Lawrence, S. (2001, May). Free online availability substantially increases a paper's impact. *Nature* (Web Debates), Retrieved from http://www.nature.com/nature/debates/e-access/Articles/lawrence.htm

Mabe, M. (2003). The growth and number of journals. Serials, 16(2), p. 191-97. Retrieved from: http://uksg.metapress.com/media/h83ak04yym4jxhagxj7w/contributions/f/1/9/5/f195g8ak0eu21muh.pdf

Mabe, M., & Amin, M. (2001). Growth dynamics of scholarly and scientific journals. *Scientometrics*, 51(1), 147–162.

Mokyr, J. (2002a). *Useful knowledge as en evolving system: the view from economic history*. Presented in the Conference "The economy as an evolving system," 2001, Santa Fe, NM. Chicago, IL: Northwestern University.

Mokyr, J. (2002b). The gifts of Athena. Princeton, NJ: Princeton University Press

Mokyr, J. (2005). The intellectual origins of modern economic growth. *The Journal of Economic History, 65*(2), 285-351.

Mørk, B.E., Aanestad, M., Hanseth, O., & Grisot, M. (2008). Conflicting epistemic cultures and obstacles for learning across communities of practice. *Knowledge and Process Management, 15*(1), 12-23. Electronic version: Wiley InterScience, DOI: 10.1002/kpm.295

National Science Board, NSB. (2010). *Science and engineering indicators 2010*. Arlington, VA: National Science Foundation.

OAD. (2011). Timeline of the open access movement. Retrieved from the Webpage of the Open Access Directory (OAD): http://oad.simmons.edu/oadwiki/Timeline

OpenDOAJ. (2011). *DOAJ statistics*. Retrieved from the Webpage of Directory of Open Access Journals: http://www.doaj.org/doaj?func=newTitles&uiLanguage=en

OpenDOAR. (2011). *Most Frequent Languages in OpenDOAR-Worldwide*. Retrieved from Webpage of the Open Access Repositories: http://www.opendoar.org/onechart.php?cID=&ctID=&rtID=&clID=&lID=&potID=&rSoftWareName=&search=&groupby=l.lName&orderby=Tally%20DESC&charttype=bar&width=600&caption=Most%20Frequent%20Languages%20in%20OpenDOAR%20-%20Worldwide

Oblyzko, A.M. (1994). *Tragic loss or good riddance? The impending demise of traditional scholarly journals*. AT&T Bell Laboratories. Retrieved from http://www.jucs.org/jucs_0_0/tragic_loss_or_good/Odlyzko_A.pdf.

Olson, M. Jr. (1965). *The logic of collective action: Public goods and the theory of groups*. Cambridge, MA: Harvard University Press.

Ostrom, E. (2003). *Governing the commons: The evolution of institutions for collective action*. (Kindle's Edition). Cambridge, UK: Cambridge University Press.

Polanyi, M. (2009). *The tacit dimension*. Chicago, IL: University Of Chicago Press

Price, D. J. de S. (1961). *Science since Babylon*. New Haven, Connecticut: Yale University Press.

Ruggie, J. (1975). International responses to technology: *International Organization, 29*, 557-84.

Sady, W. (2001) Ludwik Fleck: Thought collectives and thought styles. *Poznan Studies in the Philosophy of the Sciences and the Humanities, 74*, 197-205. Retrieved from

http://fleck.umcs.lublin.pl/teksty.sady.introduction.htm

Shirky, C. (2008). *Here comes everybody: The power of organizing without organizations*. New York, NY: Penguin Press HC.

Suber, P. (2007). Creating an intellectual commons through open access. In C. Hess & E. Ostrom (Eds.), *Understanding knowledge as commons: from theory to practice* (pp. 171-208). Cambridge, MA: MIT Press.

Swan, A. (2010). *Open access citation advantage: Studies and results to date*. Draft version retrieved from University of Southampton website http://eprints.ecs.soton.ac.uk/18516/2/Citation_advantage_paper.pdf

Waters, D. (2007). Preserving the knowledge commons. In C. Hess & E. Ostrom (Eds.) *Understanding knowledge as commons: from theory to practice* (pp. 145-167). Cambridge, MA: The MIT Press.

Wenger, E., McDermott, R. & Snyder, W. (2002). *Cultivating communities of practice*. Boston, MA: Harvard Business Press.

Wenger, E. (2006). *Communities of practice: A brief introduction*. Retrieved from http://www.ewenger.com/theory/

WIPO International Bureau. (2011, May 20). *The Surge in Worldwide Patent Applications*. Geneva, Switzerland: World Intellectual Property Organization.

Notes

---

[i] 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.

[ii] 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 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 conceptualization 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.

[iii] 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 consistence, and without 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 object are more relevance than its epistemology.

[iv] 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 advancement, 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.

[v] Analyzing the challenges of ecosystem conservation, Hammond, Moritz and Agosti (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.

[vi] My experience working with communities in the highland of Peru confirms the importance of general, mostly external, knowledge to grasp the systemic nature of the problems the communities were facing. I was discover that disturbing the beliefs and assumptions of communities was an effective way to stimulate them to move out of the box and to become more creative.

[vii] 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.

[viii] In communities of practice (Wenger, McDermott & Snyder, 2002), most of the knowledge deployed by the community of practice is embedded in the brain of their members.

[ix] Thinking of the conditions of the global south, this set of criteria may deserve further analysis. For example: Are they sufficient, or some critical aspects of the knowledge commons are being missed? Under which conditions, are these criteria adequate? Which criteria should receive priority, in which situation? Which actors could become, unintentionally, excluded of the access to the knowledge commons by this set of criteria?

[x] 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.

[xi] As Mokyr (2002) has explained, non-academic knowledge plays important role supporting economic activities and innovation. One part of this knowledge is tacit or barely externalized under the form of lessons learned, dispersed and invisible inside people's mind. Another part of this knowledge may be documented in private documents of companies and institutions, not so accessible to external people.

[xii] In 1907, there were roughly 800,000 academic articles (accumulated from 1650 to that date), and in 2008 this number has increased to roughly 50,000,000 (Jinha, 2010b). The growth of academic articles in 1907 was of 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.

[xiii] 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.

[xiv] In an early phase of the movement, the mathematician Andrew Michael Odlyzko (1994) envisioned the emergence of on-line through Internet alternative ways of diffusing academic works. Odlyzko imagined a future when on-line publishing of academic articles has become mainstream, displacing old-fashioned paper printing. Although Internet

publishing evolved differently of the vision of Odlyzko, his idea of open access has become more and more important.

[xv] The meta data 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.

[xvi] The findings of Florida do not mean that people of less developed countries lack creativity. Staying alive, free, safe and healthy in some countries, require huge amount of creativeness. However, the economic value generated by that creativeness is not the same as in developed countries.

[xvii] Most of the existing meta-data refers to academic articles that are published in English, or with abstract in English. Particularly underestimated in current meta-data are publications from Asia. The annual growth rate of academic journals on science and engineering in China is between 12% and 16% (estimation based on information of the US National Science Bureau, 2010, p. O-10) but its representation in English written articles are 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 Open Access movement is an emergent phenomenon that concentrates mostly 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, respect to academic articles in general, not only open access articles, the concentration in English is higher than in the Open Access movement. Clarke, Gatineau, Grimaud, Royer-Devaux, Wyn-Roberts, Le Bis, et al (2007) have found that in health subject 96.5% of the academic literature was in English and only 3.5% in other idioms, being German the second one (as cited in Larsen et al, 2010). Larsen et al 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 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.

[xviii] The Institutional Analysis and Development (IAD) framework of Hess and Ostrom (2009) 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.

xix 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.

xx 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 protect them from the obscurantism was a real challenge. The increase in the number of copies of documents, enabled by the movable type printing and now by digital technologies, has become a kind of insurance against knowledge destruction.

xxi Demand for the knowledge commons is quite different from 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 guaranty 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 of resource units, but beyond a threshold, nature cannot restore the resource pool. Sop, before the system reaches that threshold extraction of resource unities have 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 good, 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 artifacts does not generate erosion, and the risk of total depletion of artifacts in the knowledge pool of Internet is quite low. As Internet has already proved, as more copies are made of a digital document, greater is the likelihood 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 behavior do not exclude others from using the same artifact or idea.

These are important differences of the knowledge commons from natural resources commons: non-rivalrous, continuing growth, unlikely of depletion, decreasing access cost, and expanding outreach of access facilities. As technology evolves, the number of people who can access to a knowledge reservoir will move higher and higher. Additionally to this trend, the access costs to the facilities, artifacts and ideas are decreasing everyday.

Assuming that knowledge will keep 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.

[xxii] For those cultures and religious beliefs that do not feel adequately represented by science or 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 conceptualizing reality and knowledge is a challenge for anyone interested in developing the cultural heritage of humanity and supporting the aspirations of new generations.

[xxiii] 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 of new interpretations and conceptual approaches that are being generated in those fields. When they fill the need of becoming 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.

[xxiv] I treated the issue of language in the supply side of knowledge sharing, however it also influences greatly 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.

[xxv] 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 (2002) has explained with details, 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.

[xxvi] Under situations of complexity and uncertainty, it is better to have more than one person playing the role of interface to capture the diverse dimensions of the complexity of external knowledge.

[xxvii] 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 graphical presentation of data can make relevant patterns much easier to see and analyze than a simple matrix of numbers.

[xxviii] When analyzing demand of knowledge, it is possible to look at individuals, communities and the whole society in 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 only communities con hold the knowledge required to develop any theoretical or technical field.

[xxix] Originally, I felt tempted to generalize 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 Hass, 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.

[xxx] Originally, John Ruggie started using the concept of epistemic community for international issues (Verdun, 1997). Ruggie conceptualized 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 Hass, 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, Hass (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.

[xxxi] Comparing the patterns of 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, Aanestad, Hanseth, & Grisot, 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.

[xxxii] The Delphi Method also draws on expert knowledge to address complex subjects, but take expert knowledge as an input into another methodological approach.

[xxxiii] This universal knowledge pool is not absent of controversy. Many social groups do not feel their conceptions and epistemic beliefs represented by the current standards procedures for generating trustful knowledge. Most indigenous communities do not agree with the predominant procedures of scientists and academies, and feel their knowledge wealth misinterpreted and undervalued. Some schools of thought, stressing the social character of knowledge construction, call for an opener 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 next decades.