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Knowledge as Global Public Good

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Abstract

This chapter applies the framework of public goods to knowledge. It shows that knowledge has some characteristics of public good, such as being non-rival in consumption and in the long run non excludable. But it also argues that knowledge cannot be transferred from producers to users at low or negligible costs: to effectively use knowledge, prospective users should devote time and energy to its assimilation. Consequently, free-riding in knowledge is less likely to be successful than with other public goods. This has also important implications for national and global policies. Catching up countries need to implement policies of active learning if they really wish to get the benefit of knowledge. Intellectual property rights have the purpose of making knowledge institutionally excludable, and this contradicts the objective pursued by governments and international organization to disseminate science and technology. It is finally argued that the normative implication of the global public goods analysis in the case of knowledge requires greater public investment and international cooperation.

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Anonymised Version

Summary

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Keywords

Information, non-rivalry, non-excludability, intellectual property rights, cooperation

Introduction

Economic and social development is strictly associated to the capacity to generate, absorb and diffuse knowledge. The economic characteristics of knowledge have for long intrigued thinkers. Already Richard Nelson (1959), Fritz Machlup (1962) and Kenneth Arrow (1962), among others, noted that knowledge is a very peculiar commodity. On the one hand, it is often generated for competitive purposes: armies and companies do invest time and money to develop new and superior knowledge to be used against their rivals. On the other hand, it happens seldom that those who generate knowledge manage to keep it for their own private benefit. Neither industrial and military secrecy nor intellectual property rights can, in the long run, impede the dissemination of knowledge. The knowledge about nuclear fission, in spite of all the efforts made by the United States government to keep it confidential, soon was assimilated and put in practice by the Soviet rivals. And for sure business corporations are not any better than the military in preserving for a long time the secrets about their innovations. But this is part of the story only. A large portion of those generating knowledge, including academicians and their Universities, diffuse the results urbi et orbi for the sole satisfaction of seeing their achievements acknowledged and their reputation enhanced. In fact, the dissemination of knowledge is the ultimate goal of their activity.

Related problems can be encountered when the spatial benefits provided by knowledge are taken into account. We know from the past that only craftsmen from Murano were able to produce mirrors above a certain size and that the best violins were produced in Cremona. Even today knowledge tends to cluster in specific districts and some of the best software is generated in the Silicon Valley. But these clusters are increasingly sparse across the globe as well as deeply integrated in the global economy (see Lorenzen and Mudambi, Iammarino and McCann). These days, along with the Silicon Valley and Cambridge, also Bangalore and Shanghai have become global centres of knowledge production. Inventions and innovations tend to be disseminated across cities, regions and countries, and they often involve brains, instruments and equipment originated from worlds apart. In our own epoch dominated by information and communication technologies, the channels to transmit ideas and artefacts have increased at an exponential rate, and their costs have considerably decreased. Knowledge is generated globally through an increased variety of devises, and it is also transmitted globally, as several chapters in this handbook clearly indicate.

It is not easy to identify the components of knowledge that are “private” or “public”, “national” or “global” (Nelson, 1992). The debates on these issues are often passionate, especially when they have normative implications - should knowledge be generated for the benefit of everybody? Is it right to keep secret or proprietary some knowledge that may have crucial implications for health or security? Should the outcome of knowledge generated with the money of the taxpayers of a country be disseminated globally? These discussions are not only theoretical but have important policy implications leading to very practical issues.

- To what extent public institutions, regulations and norms should protect the intellectual property rights of inventors and innovators?
- Should Universities make a profit from the ideas they generate?
- Should national institutions provide free access to scholars and students of rival countries?

One way to explore these issues is through the well established framework that economists have developed for public goods. This chapter aims to investigate what are the characteristics of knowledge as a public or private good and to look at the implications for national and global actions. A better understanding of its nature will hopefully help to design better policies for its generation and diffusion. The next section recaps the basics of a public good, while the following section applies it to the case of knowledge. We continue to examine a key instrument to make knowledge appropriable, namely intellectual property rights. The global nature of knowledge as a public good is discussed in the subsequent section, also with the illustration of the case of research on vaccines. The last section discusses the implications for global governance and policy.

What is a Public Good?

Sixty years ago, a young and brilliant economist, Paul Samuelson (1954), made an attempt to define public goods. He identified these goods as those “which all enjoy in common in the sense that each individual's consumption of such a good leads to no subtractions from any other individual's consumption of that good”, in other words goods that are non-rival. A pen, for example, is rivalrous since either Laurel or Hardy can use. Moonlight, on the other hand, is non-rival since both Laurel and Hardy can enjoy it. In addition, it should be considered if it is possible to exclude some potential consumers from the use. Exclusivity applies when an owner can effectively prevent others to use its good. Laurel can exclude Hardy to use his pen but he cannot impede him to enjoy the moonlight (Ostrom and Ostrom, 1977). When a good is both rival in use and excludable is very likely to be a typical private good. When, on the contrary, it is non-rival in consumption and it is non-excludable it is very likely to be a pure public good.

Public goods are generally considered those that benefit the whole community, and this in turn justifies the assumption that the group of beneficiaries should contribute to their provision and maintenance. While moonlight and sunshine are not produced by humans, and therefore do not need a pro-active role of the government, roads and street lightening are typical examples of goods that need somebody to be in charge to be produced and/or maintained. In absence of such an intervention, it is unlikely that these goods are produced at all.

The rise of adverse conditions that affect everybody and that generate negative externalities has led to the developed a specular concept, public bad. Actions that generate negative externalities, such as littering in a public space, are public bads. Pollution and climate change are public bads that affect everybody and cannot be prevented through individual agency only. This category includes human related phenomena (such as pollution, climate change, financial instability) but also natural phenomena (such as earthquakes and other natural disasters).

The concept of public goods implicitly indicates that supply is feasible when it is provided by collective agents such as the government. Profit-seeking agents have little interest to provide and to pay for public goods that everyone can use without paying: who will build a road if a toll cannot be introduced? Since each individual has an incentive to be free rider, it is not possible to provide roads and street lightening without coordination and voluntary or binding agreements. These types of goods require some forms of collective actions. In the absence of agreements about the production of these goods, the quantity produces of these goods could be lower than the level desirable for the society. In this sense, the theory of public goods can also be seen as a justification for the economic role of the government.

As reported in Table 1, it is also interesting to consider intermediate cases. Some goods can be rivalrous but non-excludable, and others can be excludable but non- rivalrous. The former are called common goods, the latter network or club goods.

Table 1 – Private and public goods

	Rivalrous	**Non-rivalrous**
Excludable	Pure private goods (pen, bread, car)	Network or club goods (cinema, cable TV, canals, waterways)
Non-excludable	Common goods (Ocean fisheries, free access pasture) Congestible goods (Pest control, open pathways)	Pure public goods (Clean air, defence, street lightening) Public bads (pollution, financial instability)

Source: Adapted from Ostrom and Ostrom. 1977; Kaul et al. 1999.

The Network or club goods are those that are not necessarily rivalrous in consumption, but whose access can be made excludable. Cinema is a typical example: there is no pleasure to watch a film in an empty theatre, indicating that enjoying a film is non-rivalrous, but those who do not pay the ticket can be excluded. Common goods are potentially rivalrous but there are not (yet?) the conditions to exclude consumers from access. Ocean fishery is rivalrous because fish is scarce, but it is not excludable since there is virtually no possibility to regulate the access of fishermen to the open sea. These are the goods more at risk of being depleted through over-exploitation, i.e. those for which Hardin's tragedy of commons could happen (Hardin, 1968)

The conditions of rivalry and excludability do change are not absolute. It is more precise to define goods on a scale and attribute to them a level of low, medium or high rivalry and excludability. These conditions are different across locations (for example, wood may be scarce and therefore rival in some dry country but may be abundant and therefore non-rival in Canada) and across the existing institutions (for example, access to beach can be made excludable in some countries while it is open in other countries).

These conditions also change over time. Fish has become more and more scarce and, therefore, it has become more and more rivalrous. ICTs have also changed access to many services and they have allowed making excludable many products that a few years ago were not excludable. When TV programmes were broadcasted through aerial only it was not technically possible to exclude users and TV programmes had the typical characteristics of pure public goods. Anybody that was not paying the TV license acted as a free-rider. Cable TV programmes continue to be non-rival but they have become excludable. Similarly, until a few years ago it was not technically possible to exclude automobiles to access the centre of cities: if private traffic was banned, this applied to everybody. Through CCTVs, the centre of London and of other cities is selectively accessible to those who pay the access ticket.

We have also learnt that public goods depend from a variety of social and institutional aspects. Fred Hirsch (1976) introduced the concept of "positional goods" to describe those goods that are not necessarily rivalrous, but to which access is associated to a peculiar social status. The premiere of a TV programme in a theatre accessible to invitees indicates that what is rival is not the TV programme itself (everybody can watch it at home), but the VIP status associated to the invitation. Similar cases can be found in several goods that are potentially non-rival but become rivalrous as status symbols (access to news, social clubs, and touristic resorts).

The concept of rivalry is also associated to the community taken into account. Defence has for long been considered the typical public good and, on the ground of that, all citizens of a given state were asked to contribute to its costs. Since the foundation of the United States of America it has not been asked to the inhabitants near the frontier to pay more taxes to support the army than those farther away.[1] The basic assumption is that the benefits of defence are indivisibly provided to all inhabitants of a community. But since the frontiers of states have become blurred, the "public good" defence of state A might automatically increase the "public bad" of insecurity of state B. If both states A and B increase defence expenditure, the outcome might be more insecurity rather than the opposite, while the public good security could be guaranteed by mutual security agreements such as non-aggression treaties. According to the community to which you apply the concept, defence can be either a pure public good or a club good (for example, for states that belong to a defence union), or a public bad (for example, for neighbouring states that may feel threatened by next-door military capacity).

Is Knowledge a Public Good?

For many years, knowledge has considered to be a public good. Economics Nobel Prize winner Kenneth Arrow (1962) contributed to disseminate this view, arguing that knowledge is costly to produce (as many other public goods) but could be disseminated as information at zero or very low costs. This view is rather persistent if it was re-stated by another authoritative Nobel Prize winner such as Joseph Stiglitz (1999). The modern economics of science and innovation, on the contrary, has argued that knowledge is neither a totally private nor public good. It is, in fact, a combination of the two (Pavitt, 1987; Nelson, 1992, Callon, 1994). Each single aspect of knowledge has a different balance of "private" and "public" components. Seen through the public goods lens, knowledge is only partially non-rivalrous and non-excludable. Let see in detail the two components.

Knowledge and Rivalry. - If Laurel develops a new method to get rid of headaches, let call it NoheadachesA, he will be able to use it and to get a direct benefit. If Hardy, a generic member of the public, buys, rents, imitates or steals the new method, Laurel will not lose its control; he will continue to be able to use NoheadachesA. Two people will benefit from the same method and this will double the social advantages provided by the new knowledge. While the transfer of a physical commodity (a pen, a car, a machine) implies that the original proprietor loses control of the object, nothing like that happens when knowledge is acquired or transferred to others. In this sense, knowledge is non-rivalrous in consumption.

If Laurel has invested massively to develop NoheadachesA, he might be willing to sell or licence the knowledge rather than disseminate it for free. Laurel might be eager to find a market for his knowledge, especially since the sale will not imply that he will forget about it, and he can continue to use it. As with mass production, there are no limits to duplications, but variable costs are zero or very low. Even if Laurel sells the exclusive right of NoheadachesA to a client, he might continue to use the knowledge acquired to generate new one. If Hardy acquires the licence for NoheadachesA for a limited period, at the end of the lease he will still possess it and it will be difficult to prevent him from using it again.

Both buyers and sellers of knowledge have to face a market that is highly imperfect.[2] Hardy might not be willing to pay a price for knowledge that he has not yet seen in operation (we do not often buy an item unless we have a degree of certainty that it will serve our purposes). But if Laurel discloses his knowledge to Hardy, up to the point that he can be sure that it serves his purposes, he will not need to pay a price for something that already knows.

If another inventor, Bernard, also develops a competing device, a fierce competitive race may occur between Laurel and Bernard since both of them potentially aim to sell the product to the same consumers. Laurel and Bernard will compete for market shares and this will imply: i) to upgrade the knowledge to make it more appealing to prospective customers, ii) to protect it according to the available systems. This process has all the characteristics of economic rivalry. Although there is no rivalry in consumption, there might be a substantial rivalry in the generation and upgrade of knowledge.

Knowledge and Excludability. – The motivations that induce individuals to generate new knowledge are diverse. Some may be willing to invent for their own personal pleasure, and may not necessarily be looking for material rewards. For a large part of the academic community, fame and reputation are already sufficient rewards for their commitment. For this community, the diffusion of research results is a priority, up that the community itself undertake active policies, including science communication, to reduce the number of those excluded from access.

But if prospective gains induce Laurel to devote time, energy and resources to generate new knowledge, he will try to do his best to profit from it. Therefore, although Laurel does not lose the control over his knowledge when Hardy is using it, he will not look for its personal use only but will look to commercialize and to profit from it. In order to get some form of remuneration, Laurel will search methods to exclude individuals that do not pay a price to use the method (excludability). If Laurel succeeds to do that, the knowledge generated is still non-rivalrous in consumption but it will become excludable, or accessible to members that have been granted access, i.e. it will become a network or a club good.

Since knowledge is non-rivalrous in consumption, excludability needs to be artificially constructed. There are several methods that inventors and innovators can use to exclude others from the benefits of knowledge they generated:

1) **Secrecy**. To maintain a certain discovery secret allows the inventor to prevent others to use it without charge. The practice is rather diffused not only in the military sector but also in business companies. Secrecy offers a partial protection since can be broken: military and industrial espionage, headhunting, reverse engineering and other practices do not guarantee that the original inventor retains its secret. And, in parallel, the strategy to prevent the secrecy may hamper the marketing and commercial diffusion of an innovation.

2) **Access codes**. Develop technical methods that make it more difficult to use the knowledge without authorization. Access codes, passwords and software protection belong to this category. Access codes are the paradox of the digital society. On the one hand, the technical reproducibility of artefacts increases the part of knowledge non-rival. On the other hand, this is pushing towards the creation of devices that can prevent the open access (this issue is explored in Hess and Ostrom, 2007). But access codes, passwords and other devices do not guarantee absolute protection, as hackers and their victims well know.

3) **Intellectual property rights** (IPRs). The two economic methods above are complemented by IPRs, namely the family of legal devices (patents, copyrights, trademarks) that should guarantee the inventors and the innovators to the exclusive right over the product of their activities, although for a limited span of time. These tools are an institutional solution provided by the government in the hope to solve the under-production problem of public goods. The rationale in setting IPRs is the comparison of static versus dynamic advantages: in the short run, there is a loss of welfare associated to the fact that the dissemination of knowledge is constrained, but in the long run they may induce profit-seeking agents to invest in knowledge and/or to make it public rather than keeping it secret. Even more than in other areas of economic life, institutions are in fact needed to enforce the excludable nature of knowledge. Also IPRs are often infringed and they do not manage to guarantee full protection.

Companies generally use a combination of the three methods, integrating industrial secrecy, codes and other technical devices and IPRs. The economic literature on technological appropriability (Levin et al. 1987; Cohen et al. 2000; Arundel, 2001; Odagiri et al., 2010) has shown that each technical field, industry, company and country has specific way to appropriate its knowledge using differently excludability devices. If industrial secrecy cannot be guaranteed because the knowledge is visible in use and easy to imitate, inventors and innovators may devote a considerable amount of the resources to produce devices which will obstruct others from using the knowledge without permission. Software companies invest substantial resources not only to improve software, but also to prevent its unauthorized duplication.

Not all fields can be equally protected, and profit-seeking inventors will take that into account before devoting time and energy in one field rather than another. If we assume that some knowledge is more likely to be made excludable and it is easier for their inventors to generate profits, excludability may steer agents to work in an area rather than in another. If appropriability is not possible, there is the danger of a "tragedy of knowledge" similar to the tragedy of commons (Harding, 1968), since the economic incentive to generate knowledge will be reduced. Since institutions have an impact, for example making IPRs protection weaker or stronger, excludability raises an important policy issue: what is the suitable level of excludability that governments should guarantee to inventors and innovators? The more institutional devices contribute to make knowledge excludable the less it will have the characteristic of a pure public good.

Knowledge is not freely available. – The sections above have seen the generation of knowledge through the lens of non-rivalry and non-excludability. But the standard framework of public goods, when applied to knowledge, has also some limits. The typical cases of public good, such as defence and clean air, assume that economic agents receiving the "good" do not have to make an additional effort to reap the benefits. If a citizen lives in a well-defended country, or breaths clean air, he or she is not even supposed to notice it. The story is entirely different with knowledge: even when the producers of knowledge have the best intentions of transferring their expertise, the economic agent has to invest his or her time, efforts and resources to acquire the expertise and to be able to benefit from it. And not even those efforts will guarantee that he or she will at the end manage to acquire and master the expertise. Stiglitz (1999) has argued that "Knowledge of a mathematical theorem clearly satisfies both [non-rivalry and non-excludability]: if I teach you the theorem, I continue to enjoy the knowledge of the theorem at the same time that you do. By the same token, once I publish the theorem, anyone can enjoy the theorem. No one can be excluded." This statement does not take into account the costs and efforts needed to learn and to exploit the economic benefits of the theorem. To be sure, Stiglitz is not silent about the costs of acquiring and use knowledge of individuals but they are conceived basically in terms of transaction costs associated to the transmission of knowledge. However, he argues that this does not affect the public good nature of knowledge, since private will simply charge a fee reflecting the marginal cost of transmission. So overall the problem of transferring knowledge is largely underplayed.

The art of playing the violin is well codified in hundreds of books, scores, records and videos, and all this wealth of information is publicly available at zero or very low costs. But only a few of those who make an attempt manage to become professional violin-players. Companies selling mobile phones or cameras do their best to transfer the knowledge on how to use these products to their clients up to the point that they invest resources to hire writers, designers and cognitive psychologists to make instructions easily understandable. But only a few customers devote enough time and energy to use at their best these appliances. To play the violin decently and to use a mobile phone properly both requires that the would-be imitator devote time and resources to learning. This is even more evident in the case of technical knowledge in which the recipient needs to have basic knowledge to scan, understand, and use it. Economic development studies have convincingly shown that North-South technology transfer is unlikely to be successful unless the recipient of knowledge invests his or her time and resources to absorb it (Bell and Pavitt, 1997, Athreye and Kapur, in this volume). Technology transfer, like the generation of new knowledge, is an uncertain activity with successes and failures.

This is why it is wrong to equate knowledge and, above all, its technological component, to information (Pavitt, 1987). Most knowledge, and certainly scientific and technological knowledge, is not available without costs since those willing to learn should make their own efforts. There are a few cases in which the benefit of knowledge is fully incorporated into products and it does not require an active role of users: for example, to benefit from a new drug it is sufficient to swallow the pill. These cases can be labelled turnkey knowledge. But turnkey cases are rather exceptional.

Callon (1994) has introduced the difference between knowledge and technology that are freely available (i.e. not protected by legal or technical devices) and that can be used without incurring in costs (i.e. that can be directly applied without additional investment by the prospective user). Freely available knowledge is a rather large basin: all knowledge in textbooks and in the scientific literature is freely available. Also technology that in its origin is proprietary is often freely available: patents, for example, have a legal validity of not more than 20 years, and the majority of them elapses earlier than that since companies do not even bother to pay their renewal fees (Hikkerova et al., 2013). But this does not mean that everybody can have a direct benefit from them. In order to exploit this basin of knowledge, a lot of additional effort in learning, tooling up and development is needed. In this sense, the amount of knowledge that can be used without incurring in costs seems to be very limited. As we have seen, not even the knowledge embodied in some products, such as computers, cameras, mobile phones, can be used without incurring in costs, since the effort undertaken by consumers could considerably change the way in which they manage to exploit the products.

The economics of innovation has also shown that there are huge inter-industry differences. There are areas in which the transfer of knowledge is easier, and the infrastructures needed by would-be imitators are rather basic. In other areas it is the opposite. Drugs can be imitated and replicated rather easily while in nuclear physics entry barriers are much stronger, and only a few organisations are today able to manufacture a nuclear reactor. There are very significant differences across typologies of knowledge, products and industries. According to the product and the industry, excludability can change considerably. This recalls a basic fact, namely that knowledge is a highly heterogeneous commodity and in many cases it is not a commodity at all.

Summing up, knowledge has some characteristics only of a public good especially since it is non-rivalrous in consumption. There are economic and institutional methods that would potentially allow making knowledge excludable, but they are never totally effective. Knowledge is very close to be a pure public good when it can be used turnkey, namely when it is not required to users to properly understand how it works and how it is developed. There are, no doubt, cases of turnkey knowledge, but they are not very frequent. In most cases, users have to learn to use knowledge, and the more it is sophisticated and complex, the more it will require investment of time and resources. In these cases, even when knowledge is free to use, it can be used only affording the relative costs. Therefore, what makes knowledge differing from public goods is not the related production process, rather its process of diffusion, which has been scarcely addressed in standard economic theory.

Governments in the Generation and Distribution of Knowledge

Knowledge is so crucial for welfare and its characteristics as commodity so peculiar, that public players have always taken a very active role in its promotion and distribution. Public policies and regulations aim in all countries to reward the producers of good ideas, to increase the investment in knowledge, and to induce inventors to disclose their discoveries. Governments have promoted knowledge to win wars, to increase security, to safeguard public health, to explore the sky, to improve communications, to advance education and learning. Policy makers may not perceive totally the public good characteristics of knowledge, but for sure they appreciate that generating and disseminating knowledge has strong positive externalities that do justify their concern. Public intervention to foster knowledge can be subdivided into four broad areas:

In-house investment. The government develops the knowledge through publicly funded institutions such as research centres (such as NASA or the Max Planck Institutes) and Universities. This includes the training of qualified people under the assumption that they will become a knowledgeable and technically competent class. In principle, the results of government-funded and performed research should be in the public domain and freely available.

Procurement. The government, through its ministries and agencies, contracts to the business sector the development of the knowledge needed for its purposes (as it is often the case with military, space and health programmes). Procurement can be in the form of knowledge embodied in final products or entirely disembodied. In the first case, the government purchase products (e.g. an aircraft with given specifications) and the executing firm is required to develop the necessary knowledge. In the second case, the government can directly ask the business sector to develop new disembodied knowledge (for example, the prototype of a new vaccine). In the case of procurement, the government generally holds the IPRs, although contracting firms are likely to retain them de facto. Since the government holds the property rights, it may also distribute the knowledge to other fields and to other companies (as it is often the case of procurement associated with defence and space programmes). In both cases, since the contracting firm develops the knowledge, it will retain the expertise. Even if contracts require that contracting firm erase all information associated, it will not be possible to erase the knowledge acquired.

Beauty contests. The government rewards the individuals and the organisations that have produced socially relevant knowledge through “prizes”. These prizes should be an incentive for individuals and companies to carry out scientific and technological investigation. The contest implies that private players disclose their knowledge, and the government can acquire it as a consequence of delivering the prize. But this is more likely to be effective for codifiable rather than tacit knowledge.[3]

Intellectual Property Rights (IPRs). Finally, the government guarantees private inventors to reap the fruits of their discoveries and IPRs are the main way this is ensured. They provide an incentive to private agents to invest in the generation of knowledge and to disclose the knowledge developed. By making knowledge property, they are designed to make it temporarily excludable and generating a market for it. As we have seen, the effectiveness of IPRs changes not only according to the institutional design in each country (Odagiri et al., 2010), but also according to the invention, the product and the industry (Levin et al. 1987; Cohen et al. 2000; Arundel, 2001).

In contemporary capitalist economies governments use all four methods using excludability differently. In the first three cases, government intervention is designed to minimize excludability and often the interventions are combined with deliberate policies to promote the diffusion of knowledge. In the case of IPRs, on the contrary, the government guarantees excludability, although for a limited period of time. The basic rationale to explain the difference is that public sources generally finance in-house investment, while profit-seeking agents invest in the knowledge generation that IPRs should reward.

It is often stated that public intervention in the market for knowledge is the result of "market imperfections". However, this should not induce us to believe that, once upon a time, there was a market for knowledge, and that at later stage governments intervened to regulate the imperfections. Historically, direct forms of government intervention have existed long before the creation of a formal market for knowledge. The first introduction of the modern patent system, the milestone of property rights, was introduced in the Venetian Republic in 1474 only (May, 2002), while public investment for knowledge and education started a few thousand years ago.

Intellectual Property Rights as a Tool for Exclusion

IPRs protection explicitly aim to make knowledge excludable and therefore to prevent imitation and to make it possible to sell and hire it. It is worth pointing out that intellectual property rights are not needed if there are technical devices that impede the forgery of technology: for instance, if an effective device prevents the illegal copies of DVDs, the film industry would no longer need to recur to IPRs, since normal property rights are sufficient guarantee. The rationale for IPRs therefore resides precisely on the fact that knowledge in itself is often non-excludable.

Since the explicit aim of IPRs is to make knowledge excludable, it is worth asking if the government is contradicting itself: on the one hand, it encourages the generation and diffusion of knowledge on the ground that it has the characters of a pure public good; on the other hand, it makes it a private good by allowing making it excludable through its IPRs legislation. This goes back to the different channels that the government can use to promote knowledge: when it uses in-house investment, there is the assumption that it does not only generate knowledge but also foster its dissemination through policies for scientific and technological transfer.[4] But when the government is willing to foster the investment of profit-seeking agents, it uses IPRs. The underlying assumption is that, in absence of such a guarantee, individuals would either not disclose the knowledge or not produce it at all.

As mentioned above, IPRs effectiveness in making knowledge excludable are not limited by government legislation only, but also by the nature of a competitive economy. In the real world, IPRs provide only a partial protection: competitors and would-be imitators are often able to by-pass the existing legal limitations by "inventing around" and many other ways. Consumers also often manage to acquire the knowledge associated to IPRs without paying its costs (or paying it only to a limited degree). As happens with pop songs, celebrity photos and software, knowledge is used, copied and imitated and the existing legal devices are far from able to provide full protection to the singer, photographer, software engineer and inventor. Legal devices to guarantee excludability are, in the case of knowledge, largely ineffective.

All property rights can be infringed, as each person with a wallet knows. But governments are less willing to enforce intellectual property rights over knowledge than they are on rights over our wallets. Software thieves are more numerous than wallets thieves, but are much less likely to be found in jail. Why? Probably, because there is the tacit awareness that knowledge is non-rival in use and, therefore, it is in the social interest that excludability is not absolute. When physical property is stolen, there is a zero sum (or even a negative sum) outcome: if Hardy steals the car of Laurel, the number of cars in the community is still the same, and Laurel got a loss equal or greater to the gain of Hardy. But if Hardy steals Laurel's HeadachesA, society has two citizens with clear heads. This also applies in the case of two countries, whereas a company from a country A imitates a technology of a company in the country B.

In this context, public policies have tried to balance the private and the public interest. Without any enforcement, IPRs would lose their meaning and other methods would prevail. To enforce IPRs strictly could imply a fee be paid every time that "Happy birthday to you" is sung, although it is difficult not only to enforce it, but even more to considered a welfare advantage to enforce it.[5] Public policy have therefore been rather keen to enforce IPRs with a certain relaxation, possibly on the assumption that a less than perfect protection would increase welfare and reduce the monopoly power associated to IPRs. This also depends on the stage of the development of the country as well as its industrial specialization. In general, governments in less developed countries tend to have low incentives for a strong enforcement of IPRs. As long as domestic innovators come to the fore, the pressure for a stronger enforcement of intellectual property also rises (see Odagiri, 2010). As we have illustrated elsewhere (see Archibugi and Filippetti, 2014), the constituency advocating a stronger enforcement of intellectual property rights in developing countries came from outside, i.e. multinational firms in developed countries.

The somewhat relaxed attitude of governments in the face of IPR infringements is also associated to the idea that the generation of knowledge is seldom down to a single owner. Inventions and innovations in contemporary society often have a number of fathers and mothers (what is known as multiple independent discoveries), each of which have been able to exploit previous knowledge, to exchange information with colleagues, to absorb what is generated in public research centres and universities. It is impossible to be a successful producer of knowledge without being an even more successful absorber of knowledge. In the world of ideas, the difference between the "pupil", the "absorber", the "plagiary" and the "robber" is very thin. To give full reward to the person who owes the IPRs does not necessarily mean to reward the person who does deserve it more.

The discussion on knowledge as a public good has a direct implication for the design of IPRs. Governments have a large number of instruments to make IPRs strong and weak: they can decide: i) what is the length of protection provided to inventors; ii) the requirements of novelty to qualify for the granting of a patent; iii) the way in which Courts rule on controversies about infringements; iv) the level of enforcement guaranteed by the police against forgeries; v) the industries involved, e.g. several countries in the past have prohibited patents in the pharmaceutical sector. The lens of global public goods, indicate that the more the government decide to make IPRs strong, and therefore to promote institutionally exclusivity, the more it will need to use other channels to promote knowledge in the areas of its priorities (such as in-house investment).

Knowledge as a global public good

Health, environment, communications, mobility and security all require the development of new knowledge. New scientific and technological competences are far from being confined to one country only. On the one side, any significant breakthrough has an impact beyond the borders of the state that has actually produced the knowledge. On the other side, it is very likely that most significant knowledge augmenting is the outcome of developments in different locations. In spite of this, many national governments develop their own science and technology policy agenda on the implicit assumption that soon or later they will manage to benefit from basic research funded and performed elsewhere. But when such an attitude becomes general, the free-riding syndrome will prevail: each country might be tempted to wait until others will invest in finding out a solution. This in turn will lead to an underproduction of the good.

In spite of the strong geographical interrelatedness of knowledge, its global governance is still very vague: how should it be organized? Who should provide the resources? The global public goods framework, developed by the UNDP (Kaul et al., 1999; Kaul et al., 2003), can perhaps provide some answers.

Public goods can be considered global when they cover a rather large group of countries and when it is difficult or impossible to identify a geographically restricted community of beneficiaries. Financial stability, peace, combating climate change and transmittable diseases are all cases of public goods that do not have a clear geographical space: directly or indirectly they affect everybody. Besides this geographical criterion, Kaul et al. (1999) also stress the existence of a temporal dimension, i.e. goods (or bads) that could benefit (or damage) not only the current generation, but also future generations.

Knowledge might not totally fit into the public goods framework, as stated above, but it is certainly a global good: only in a few occasions, and for short periods of time, institutions and companies manage to maintain their knowledge within their national borders. Even in the case of top secret investigations, such as those associated to the military sector, knowledge is likely to spill-over to rival countries. Excludability may be obtained in the short run, but less and less in the long run. If the impact on future generations is also included, it is hard to imagine how some knowledge can provide benefits to a specific local or national community and not to all the others.

Knowledge as a global public good also challenges the idea that it could be provided by the business sector alone. Private incentives do not work very well in basic research project whose results are extremely uncertain and fixed costs very high, such as the case of research in particle physics whose benefit would span the entire scientific community.[6] Moreover, the notion of knowledge benefits (or damages) for future generation challenges the idea that market forces can provide them since markets for future generations do not exist. The existence of appropriability mechanisms like IPRs does not guarantee a sufficient production of these goods. In these cases, single countries would tend to be free rider since the benefits of such a type of research are likely to span across the globe and in future generations. This poses a fundamental problem of governance related to knowledge as a global public good.

The distribution of competences is not uniformly distributed across countries, as other chapters in this volume have documented (see Castellacci and Natera, and Zhou and Li in this volume). Each country finances its own R&D and promotes knowledge-related activities. There is a huge discrepancy between the nature of the inputs devoted to promote knowledge, which continues to be national in scope, and the benefits, that are more likely to be global. An individual country can be compared to the single consumer/producer in the context of national public goods. Since each country cannot fully appropriate the returns of the knowledge produced at home, a free rider strategy might arise leading to under-production of knowledge. Greenhouse gas is a typical case of a global public bad: countries are trying to contain over-production by international regulations within international organizations (e.g. the Kyoto Protocol at the United Nations Framework Convention on Climate Change), but many of them act as free-riders. What are the implications of the public good analysis? If there are goods that provide widespread global benefits, who should be in charge to produce them? In particular, how will the free-rider syndrome, that has such an important role in many global public goods, work in the case of knowledge?

Public institutions. Members of national academic communities and of other publicly funded institutions always had a strong propensity to exchange their wisdom, insights and perceptions with foreign colleagues. Some of the instruments used to guarantee the international dissemination of ideas included academic societies, international journals, conferences, sabbatical years and mobility grants. National governments have encouraged the academic community to be open to cross-border collaborations, probability because there is awareness that the outcomes are non-rivalrous and therefore they should also be made non-excludable, within borders as well as across borders.

Moreover, there is a clear self-interest: collaboration implies not only knowledge outflows, but also inflows.

Citizens may potentially benefit from knowledge that has been generated elsewhere, and often paid by taxpayers of other countries. The propensity to act as free-rider, however, is constrained by the characteristics of knowledge: on the one hand, countries that do not invest enough have lower absorptive capacity and may be slower or inefficient in putting into practice what has been generated elsewhere. On the other hand, countries which invest more in knowledge are also those able to learn and assimilate the knowledge generated elsewhere. Countries manage to capitalize what they pay for.

The transfer of scientific and technological expertise to catching up countries is constrained by the level of capabilities of the absorbing countries. This is a typical case where the difference between freely available knowledge and knowledge that can be used without incurring in costs becomes relevant (Callon, 1994). Even if significant portions of knowledge are freely available, this does not mean that other countries are able to collect the benefit without the necessary infrastructures and skills. The countries that have managed to absorb knowledge generated are also those that have invested massively in endogenous infrastructures, R&D and education. Japan in the 1950s and 1960s, South Korea and Taiwan in the 1970s and 1980s, China in the 2000s are all cases of countries that have taken advantage from knowledge generated elsewhere because they have made an enormous endogenous effort to acquire it. To consider knowledge as a pure public good (Stiglitz, 1999) risks diffusing the view that developing countries could benefit from the competences of developed countries if the latter are prepared to remove barriers to the transfer. But this is inaccurate since institutional (such as IPRs) or economic (such as industrial secrecy) are not the main obstacles to the use of knowledge. The main obstacle faced by developing countries is the lack of endogenous absorptive capabilities.

The global public goods framework suggests also another important dimension: it is in the interest of all countries, including those that are already active in the generation of knowledge, to augment the partners involved in scientific and technological activities since this will enlarge the overall stock of knowledge. There is a potential mutual incentive for developed and developing countries to carry out and exchange non-proprietary knowledge. Public players have, in fact, pursued active policies to induce other countries to increase the pool of knowledge. Funded joint research programmes, international conferences, international disciplinary academic associations, sabbatical years and student exchanges are also methods to foster emerging and developing countries in the knowledge society. In these areas, governments are likely to have a healthy agonistic spirit similar to those encountered in the Olympic Games: each country is fostering its own academic community in order to acquire a better performance, but the methods and results are generally shared.

One way to gather empirical evidence on this form of trans-border collaboration is by looking at the scientific papers that are co-authored by scientists of different countries (see Hennemann and Liefnerin in this volume),[7] an indicator of mutual collaboration in the generation of new knowledge without a hierarchy among participants.

Internationally science and engineering co-authored papers have substantially increased, also thanks to Internet and Information and communication technologies. Internationally-co-authored papers have grown from 16% of the total in 1997 to 25% in 2012 (National Science Foundation, 2014, chapter 5). Already one fourth of academic papers are the outcome of direct cross-border collaboration. This form of collaboration has affected all countries, but it has become more and more important in small countries. Regions of the world with lower scientific capabilities are, in proportion, relying more on cross-border collaborations (National Science Foundation, 2014, Appendix, Table 5-41).

The business sector. The business sector is increasing its role in the development of knowledge not only within borders, but also internationally. Companies contribute to perform R&D, to upgrade skills, to disseminate technical and engineering capacities at home and abroad. Firms can less and less be associated to a national territory. The activities they carry out outside their nation, including R&D, have increased substantially (see the chapter by Ietto-Gilles). Several leading MNCs have built their own intra-firm and inter-national innovation centres. New products introduced by firms are traded in the international markets, new processes are scrutinized and diffused by competitors at home and abroad and ultimately the externalities associated to companies' knowledge generation are less and less restricted to a specific nation. It might be discussed to what extent the knowledge generated by MNCs is private or public, but their investment in R&D and innovation is: i) by definition multi-national rather than uni-national; ii) it generates substantial externalities across national borders.

MNCs are important vehicles for the international spread of knowledge. They do not necessarily manage to keep their knowledge ownership, and very often they act as fertilisers for skills that are picked-up and further developed in host countries. A significant case is represented by the software district of Bangalore: from an original foreign direct investment by Texas Instruments in the mid 1980s, a hub of excellence in ICTs and software has been developed, also thanks to education policies that have managed to train computer engineers at local universities (Chaminade and Vang, 2008). This led to the birth and growth of a cluster of dynamic local firms, which has further induced other MNCs to invest in the place. A deliberate policy to build competences has successfully upgraded technological capabilities.

In recent years, firms have become more willing to collaborate with other firms to develop their technological knowledge. A vast literature has started to collect evidence and data on inter-firm technology agreements, defined as something more than an occasional collaboration, involving two or more independent firms and where the generation and application of knowledge is a key component (see the chapter by Narula and Noya in this volume). Why do firms share a key competitive resource such as technological capability with their rivals? It has emerged that the need to share costs and risks with others is often a more important factor than the need to keep confidential research projects. The implication is that even profit-seeking agents are partially abandoning the search for exclusivity on their knowledge and are prepared to share it with actual or potential rivals.

International Organizations. International organizations play an important role in generating and disseminating knowledge. Since inter-governmental organizations are established by states to address common problems, it seems natural that they are also in charge of the improvement of general-purpose knowledge. Can international organizations be the genuine providers of knowledge as a global public good?

First, international organizations set common standards that allow all countries to benefit from best-practice knowledge. Transports and information and communication technologies can operate internationally only if there are joint standards. The value of the standards increases with the number of players able to use them: by definition, a telephone that does not allow communicating with anybody has no value. Producers have an incentive to transfer the relevant knowledge and expertise to the largest number of potential users. International organizations devoted to establish, disseminate and upgrade standards therefore do play an important role in the transmission of knowledge and technical competence. Standards themselves have many of the attributes of pure public goods. While the implementation of standards may seem to be just a "passive" acquisition of knowledge, often they require also the making of endogenous competences in the countries that join the standards, then enabling also "active" knowledge developments.

Second, international organizations are also in charge of the transmission of scientific and technological expertise. Specialized agencies such as FAO, UNICEF, UNIDO, WHO and the World Bank do play a crucial role in allowing countries to acquire competencies. This does not happen in development projects only. When international organizations allow people from different countries to sit together, they provide an important learning opportunity. The role of international organizations should also be stressed to counter-balance the typical and dominant direction of technology transfer, which traditionally implies the transfer of knowledge from the North to the South. In some occasions, the knowledge transferred may not necessarily be the most appropriate for the needs of the South. International organizations provide the opportunity to exchange also South-South knowledge. In many cases, knowledge developed in some countries of the South is more effective for other countries in the South than what has been cultivated for different purposes in the North, empowering what has been labelled "reverse innovation" (Govindarajan and Trimble, 2012).[8]

Third, there are also a few research centres promoted and funded under the auspices of international organizations where innovation and learning work as two sides of the same coin. In fields with high fixed costs, governments have promoted joint research centres, as in the case of CERN. The European Union has established several international centres in high-cost and high-risk scientific domains, under the assumption that the outcomes will equally benefit all member countries. Other research centres have been established by the United Nations University or under the auspices of UN specialized agencies (as in the case of the UNIDO International Centre for Science and High Technology). These are pioneering cases of a genuine transnational public financing of public goods. The research centres and learning institutions are just a few if compared with the total resources provided to the national ones. Still, they provide significant models that point out to a new way to promote knowledge for development.

If there is the genuine political interest of making knowledge a pure global public good in some areas, it might be wondered how come that the financing of cooperative international research is not larger, while the bulk of government spending for R&D is still directed towards national institutions. There are many reasons that can explain why. First, governments are well aware that R&D generates a lot of externalities, and that the local dimension is equally important. Second, government R&D spending is often taking part in an area of inter-state rivalry, either because it is associated to national power (as in the case of military programmes) or because it is devoted to support the competitiveness of national firms. But if there is the political willingness to disseminate the benefits of knowledge, transnational and collaborative R&D centres seem to be the appropriate instrument.

Vaccine Research as a Case of a Global Public Good Management

Human necessities are different across geographical areas, and even the needs of inhabitants are not equal. Take the typical case of health research: poor countries undertake a tiny fraction of the world R&D health expenditure, although they have 90 per cent of the total disease burden (what has been labelled the 10/90 gap, see Global Forum for Health Research, 2004). The countries that perform the other 90 per cent of health R&D might have very different priorities since many of the diseases affecting the South have already been eradicated in the North, for example through improved hygienic conditions. For the South, the priority might be to find workable drugs to prevent death from diarrhoea, while the problem is so rare in the North that the priority is often to find drugs for hair re-grow (for men) or hair removal (for women).

A typical case is represented by scientific research on vaccines. Knowledge leading to the identification of a successful vaccine is very close to being deemed a pure global public good: first, effective vaccines are costly to invent, but can be produced and transmitted at rather low cost.[9] Second, they can provide benefits globally and across generations. There is an inter-generational advantage both if future generations use the vaccine or, even more so, if the disease is eradicated. The transfer of knowledge requires that recipient countries should development local competences and capabilities associated to administer it (Yaqub and Nightingale, 2012). The case of smallpox eradication, as a consequence of the World Health Organisation programme, is a successful attempt that has generated advantages for both the North and the South (see Fenner et al., 1988). For example, it is estimated that the United States recover its own share of investment for smallpox eradication every 26 days (Arhin-Tenkorang and Conceição, 2003).

With the appropriate investment, vaccines can be found for some of the major fatal illnesses of our age, such as malaria, tuberculosis and HIV.[10] These three diseases are responsible for several million deaths a year (Archibugi and Bizzarri, 2004). Major long term investments could lead to an effective solution to this problem. In spite of that, investment is still negligible. Business companies apparently find it a risky area where to invest. To the scientific and technological uncertainty, they add up the social risk: if they will develop a well functioning vaccine, it is difficult that they will manage to make it excludable through patents since the social pressure for diffusion will be very high. Surprisingly, also the public investment devoted to R&D in this field is negligible (Archibugi and Bizzarri, 2004). The relatively higher level of investment in vaccines for HIV is due to the fact that this disease is a top priority for the North, while malaria and tuberculosis are not a major concern for the North since improved environmental and hygienic conditions have managed to almost eradicate the disease.[11]

It is, however, significant how globalisation is changing the perspective of the Northern countries as well: inward migration is bringing tuberculosis back and outward tourism is exposing Westerners to malaria. Vaccines are therefore a typical area where both the North and the South will have an advantage, as already shown by the smallpox case. The relative advantage of the North will be comparatively smaller than the advantage of the South, but this should not hide the countries of the North will get from this investment returns much higher than for many other fields.

A new impetuous for research, which has already achieved some important breakthroughs for malaria, was possible thanks to resources coming from private sources such as the Bill and Melinda Gates Foundation (White, 2011). It is, however, significant to compare the different strategies pursued in the 1970s to eradicate smallpox with what is currently done to combat malaria and tuberculosis: in the 1970s, the programme was promoted and carried out by an international organization, WHO, in collaboration with national governments. Today, it was promoted and mostly funded by the resources provided by the richest businessman of the world: the shift from public responsibility to private engagement is palpable. It may be wondered why such an important priorities is funded through business resources rather than through public funding. The global public goods framework does indicate that the latter is a more convincing strategy.

The Governance of Knowledge as Global Public Good

The public goods concept has strong normative implications. In a pure market economy, the goods and services that have these characteristics risk of being under-provided since profit-seeking agents have low interest to produce them and potential consumers have a tendency to act as free-riders. If they need to be produced and maintained, there is the need of a collective agent in charge. Within a national context, the public goods concept provides: a) justification for the economic activity of the government; b) legitimacy to the collection of taxes; and c) guidance for indicating the areas on which the public sector should operate.

When we deal with global public goods, similar problems do emerge. Individual governments might also be affected by the free-riding syndrome and expecting that other governments are going to invest to address and solve common problems. In the case of knowledge, we have also to take into account that scientific and technological capabilities are unevenly distributed across countries (as indicated by Castellacci and Natera, and Tan and Thanh, in this volume), and therefore there is not only a problem of nations that might behave as free-riders, but also the fact that many countries do not have the resources and the expertise required to address societal needs.

In this context, it becomes crucial to operate a distinction between the production of knowledge on the one hand and its absorption – dissemination on the other hand. We wish to point out here three important policy implications of the public good discourse applied to global knowledge:

i) The tendency towards a privatization of knowledge.
ii) The relevance of absorptive capability for disseminating knowledge across countries, particularly in developing countries.
iii) The importance of international collaboration, also through knowledge-generating institutions, to target the areas with greatest scientific and technological opportunities and of greater social relevance.

i) The tendency towards a privatization of knowledge commons. We have discussed above that the public sector has various alternative methods to achieve the proper generation and dissemination of knowledge. The first is to promote, finance and perform scientific and technological institutions. Such a portion of knowledge is generated through public money and is in the position to be fully disseminated in the social and economic fabric. The second is to guarantee sufficient incentives to profit-seeking agents willing to invest in knowledge, providing the institutional context that would allow them to profit from it. IPRs and other institutional devices are precisely designed to provide these incentives by making knowledge excludable and tradable. We have noted that there is an intrinsic tension in government's behaviour: on the one hand, it uses public resources to promote knowledge because it has the characteristics of a pure public good, on the other hand, it provides norms such as those of the IPRs that allow the business sector and, more and more, also the public sector,[12] to privatize the knowledge generated.

Governments' should make an attempt to manage this tension between the proprietary and the public components of knowledge. Any actions aiming at reinforcing IPRs should be matched with policies devoted to foster the public dissemination of knowledge. If IRPs are strengthened, the public space for knowledge dissemination should be compensated through other policies such as: a) expanding government performed R&D to generate a pool of public knowledge to which both public and business players could draw; b) financing of pre-competitive and cooperative research in the business sector to increase flows; c) rewards the profit-seeking inventors and innovators that are prepared to disseminate the results they have achieved through open source strategies.

Unfortunately, in the late decade, we have assisted to dangerous strategies to privatize knowledge in all respect. On the hand, we have assisted to a substantial reinforcement of IPRs, enlarging the scope of the Western system also to developing countries and privatizing knowledge that was previously public (Maskus and Reichman, 2004). On the other hand, the public sector has also reduced its commitment to the promotion of knowledge. For example, the share of R&D of the business sector has substantially grown in most of advanced countries while the share of government funded R&D has declined correspondently. Table 2 reports some data for four of the largest R&D spending nations: Germany, Japan, the United Kingdom and the United States. From 1981 to 2011 the share of R&D financed by the government has been reduced in all countries. The dominant R&D spender is now the business sector. When the government still finances a substantial share of R&D, as in the case of the United Kingdom and the United States, a growing portion is performed in the business sector: in the UK, the business sector finances the 48.9% of the national R&D but it performs as much as the 63.6%. Similarly, in the USA the business sector finances 58.6% of the national R&D but it performs the 68.5%. The difference being associated mostly to public contracts provided to companies.

Table 2. R&D by source of financing and performance, selected countries selected years

	Percentage of GERD financed by industry					
Year	1981	1985	1990	1995	2000	2011
Germany	56.85	61.09	63.54	60.03	66.04	65.63
Japan	62.28	68.87	73.11	67.11	72.42	76.52
United Kingdom	42.05	45.89	49.60	48.21	48.31	45.86
United States	49.41	50.31	54.60	60.23	69.03	58.58
	Percentage of GERD financed by government					
Year	1981	1985	1990	1995	2000	2011
Germany	41.79	37.48	33.81	37.88	31.40	29.83
Japan	26.95	21.00	18.05	22.84	19.58	16.41
United Kingdom	48.10	43.50	35.54	32.84	30.23	30.45
United States	47.80	46.89	41.61	35.41	26.24	31.17
	Percentage of GERD performed by the Business Enterprise sector					
Year	1981	1985	1990	1995	2000	2011
Germany	68.97	72.24	72.08	66.28	70.33	67.65
Japan	60.67	66.81	70.86	65.21	70.96	76.96
United Kingdom	62.96	64.35	69.37	64.96	64.96	63.58
United States	69.31	71.50	70.48	70.53	74.19	68.53

Source: OECD Main Science and Technology Indicators (MSTI – OECD) 2014
Legend: GERD = Government Expenditure on Research and Development

Finally, there has been an attempt even to allow private profits from R&D funded by the government and performed in the public sector. We have already highlighted the tendency to make such knowledge proprietary allowing the executing players (including Universities, public research centres or companies) to use IPRs and therefore to appropriate privately what has been funded by taxpayers.

If knowledge should really be sustained as a global public good, the first step is to reverse the privatizing trend that has dominated over the last thirty years.

ii) Absorptive capability for disseminating knowledge across countries, particularly in developing countries. Although knowledge can be assimilated to a public good in the production phase, we have strongly argued that the successful diffusion and use of knowledge requires that recipient agents invest time and resources in learning and applying it. The distinction between production and diffusion is already relevant at the country level, but we can still assume that, within the borders of an individual country, the capabilities and the institution generating knowledge manage to distribute it to users. At the global level, the transmission of knowledge between producers and users much less likely to be automatic since there is less proximity. In particular, in the absence of absorptive capability by the recipient country, the availability of knowledge is of no use.

This has major implications for an international technology transfer strategy. To build absorptive capacity requires time, effort and investment: infrastructures, education, training, and even R&D labs are needed to grasp, learn and take advantage of the existing stock of knowledge. To focus on the supply from developed countries without taking into account the absorptive capacity of developing countries could lead to a waste of resources. It is a waste of time to bring the horse to the water if nobody has taught to the horse how to drink.

For this reason, the notion that knowledge is be a public good (as argued by Arrow, 1962; and Stiglitz, 1999), which we claimed to be theoretically inaccurate, is also politically harmful since it may diffuse the view that would-be users could reap its advantages freely. We maintain, on the contrary, that individuals, companies and countries do not manage to take advantage from the knowledge developed elsewhere unless they also make substantial investment to effectively absorb it. When we consider the global public dimension of knowledge, the diffusion problem should be addressed. To guarantee that individuals/countries which should benefit from it have the necessary capabilities to absorb it. In brief, public intervention is required not only to make global knowledge producible, but also absorbable.

iii) The importance of international collaboration. Since knowledge is non-rival in consumption, the larger is the pool of resources devoted to it the more positive externalities will be generated. There is a direct interest of national governments to exchange results and to foster scientific and technological institutions in countries where they are weak. An effective global governance of knowledge, based on cooperation among governments and across national academic institutions, is therefore desirable. This, in turn, requires an increased co-ordination among national efforts, but also an enhanced role for international organizations dedicated to knowledge generation and dissemination.

The current distribution of scientific and technological capabilities does affect the priorities of scientific and technological investigation. Capabilities are strongly concentrated in one part of the world only, the North. Not surprisingly, the public expenditure and other government intervention for the advancement of knowledge are generally directed towards the problems of the North rather than those of humanity. As illustrated in the case of vaccine research, companies in developed countries do not have enough incentives to address these priorities when the potential market is uncertain and IPRs do not guarantee the appropriation of possible returns. Companies and public institutionsin developing countries may lack the required capabilities, at least in the short term. As a result, neither the public nor the business expenditure is successfully addressing some most important world human necessities.

In the long term, it is desirable and feasible that countries in the South will expand their research capabilities that will allow them to address their own societal needs by developing the required new knowledge. Some emerging countries, especially in East Asia, are expanding their knowledge-base, although their focus is more on economic development rather than on human necessities. But there is an urgent need of a policy shift, replicating the North-South forms of cooperation that have led, for example, to the eradication of small-pox.

It was possible to pull resources and competences to eradicate small-pox also scientific targets and societal benefits were clearly identified. If this example should be replicated, it be needed to identify transparent and accountable R&D targets, addressing basic human necessity. This in turn will require inclusive governance systems. It is unlikely that more public resources will be steered to knowledge if stakeholders will not be in the position to assess what the resources are used for.

A crucial aspect will be to identify in which fields investment in the generation of knowledge should be directed. Fields considered important by general consensus are those that are mutually advantageous for current and future generations and less likely to be associated to trade rivalry. Astronomy, space and theoretical physics are already some of the areas where strong international collaboration has emerged, and where permanent institutions have also been established. The public goods framework, however, has also indicated that global health and other human basic needs have been, so far, seriously denied by the research agenda.

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Notes

[1] One of the strong arguments used by the authors of The Federalist (1788) to create the new Federal state with a single army paid by taxes collected in all the states was precisely that it was unfair to put the burden of defence on the shoulders of the states more at risk to be taken back by the United Kingdom.

[2] The imperfections of the market for technology are explored in Arora et al. (2001).

[3] In a brilliant book, Dava Sobel (1995) reports how in 1714 the British government made use of a contest to solve one of the fundamental problem in marine navigation, which is that of determining longitude at sea. The prize was won by a clockmaker who created the first clock (chronometer) sufficiently accurate to be used to determine longitude at sea—an important development in navigation.

[4] Over the last 30 years a fundamental change has occurred in many countries: through the Bayh-Dole act of 1980 and similar legislation in other countries, governments have allowed Universities to commercialize the results of their inventions even when funded from public sources. For an assessment, see Grimaldi (2011). For the changes in European countries, see Geuna and Rossi (2011).

[5] The legal controversies about "Happy Birthday to You" are summarised in the Wikipedia page with song's title.

[6] It is worth noting that benefits for the industry from public funded projects even in basic research can be considerable. A case in point is represented by research at CERN, whose results have had a big impact in terms of technological transfer to the European industry, (see here http://knowledgetransfer.web.cern.ch/).

[7] In spite of the increasing amount of publications generated by researchers in the business sector, the bulk of scientific papers are still authored by members of academic institutions. Researchers and engineers in industry are contributing more and more to academic journals, showing that even the results of their research are sometimes publicly disclosed.

[8] UNDP, 2001, p. 28, provide the case of the oral rehydration therapy developed in Bangladesh to fight diarrhoea. Developed countries have sufficient medical infrastructure to combat the same disease by providing sterilized liquid through an intravenous drip. But when these medical infrastructures are not available, a second best is a simple tablet with the appropriate combination of salt and sugar. The therapy has often proven effective to prevent children's death. Since the same problem affects the majority of developing countries, it is a typical case where South-South technology transfer is needed.

[9] Certainly it is much easier to transfer between countries the knowledge to successfully administer vaccines than the knowledge related to nuclear programmes. However, not even in the case of vaccines is it possible to ignore absorptive capacity. Woodle (2000) shows the difficulty encountered by developing countries when they have to rely on external supply sources only.

[10] The World Health Organization periodically assesses the number of infections and casualties of these diseases. See, for example, http://www.who.int/topics/millennium_development_goals/diseases/en/

[11] The only high-income country with reported malaria mortality is Barbados (UNDP, 2013, table 7, p. 168).

[12] We refer here to the propensity of an increasing number of governments to allow protecting through patents and other IPRs also the outcome of publicly funded R&D. See endnote 4.