

Scientific and technological knowledge as a global public good: the role of the Internet and the Open Access policies

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Abstract

Currently, a transition towards a knowledge economy is being completed. This paper delimits the fields of knowledge with an immediate economic relevance and confirms their global public good nature. This feature involves the existence of efficient provision problems, whose causes are analysed. Based on that analysis, some proposals to solve such provision problems are gathered, especially referred to the Internet and the Open Access policies.

Keywords: knowledge, global public goods, Internet, Open Access.

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1 Introduction

In the last years, the intangible goods have gain relevance in comparison to the traditionally studied tangible goods in economic, social, political, and academic discussions. Concerning the intangible goods, there are many goods that have a key role for the future of the society. One of them is knowledge.

The growth and evolution of knowledge have determined the economic development along the History. The most immediate relation between knowledge and economic growth is represented by the successive industrial revolutions, preceded by scientific revolutions, such as discoveries and innovations, and by changes in the main paradigm, such as the Enlightenment (Mokyr, 2011).

Several types of research have proved the externalities linked to knowledge, to its production and consumption (Anselin, Varga, & Acs, 2000; Gehringer, 2010, Giovanni, 2002; Raspe & van Oort, 2011; Romer, 1990). These researches usually employ models of economic growth to explain the effects of knowledge over the economy and its behaviour as a good, as well as the effectiveness of technological advances or the effects of research, mostly from a local or sectorial perspective.

Consequently, this paper aims to provide a theoretic and applied vision of knowledge from the global public goods perspective, focusing on its provision. In order to reach this proposal, it is essential to go in depth in the means of diffusion, such as the Internet or the Open Access policies.

At first, the field of study is delimited from the relevant perspective of the proposed research. Secondly, the adaptation of the topic is determined according to the global public goods theories. Then, the underlying problem of provision is specified analytically and empirically, with the aim of finding possibilities of action to solve it. Finally, these possibilities are addressed, with special reference to

the role of the Internet and the Open Access policies.

At the beginning of this research, a group of goals to achieve has been fixed. Such goals are based on a series of research questions and, hierarchically, are the following:

The main research goal is providing an analysis of knowledge as a global public good, its problems of provision and the possible solutions to that problems, mainly based on the Internet and the Open Access initiatives. To reach this goal, it is needed to fix some secondary goals:

First. Delimiting the types of knowledge relevant to the field of study covered by Economics, the global public goods theories and the globalisation phenomenon. Is available knowledge as a whole important to the economic analysis? Can economic relevant knowledge be analysed from a global public good perspective?

Second. Demarcating the degree of compliance that knowledge shows following the global public good features, as well as its place in these theories and its interaction with other global public goods. Does the notion of a global public good fit the essence of considered knowledge? How are these features related to other goods?

Third. Detecting the main provision problems and its causes. Why is the provision of knowledge said to be problematic? What are its peculiarities?

Fourth. Gathering proposals to solve the problems of provision. Once that the fails of provision and their causes are detected, what correcting measures are susceptible to be applied to obtain a satisfactory provision of knowledge?

Fifth. Showing the possibilities of the Internet and Open Access as correcting mechanisms of provision. What possibilities can such tools provide to the efficient provision of knowledge? Are they adequate tools?

Reaching these goals depends on the selected and applied re-

search strategy. With the aim to ensure their observance, an applicable methodology has been required. The designated methodology is inspired by the steps habitually followed in the analysis of global public goods theories. At first, an economically relevant good that can be analysed in that terms is detected. Then, its empirical features are verified according to the theoretical paths found through an initial state of the art revision and the observation of economic realities. Once the favourable nature of the good is verified, the problems of provision are detected through a comparative with an accepted theoretical paradigm. This paradigm is the canonical orthodox microeconomic model with private equilibrium and Pareto optimality. The comparative highlights the more conflictive ways of provision, so that they can be analysed and solved.

The considered topic involves the appearance of approaches with an elevated degree of abstraction. In order to reduce the level of abstraction, successive conceptual filters have been performed. These filters have also been used to delimit the correct field of study. Knowledge as a whole has been filtered and the knowledge that cannot be studied in Economics or from a global public good perspective has been cast aside. This process has put the focus on scientific and technological knowledge. The resultant field has been separated into three elements to facilitate the analysis: knowledge itself, the means of obtaining knowledge and the means of disseminating knowledge.

Along the research, it has been found that the analytical proposals coming from the economic institutionalist background are convenient to deal with the proposed topic. The problems to provide knowledge have evolved according to the socioeconomic context, thus, it is indispensable to understand the institutional dynamics. As a consequence, institutions are the guide that shapes the applied analysis. Institutions are the set of collectively accepted realities,

such as social, economic, technological, normative or organisational structures, with a formal or informal nature, and a capacity to influence the social incentive schemes in order to reach a functional goal (Hodgson, 2006; Searle, 2005) related to the studied topic: the provision of knowledge.

The research has employed both primary and secondary sources of information: academic articles, books and reports. The sources have been selected by prioritising their updated content, relevance and impact measured through bibliometric indicators. The academic literature comes from recognised repositories that count on materials in an adequate state of access or in Open Access. Other resources come from international organisations or independent research institutions under Open Access licences.

2 Conceptual contextualisation

Before carrying out a provision analysis of knowledge, its effects and implications from the proposed perspective, it is necessary to delimit the field of study. With the aim of reaching this goal, it is required to set a generally accepted definition of ‘knowledge’ and to justify the importance of its provision (Pritchard, 2014).

The delimitation of what can or cannot be considered ‘knowledge’ has historically been problematic. In Epistemology, the reflection on knowledge, it is generally accepted that the existence of knowledge implies two elements: the existence of a belief and the confirmation that such belief is true. There is a trend to identify ‘knowledge’ with a mere ‘true belief’. This trend could be wrong. Knowledge usually implies an effort made by the agent who receives it or incorporates it. There are chances to reach a belief that, afterwards, results to be true without making any effort, without justifying it. That is to say, the belief should be justified, and the verifications of the truth should be the result of an effort. Determining whether an action,

the use of certain means or similar can be considered ‘an effort’, like determining the consideration of ‘truth’, are also problematic questions that go beyond the purposes and the topic of this research. Thus, ‘effort’ is considered to be a wide category and ‘truth’, an intuitive notion, as Pritchard (2014) does. The relevant point is that knowledge is not accidental, but causal and deliberated: it is generally caused by an intentional effort. Precisely, this intentional effort is one of the elements that allow analysing the provision of knowledge as a good. Economically, if there is an effort destined to obtain the provision of knowledge, it implies that the utility derived from such knowledge is at least equal (or maybe greater to) the economic cost of the effort. Otherwise, societies would not give that importance to knowledge.

Economics itself depends on knowledge to carry out its main goal: assign limited resources that are susceptible of alternative uses to satisfy non-limited material needs, according to the canonical definition (Robbins, 1932). Determining the nature of that available resources or the best assignation for them requires information: it requires knowledge (Hayek, 1945). This idea is linked to historically previous approaches, such as the ideas of Marshall that considered knowledge to be the most powerful driving force for production (Marshall, 1890). Considering these ideas show that the utility of knowledge is instrumental, as long as it is used as a mean to satisfy other ends. However, the utility can also be derived from knowledge as an end itself, without instrumental considerations, as Pritchard shows (2014). This relevance given to knowledge, whether it comes from its instrumental value or from its intrinsic value (non-instrumental value), points out the necessity of studying its means of provision.

The definition of ‘knowledge’ provided immediately implies the existence of other kinds of knowledge that cannot be studied from

a purely economic perspective or that cannot be analysed from the global point of view. There is some knowledge that has no economic return or that does not show the requirements to be considered a global public good. Consequently, the research focuses exclusively on scientific and technological knowledge, as it is a priori economically quantifiable, tradable and susceptible of being translated to an international scale. In the words of Hayek (1945), this type of knowledge is suitable to be used by authorities to assign the resources, but it cannot be considered the total amount of knowledge in general.

3 Scientific and technological knowledge as a global public good

Once the adequacy of scientific and technological knowledge has been confirmed as a good that is an object of study in Economics, it remains to connect the concept with the global public goods theories. The notion of knowledge as a global public good developed along the XX century and has gained relevance currently. At the beginning of the academic discussion, the formulation of public goods was exclusively postulated (Samuelson, 1954) to transition progressively to the global level. The features of knowledge according to the global public goods theories are the following (Arrow, 1962; Stiglitz, 1999a):

Knowledge is a non-rival good. Sharing knowledge has a marginal cost equal to zero: an additional agent consuming knowledge does not diminish profits from other consuming or potentially consuming agents. Thus, knowledge should be provided at zero price from the efficiency point of view, as efficiency implies the equalisation of price and marginal cost. Usually, knowledge is provided at a price greater than zero. This fact can lead to a misconception: that price does not reflect the nature of knowledge itself, that has a zero marginal

cost, but the costs linked to its obtaining process or its transmission.

Knowledge is a non-excludable good. No agent should be excluded from its consumption because it is non-rivalrous and, thus, there are no marginal prejudices for consumers. According to Stiglitz (1991a), the existence of mechanisms like the intellectual property rights or industrial property rights does not initially restrict the access to the good, it restricts the identity of its provider to stimulate the obtaining process of knowledge. Even though the identity of the provider was restricted, knowledge itself has been obtained. Other authors argue that, empirically, the current disposition of intellectual property rights is damaging, especially in countries with lower levels of development (Maskus & Reichman, 2004).

These two features, non-rivalry and non-excludability, show that knowledge is a public good, but in order to be considered global, additional features are required:

Knowledge is not linked to a country, it can be enjoyed in a number of countries so wide that it has a global transcendence.

Knowledge is not linked to one sociodemographic group in each country where it is provided: scientific truths are universal. This fact involves an interpersonal transcendence.

Finally, the obtaining process and its effects echoes over past, present, and future generations. Knowledge is constructed along a process made by phases that last over time: comprehension of an idea, conceptual application, analysis, findings synthesis, and evaluation of the finding and the process (Bloom, 1956). The positive effects derived from reaching knowledge last, equally, during wide time horizons. It has, therefore, an intergenerational transcendence.

Scientific and technological knowledge presents all the features required to be analysed from the global public goods theories. However, the fact that it satisfies all the theoretical features does not mean that it satisfies them with the same intensity. As long as the

public features are concerned, there are no static qualitative categories, but a continuum in which opposite parts are pure public goods and private goods, and along the spectrum, there is all kind of goods, including knowledge. The intensity of the features showed by knowledge has motivated that a part of the academic discussion does not consider knowledge to be a global public good (Daniele & Filippetti, 2015). Theoretically, non-rivalry is not normally put in doubt, or at least, it is not put in doubt as frequently as non-excludability: knowledge is considered a partially non-excludable good (Kaul, Grunberg, & Stern, 1999). This statement is the result of the possible deprivations in its consumption associated with its ways of diffusion, that are susceptible of generating exclusive costs, and no to its intrinsic features, as mentioned before. That is why there are some analytical formulations that disagree with this conception and do not consider the partiality of knowledge, on the contrary, they consider it to be a pure public good (Sandler, 1999; Stiglitz, 1999a).

Beyond its public features, knowledge can be contextualised in the frame of some commonly found classifications in the global public goods theories (Kaul et al., 1999; Marín & García-Verdugo, 2003; Sandler, 1999). In these classifications, knowledge is considered a human-produced global public good, symmetrically associated with the global public bad of raising disparities, as well as to a problem of lack of access and insufficient use.

The problem of the provision does not only affect the knowledge in its condition of finalist global public good, but also to other global public goods when knowledge acts as an intermediate good. Previously, it was mentioned that Hayek (1945) used to say that Economics needs the knowledge to assign resources. In the same way, there are activities that need it in order to be planned and executed. Some examples of these activities in the frame of global public

goods are sanitary activities, economic development, environmental preservation, cultural heritage management, peacekeeping, the diffusion of Human Rights, etc. (Chan, Kirsop, & Arunachalam, 2011; Stiglitz, 1999b). In all these cases, knowledge plays an intermediate role.

4 Problems of provision

Once that the cited consensus in its problematic provision has been reached, it is time to ask about the origin of the lack of access to knowledge and its insufficient use.

Theoretically, the efficient provision of a good is achieved in the equalisation of the marginal revenue (the price in perfectly competitive markets) and the marginal cost because this condition ensures the profit maximisation, the theoretical goal of the model. Thus, the efficient provision price of knowledge should be zero. In practice, in contrast, its provision price is not equal to zero. This circumstance does not justify the problem completely: the situation is much more complex.

The reasoning clarifies that, if these theoretical precepts are followed and a price equal to zero is fixed for knowledge, therefore only the knowledge that can be provided at zero cost will be produced (Stiglitz 1999: 309). This statement implies that knowledge itself is still a global public good as it still verifies all its theoretical features: its cost is zero even though the price is not zero. Knowledge remains free of marginal cost, its creating mechanisms or its diffusion mechanisms are those who present a positive marginal cost. Studying the provision of knowledge involves analysing how this knowledge is obtained and how it is transmitted after being obtained. This conclusion is related to the differences observed by Kaul et al. (1999) and Sandler (1999) in the compliance of theoretical features.

After confirming the nature of knowledge and its problems of

transmission, there is room for observing the phenomena occurred when knowledge arrives at the creating and transmitting mechanism par excellence in our institutional context: the market.

With the intention of determining these phenomena, it is essential to pay attention to the costs, previously defined, and to the profits. The potential profits are derived from the private utility that knowledge reports due to its nature as a good, in addition to the social profits generated by knowledge with the appearance of positive externalities (Krugman, Olney, & Wells, 2008; Parkin & Esquivel, 2006). Knowledge increases the welfare of the private consumer that pays the cost of generation/transmission but also increases the welfare of the society in which that user lives, without charging that cost to the remaining individuals and without the possibility of excluding one of them as a consequence of the three-dimensional public features of knowledge.

Private market computes the private costs and profits. That is to say, it takes into account the creation and transmission cost, and the user's utility, but it does not consider the social profits because these social profits are external. The consequence of this private failure is the resultant gap between the private equilibrium and the social equilibrium, followed by the inefficient quantity supplied and the inefficient charge of costs via price. This conclusion involves the lack of access or the insufficient use detected by the preceding theoretical classifications of knowledge as a global public good.

This idea can be explained in analytical terms. In this case, the demand is not the usually conceived demand: now it is a social marginal profit function (Marín & García-Verdugo, 2003). The cause of this modification is the public nature of the good. The demand for a private good represents the horizontal addition of individual demand functions corresponding to the potential consumers for each price. In contrast, the social marginal profit function aggre-

gates vertically the individual demands for knowledge, as there are non-rivalry. This modelling adaptation allows to catch social assessments rather than exclusively private assessments and to perform a comparison between both assessments and its effects on efficiency.

Analytically, the described situation is normally formulated in the Samuelson's Rule (Samuelson, 1954). Calling h to each individual agent, the aggregate demand of a private good is $\sum_h X_h = X$, while the peculiar aggregate demand associated to the public good is $X_h = X$, leading to $X_h \leq X$ for each agent. Usually, two theoretical goods are considered: X , a private good (demand equal to $\sum_h X_h = X$), and G , a good that can be private or public depending on analytical needs:

If G is private, then its demand is $\sum_h G_h = G$ and the utility derived from the joint consumption of the two existing goods in the theoretical economy is $U_h = U_h(X_h, G_h)$, increasing in X and G . The social welfare is defined as the aggregation of utilities for each h weighted using a factor β_h so that $\beta_h \geq 0$ and at least one factor $\beta_h > 0$. Calling the production F , then the efficient provision in Paretian terms is the solution to maximise $\sum_h \beta_h U_h(X_h, G_h)$ so that $F(\sum_h X_h, \sum_h G_h) \leq 0$, meaning that the Marginal Rate of Substitution between the private goods is equal to the Marginal Rate of Technical Substitution in the efficient optimum point for every agent: $MRS_{GX}^h = MRTS_{GX}^h, \forall h$.

Nevertheless, if G is a public good, like knowledge, then its demand is $G_h = G$ leading to maximising $\sum_h \beta_h U_h(X_h, G)$ so that $F(\sum_h X_h, G) \leq 0$. In this case, the efficiency condition requires that the aggregation of Marginal Rates of Substitution between the public and the private good equalises the Marginal Rate of Technical Substitution: $\sum_h MRS_{GX}^h = MRTS_{GX}^h$. This inequality between the results generated by each type of good points out that knowledge, because of its non-rivalry, should not be provided regarding

mere private criteria if a Paretian efficient situation is needed.

If the absence of non-rivalry in the consumption justifies the introduction of social elements, what happens with the non-excludability? Earlier, it has been shown the variety of conceptions about the presence of non-excludability in knowledge: there are analyses that contemplate it as a pure public good and others that contemplate it as a non-rival and a partly non-excludable good. This problem has been solved, as Stiglitz (1999) mentioned, by distinguishing between knowledge itself, totally non-rival and non-excludable, and the means established to its creation and diffusion, that can present a rival and an excludable nature. Once the knowledge is obtained, it is difficult to exclude an agent from the acquisition of its profits. The most meaningful difficulty derives from the intangible essence of knowledge itself. It does not occur the same way in the case of the means established for obtaining or transmitting knowledge, that are generally tangible and potentially rival and excludable. For instance, a scientific truth is a pure global public good: several agents can consume it simultaneously without restricting the possibilities to other agents, with zero marginal cost, it is intangible, hardly never excludable, of universal comprehension, with temporal repercussion, etc. The material book or the scientific journal that contains it is a private good that cannot be consumed simultaneously, presenting a positive provision cost, restricted to individuals that pay the cost, etc. (Fagiolo, 2012).

At this point, it is suitable to consider that the described problem is not such a problem: if knowledge maintains its features and the creation and diffusion of knowledge requires the use of a private resource, shouldn't each resource be remunerated according to the efficiency criteria? The answer is no. Such a proposal makes that the creating and transmitting means present an efficient provision, but causes an inefficient provision of knowledge itself because the

final price is always greater than the marginal cost of knowledge, that is zero, omitting, moreover, its possible externalities. Hence, knowledge, provided in an exclusively private frame, is causing inefficient situations (lack of access and insufficient provision) through the creating and transmitting mechanisms, intrinsically and necessarily linked to knowledge itself. A social optimal equilibrium, different from the suboptimal private equilibrium, must exist so that it contemplates the non-rivalry, the non-excludability and the three-dimensional transcendence (global, interpersonal and intergenerational) of knowledge.

The fact that the provision of knowledge in a private context is problematic does not mean that its provision should be totally carried out by the public administration. The terms ‘public’ and ‘private’ does not refer to the kind of providing agent or mechanism, but to the nature of the cost-profit flows taken into account by the analysis (that is why is it preferable ‘social’ and ‘private’ rather than ‘public’ and ‘private’ to catch these nuances). Any proposal formulated to move the situation closer to the social optimum should consider private solutions as well as public solutions. In the case of opting for a public provision, and not for a private mechanism, basing the decision on adequate social criteria, the provision could be problematic again if the called ‘public failures’ appear (Perez-Sebastian, 2015; Van De Walle, 2016). A ‘public failure’ is the situation produced when the public provision means associated to a good fail and they do not manage to provide the adequate level of efficiency, as it happens with the private failures in non-intervened markets. Its origin is located in the public administration. Situations compatible with a public failure are the excessive bureaucracy, the formation of wrong public expectations, the lack of coherence and consistency of public policies, the absence of suitable funding instruments, and the lack of dialogue among agents. A form of pro-

vision of knowledge is not right or wrong for being public or private: it is right or wrong concerning the attention that it pays to social criteria.

Empirically, the exposed formal system can be completed by identifying what are the creating and transmitting mechanisms associated with knowledge.

The conceptual contextualisation highlighted the existence of an effort as an essential element to distinguish knowledge from the rest of true beliefs. At this point, that effort is identified as the obtaining means. As stated, the obtaining process of knowledge can be contemplated as a progression of several consecutive phases: comprehension, application, analysis, synthesis and evaluation (Bloom, 1956). The canonically described procedure can be labelled under the range of research and development activities (R&D). Every process to obtain knowledge begins with the comprehension of the observed reality. This comprehension needs a training, that is, a previous expertise that allows the individual to understand the scientific state of a question and its fitting in a real situation, along with an availability of verified information sources allowing to access such scientific state. This training is currently identified with the education system. It is what Stiglitz calls 'knowledge decoding'. The education system not only serves to decode knowledge, it also serves as a transmitting mechanism. Other transmitting mechanisms are scientific publications. In coherence with this reasoning, it is necessary to focus on education and research as obtaining mechanisms, to transition to the problems of diffusion in the last section.

Knowledge has a zero marginal cost that should result in a zero price. Freely, no private agent should have incentives to obtain or provide knowledge. It is, then, necessary to give incentives to these agents. The agent with sovereignty to accomplish this mission is the State, who can assure a favourable institutional framework by

employing a minimal intervention, even compatible with the most minimalist visions of public intervention (Stiglitz, 1999b). A minimal incentive usually includes the acknowledgement of property rights applied to research. As cited before, it is needed to remark that there are voices stating that the protection of these rights does not affect the knowledge itself, but the providing agent, while there are other movements that consider it to be harmful. Other contemplated possibility is the concession of public subsidies. These subsidies try to compensate for the potential losses attached to fixing a zero price while remunerating expenditure and opportunity costs in knowledge obtaining activities. Usually, R&D activities, as well as private educational activities, can benefit from the acknowledgement of intellectual property rights and the reception of subsidies.

Another provision manner distinct from private is the direct public provision. It consists of a more ambitious intervention made by the public sector that involves the internal production of activities leading to knowledge. In each socioeconomic context, this intervention has a different relevance, easily verifiable in the public budgets. In the majority of the current economies worldwide, it is possible to distinguish completely private activities, private activities supported by the public sector and purely public activities. The mechanisms of knowledge generation are, therefore, mixed.

Concerning education, for the past two decades, the public expenditure as a percentage of the national Gross Domestic Product has remained relatively constant near 4.5% on average, with a significant dispersion also constant. In the last comparable year available, 2014, there are expenditures such as those registered by Monaco, South Sudan, Bermuda or Cambodia, 1%, that contrast with those in Sweden, Norway, Denmark or Zimbabwe, 7%. The same differences appear when guaranteed public school periods are observed (UNESCO

Statistics Institute, 2018). The disparity in the socioeconomic situation in the countries that share the same level of public expenditure and the fact that data come from national governments recommend observing other indicators that focus on the results reached with the level of expenditure rather than on the expenditure itself. For that purpose, it is appropriate to revise the PISA reports (OECD, 2018), that allow assessing the education quality offered worldwide using an independent methodology and supplying comparable results. ‘Programme for International Students Assessment’ (PISA) reports are elaborated by computing the results obtained in a test done by students samples in emerging countries or in countries with a higher degree of development, separating the grades according to the subject, the sex and the social context. In spite of the differences registered in each subject, it is observable that the countries with a higher degree of development have more opportunities to reach the world average or higher levels. In terms of sex, inequalities are present in the majority of the countries in the sample, with a lower prevalence in the North-West, Russia and Australia. Socioeconomic conditions have a greater impact on students located in Central Europe, Eastern Asia and Latin America. Actually, being a migrant adds difficulties to the educational results, especially prominent in Northern Europe. If this is the situation in the countries that benefit from a better socioeconomic condition, the context of less developed countries is revealing. According to the United Nations Development Programme, who computes the state of the education system in every country of the world, the least developed countries have improved their results over the past two decades, but still have unsatisfactory results (UNDP, 2016). Consulted statistics point out an unequal access and use of the education system as a mean to access the necessary training to decode the knowledge. There are barriers in access related to development and demographic variables. An

unequal or inefficient possibility to decode the knowledge is also an excluding mechanism different from the mentioned price (Daniele & Filippetti, 2015) that affects the international and the interpersonal dimensions.

Concerning R&D, it is convenient to perform a comparison between the number of researchers per million of inhabitants and the R&D expenditure in purchasing power parity (UNESCO Statistics Institute, 2018). The usual range for expenditure as a percentage of national income is 1% to 3%. According to the two-variable classification, countries with a lesser level of development are located in the lowest part of the ranking, and the countries with a higher level of development, in the intermediate part. The country with the most quantitative significant activities in R&D is the United States of America, followed by Germany and Japan, with comparable levels to those in the USA; countries in Western and Central Europe, with lower expenditures, but similar number of researchers; China, in an expenditure range similar to the European, but a low number of researchers; the Nordic countries, in a lower expenditure range to that of the leaders, but with a significant higher number of researchers; and finally, Israel and South Korea, the outliers in the ranking, with moderate incomes and expenditures close to 5% combined with high number of researchers. Data show, in coherence with the patterns detected in the analysis of the education system, that the generation of knowledge through R&D is gathered in the biggest world economies, with levels highly determined by the activity structure in the country, leaving again the countries with less income and development apart from the global attention. Private R&D, in contrast with the public one, has empirically suffered a reduction in the number of scientific and technological articles published. This trend is related to the strategic protection of knowledge and the expenditure savings imposed by private profit-maximising

enterprises (Tijssen, 2004). Again, there are excluding dimensional mechanisms. Hence, a relevant public intervention normally takes place in the most part of the countries, whether in the education system or in the researching system.

The analysed generation of knowledge is just one part of the problem: the diffusion of knowledge, attached to the private features and the tangible nature present in the means, is the other part of the problem. Thus, scientific and technical knowledge accessibility is a global problem that requires more attention (Swan, 2013). This is the reason why the next section is dedicated to formulating a very specific proposal to solve the knowledge provision by influencing the transmitting mechanism primarily, but with a secondary impact on the obtaining mechanisms, as far as the transmitting mechanisms support the obtaining mechanism and vice versa.

5 A proposal to solve the problems of knowledge provision: the diffusion through the Internet and the Open Access policies

The state of the art review, summed up in the past sections, recommends studying the solution to the provision problems by focusing on the generation of knowledge and in its transmitting means, as done theoretically and empirically. This analysis cannot be unconnected to the institutional moment in which it is performed. Knowledge has historically maintained its features because, by definition, they are invariant. Notwithstanding, the social development and the triumph of a globalisation model based on information and communication technologies have modified the transmitting mechanisms of knowledge, as well as the current socioeconomic powers. Following the presented example, a scientific truth has always been a scientific truth, but the transmitting mean of this piece of knowledge has not been the same in the ancient Greek academies, after the invention

of the printing machine or in the digital revolution era. It is said that, at the present moment, a transition from an industrial economy to a knowledge economy is being completed. In this knowledge economy, the risk of monopolistic behaviour has more harmful consequences and the former socioeconomic powers have been deeply modified (Stiglitz, 1999b). The triumph and the diffusion of the current predominant economic paradigms together with the globalisation process and the development of a knowledge economy have deeply change the socioeconomic context (Olssen & Peters, 2005). This redistribution of power and the alteration of the socioeconomic context due to knowledge is summarised in the ‘economy of abundance’ in contrast to the theory of scarcity, in the minimisation of distances and geographic location impacts, in the modification of national sovereignties, and in the features of human capital. Accordingly, the institutional analytic scope, as long as it permits the understanding of produced alterations over the incentives schemes on a social scale, acquires a substantial utility.

Once knowledge is generated as a combination of public and private efforts depending on the type of the good object of study and the institutional framework, it is time to consider the transmitting means for the obtained knowledge. The main problem found during the initial academic revision is the private features that the transmitting means show: regularly, they present rivalry or excludability. The example provided was the case with the tangible book and the printed scientific journal. Therefore, the proposals to solve the problems must look for the minimisation of rivalry and excludability. In the current institutional framework, conditioned by the development of Telematics and the globalisation process, two diffusion tools stand out with special intensity in coherence with that pretentions: the use of the Internet and the generalisation of Open Access policies.

The use of the Internet as a transmitting mean for knowledge

reduces the found rivalry. The problem of insufficient provision or the difficult access is linked to the rivalry of diffusion channels: the mentioned tangible books or scientific journals cannot be consulted simultaneously by multiple users. Rivalry, in this case, appears attached to the tangible nature of means. If these means avoid using tangible formats and opt for a digital format that is stored in a physical location only, like the computers in a library, the problem is identical to the initial one: computers are rival and knowledge cannot be consumed simultaneously. However, if the digitalised documents are uploaded to a global, wide and accessible network, the rivalry problematic is reduce to a minimum. In this analytical moment, the Internet is proposed as a solution. In fact, the Internet as an economic good, is habitually considered an impure global public good (Marín & García-Verdugo, 2003; Sandler, 1999). The Internet access is normally private. Nevertheless, its ability to reduce the information rivalry leads to the equalisation of private profits and social profits. This equalisation moves the provision of knowledge closer to its social optimum. In spite of these advantages in comparison to material means, the employment of the Internet as a transmitting channel does not avoid all difficulties, that is why it is considered an impure global public good:

The Internet reduces the rivalry in transmitting channels, but it can face congestion in some contexts (Huberman & Lukose, 1997). Congestion is a phenomenon produced by a massive employment of the Internet, partially or totally blocking its correct functioning and its derived utility as a non-rival channel. The congestion problems can be tackled with the development and use of technological innovations that order traffic and optimise the capacity and employability of the network. However, as the Internet grows and evolves, the challenges that must be faced are bigger are require, coherently, more advanced solutions (Papadimitriou, Welzl, Scharf,

& Briscoe, 2011). Not only does it refer to congestion, but also to the security of users, challenged by threats such as the propagation of malicious codes (Jang-Jaccard & Nepal, 2014) or the facility to spread biased or false information (Anderson & Rainie, 2017). The Internet is a tool born thanks to the generation of knowledge, as the rest of mentioned innovations that must be put in force to maintain its functionality. It is curious that, in order to solve the problems in the provision of knowledge, knowledge must be previously available.

Concerning its excludability, the Internet is susceptible of being provided at a determined price and could be unavailable under some circumstances. Certainly, its price (the cost of the access plus the cost of the necessary hardware and software) is inferior to the potential profit that it provides (Huberman & Lukose, 1997). Nonetheless, the need of satisfying a price or having an initial training to understand the functioning of this technology, compatible with ‘knowledge decoding’, generates interpersonal access difficulties, restricting the access in some social sectors. Due to cost and availability, since its introduction, the Internet penetrated successfully in entrepreneurial and academic contexts, where the precise investment in infrastructure and maintenance could be made. Domestic units had to make greater efforts to get access. Consequently, the level of domestic use is a more significant indicator when it comes to detecting the technological democratisation.

Between 2010 and 2016, the number of world users grew by 70% (ITU, 2018). In 2016, 85% of domestic units in the European Union had Internet access. 97% of them accessed through broadband. This datum means a major increase in its use during the last decade. In 2007, an access point was present in 55% of households, and only one half used broadband. However, 14% of the population have never used the Internet. Pioneer countries in Internet availability are located in Western Europe and, especially, in the Nordic area, where

domestic users were already high at the beginning of the decade. The areas where it was less used and that have registered a bigger increase in the last years are in Southern and Eastern Europe. People who never used this technology before tend to be located in the South-East of the Union, especially in the Mediterranean area and the Balkans. People who use it on a daily basis tend to be located in the Nordic area (EUROSTAT, 2018). It can be observed that countries with higher purchasing power have had a more intensive use of the Internet or have reached a higher level more quickly, while countries with lower purchasing power have access difficulties and the least broadband availability. This European trend has been empirically found at a global level. There is a positive correlation between the purchasing power measured by the income and the degree of Internet access (Poushter, 2016). In Poushter's (2016) data, a direct relation between income, access and location is also perceived. Developing or emerging economies, with per capita income in purchasing power parity lower to USD 30,000, use the Internet less than 80%. Countries under USD 10,000 register less than 40% of accesses. Between USD 10,000 and 20,000, the rate increases up to approximately 80%, and between USD 20,000 and 30,000 there is barely any increase. It is, thus, the income range from USD 10,000 to 20,000 the one that allows an occasional access to the Internet. However, as stated, the geographical location combined with income plays a fundamental role. Ukraine and Philippines have the same income level in the sample (approximately USD 10,000). While Ukraine presents an access equal to 60%, Philippines remains in the 40% area. Generally, countries in Africa and Asia-Pacific are the ones with greater difficulties to access in spite of income, whereas Latin America, Middle East and Eastern Europe have fewer difficulties. The generalisation and the advances in wireless connections during the past decades have decreased its price and facilitated the

democratisation of this technology (ITU, 2018). Yet, there is also a barrier to its use caused by other sociodemographic conditions apart from purchasing power, like sex, age and education level. In two-thirds of the world, the percentage of male Internet users is superior to the percentage of female users. The areas having a higher parity of composition are America, the Nordic countries, Western Europe and Western Oceania (ITU, 2018). In the European Union, the data in 2016 proved a relation between use, age and education. 96% of Europeans aged between 16 and 24 use the Internet at least once a week, while only 57% of the citizens aged between 55 and 74 use it in such frequency. By the same token, 96% of European with higher training access with the mentioned frequency, a percentage that falls to less than 60% in the less trained group (EUROSTAT, 2018). Countries with greater gender equality in higher education also register a higher equality in the Internet use (ITU, 2018). Internet access problems are related in its demographic variety (age, education, and sex) to the problems of access to an equalitarian and efficient education system described in the previous section: an inadequate education level is an excluding mechanism to access technological transmitting mechanism, such as the Internet. Internet unavailability caused by technical determinants is placed in rural areas and in countries with a smaller degree of development. In less developed countries, the number of physical connections per 100 inhabitants are nearly non-existent and have grown more than 50% since 2012 (ITU, 2018). Technical improvements are also used to alleviate the problem of access in these places.

As shown, the Internet is an appropriate transmitting mean to solve some problems in the diffusion of knowledge. However, according to these findings in a global scale, it does not seem to be very recommendable to provide a global public good like the knowledge, as it can create biases in the access: there are interpersonal, inter-

national, and intergenerational barriers related to sex, age, location, income and education. If societies want to leverage the advantages that the Internet provides as a diffusion channel, something more than improving its technical development and its coverage is needed. It is necessary to apply a comprehensive policy to reach the equal opportunities that require the provision of a global public good with powerful social effects like knowledge. That is the reason why, in a majority of countries, a public intervention has been carried out to promote laws and plans to assure the equal access and the effectiveness of the Internet in harmony with the mentioned goal (European Commission, 2018; Dutton, Dopatka, Hills, & Nash, 2011). Currently, there are equally harmful regulations to the users such as the censorship and the measures that threaten Internet neutrality.

Even though the found difficulties could be solved, having an Internet connection with a low congestion, affordable, technically advanced and egalitarian does not solve all knowledge provision problems. What happens if there is an adequate Internet access but online available knowledge is exclusive? With the aim to ensure that the social efficiency is present in the provision of knowledge through the Internet, besides alleviating the rivalry problematics (congestion) and the excludability (non-affordable price and lack of equity) in the accessing technology, it is indispensable to solve the problematics of excludability that diffused information can show. An Internet where information can only provide utility to some user is not a socially useful tool to disseminate knowledge. This is the case of high access costs, censorship, etc. (European Commission, 2018; Dutton et al., 2011; Gillies, 2012). All of these problems present again exclusion mechanisms over international and interpersonal dimensions. In the group of policies oriented to favour the universality of online information, the most outstanding measures in the current moment are the so-called 'Open Access policies'. The three sources

that established a compromise with the diffusion of information in an Open Access format were the Bethesda Statement, the Berlin Declaration and the Budapest Initiative, that gathered both private and public efforts.

The Budapest Initiative summed up the definition of ‘Open Access’ as the free online public availability of knowledge so that any user can benefit from it without financial, legal or technical restrictions different from those linked to the Internet access itself (The Budapest Initiative, 2001). The Bethesda Statement and the Berlin Declaration gave a more agreed and detailed definition. ‘Open Access’ is the knowledge contributing policy in which the author and the intellectual property rights holder guarantee to every user in an equal way the free, permanent, and global opportunity to access a contribution, in an online acceptable format, as well as the right to replicate it, use it, share it, transmit it, and display it publicly and responsibly with the only limitation of specifying the authorship (Berlin Declaration, 2003; Bethesda Statement, 2003). Open Access is positive because it streamlines and highlights the research efficiency and the obtaining means of knowledge, facilitates the interdisciplinary cooperation, increases visibility and the impact of knowledge and its generating mechanism, and allows everyone to benefit from knowledge (Swan, 2013), even easing the intellectual property rights problematic.

The European Union, since an Official Communication in 2007, has been especially working on the development of open institutional repositories in coherence with its education and R&D policies (for instance, OpenAIRE and H2020). This kind of repository is managed by verified and recognisable institutions, such as universities or research centres. These institutions gather the materials, digitalise them, adequate them to the legal requirements, disseminate them, and supervise the good academic practices compliance.

The majority of repositories have only existed for a decade, but it is said that they have become an innovative channel of spreading knowledge that has deeply modified the research, communication, and education paradigm. It is especially remarkable the feedback that the creating and transmitting processes present. At the beginning of this paper, the analysis distinguished between the generating mechanisms and the transmitting mechanisms. The evolution of the transmitting mechanisms has an impact on the generating mechanisms of knowledge. The availability of high-quality Open Access information is sided with the advances of technology and communications that have motivated the spreading of new online education models, such the triumph of ‘MOOC’ (‘Massive Online Open Courses’), the distance education or the cooperation between research networks in a global scale (Koutras & Bottis, 2013). The popularisation of MOOC and distance education, in general, proved that scientific publications not only have lost their rivalry and excludability but also courses and institutions have suffered the same process. A growing number of users can benefit from an education service or research results hundreds of kilometres away from the place where knowledge is generated, in an instantaneous manner, with little rivalry or excludability. Knowledge globalisation is a reality. Currently, Open Access gathers diverse issues like open education resources management, open science, open innovation, and open data, setting a wide socio-political agenda (Swan, 2013).

More recently, the Open Access movement has received the support of the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2013). Since the 31st July 2013, UNESCO publications must be published under an Attribution 3.0 IGO, that allows the transmission of knowledge in any channel as well as its adaptation on any circumstance (even commercial) with an unlimited duration and without any legal or technical barriers as long as

authorship is recognised (Creative Commons, 2018). This licence is suitable to disseminate Open Access knowledge because, as can be seen, it satisfies all requirements proposed by Bethesda, Berlin, and Budapest. Besides, it alleviates the possible harmful effects of intellectual property rights while protecting the legal authorship.

Beyond the cited statements, declarations, and initiatives on a global scale, there are some compromises in an international, national and regional level. At an international scale, it is remarkable the existence of recommendations launched by the European University Association, the Alhambra Declaration jointly with the Southern European Libraries Consortium, the Hague Declaration made by the Consortium of European Research Libraries, and the Statement of the Science Ministers at the G8. In Spain, it is remarkable the compromise of the Spanish Science and Technology Foundation (FECYT) at a national level, and the Madroño Consortium Statement at a regional level, in the Community of Madrid (FECYT, 2018).

The statements, initiatives, and proposals developed by the organisations in different administrative levels highlight that the Internet is a key technology to transmit knowledge and must be open, neutral, transparent, and social to work properly. They also believe that the proliferation of Open Access projects is causing serious economic, political and social changes, some of them, like the decreasing revenues in editorial companies or the increasing costs of authorship, are hardly acceptable by the establishment. Thus, they request the existence of public measures because, in spite of these consequences, they consider that Open Access is a priority to preserve the essence of the Internet and to stimulate the scientific and technologic progress in a globalised society. The main political proposals are: stimulating the Open Access publishing among researchers, encouraging the support of knowledge holders, develop-

ing assessment methods that enhance the quality of disseminated Open Access knowledge (like double-blind peer to peer review), including Open Access publishing among the assessment requirements of research activities, and developing computing tools to protect and recognise authorship.

Among promoters and supporters of Open Access, there are public agents as well as private agents, international institutions as well as national, regional or local institutions, non-profit organisations, and scientific communities. Despite their diversity, they all have in common that they work to internalise the external social profits caused by knowledge and reach, therefore, an efficient provision of knowledge consistent with the mentioned issues along this paper.

At a practical level, Open Access has two modalities: gold Open Access and green Open Access.

The gold Open Access refers to the transmission of knowledge through regular journals. According to the Budapest Initiative (2001), Open Access journals must use the tools linked to authorship rights to ensure the widest possible diffusion of knowledge, instead of restricting it. Beyond this right, the possibility of charging subscription or access fees to journals is rejected. In order to obtain funds, journals must look for alternatives like private foundations, public subsidies, donations or cooperatives. Gold Open Access is currently facing problems derived from the changes that Open Access has caused on the editorial sector (Alizon, 2018). Provided that knowledge must be available to any user in a permanent and free manner in the same terms stated by the declarations, the traditional business model of scientific and technologic publishers is undergoing a paradigm modification that impacts on its profitability. One of the most immediate solutions that publishers have implemented to take control of the situation is the APC ('Article Processing Charge'). The APC is a fee that publishers collect from authors or from the

funding agents of these authors with the aim of compensating the impact on their revenues while ensuring the accomplishment of Open Access principles. That is to say, APC is a way of transferring to the author the traditional price that users used to pay to access the knowledge: the excluding mechanism via price moves from the user to the creator. This practice is problematic in many ways. At first, the revision process is subject to the advanced payment of the APC independently of the quality: private profitability is prioritised to quality and social impact of obtained knowledge. Secondly, this practice complicates the diffusion of low-budget researches that cannot afford the payment of the APC: the knowledge that is obtained with fewer resources faces a discrimination in comparison with that supported by higher funds, again leaving in a minor position the social criteria that lead to the provision optimum. Thirdly, this trend covers the falling publishing costs over the past two decades. Precisely, the same technological development that combines the Internet and the Open Access availability has motivated the reduction of publishing costs worldwide. Tangible means have been replaced by the Internet and, therefore, the biggest costs for publishers are the ones attached to editing and revising activities, that are also being minimised technologically (in the best of cases). This cost minimisation has attached a tendency to reduce the quality of knowledge, whose diffusion is damaged by the APC and the cost saving actions. The ambition of publishing any knowledge, socially relevant and quality adequate or not, with the aim of benefit from high APC combined with edition savings is called ‘predatory Open Access’. Other usual situations involve the authorship right infraction, the scarce transparency in authorship attribution, the publishing of pseudoscientific contents, the publishing of big journals that gather a thematic ‘hotchpotch’ to attract the highest number of articles, as well as using international enterprises schemes with financial or

marketing purposes (Beall, 2015). Predatory practices, that submit the social and global impact of knowledge to local private profitability, are harmful practices and cannot be considered an appropriate transmitting mechanism: they generate excludability on the interpersonal and international dimensions. In more recent researches applied to some scientific and technical areas, a massive proliferation of predatory practices has been found. Between 2010 and 2014, the number of published articles following these practices have increased approximately 700%, resulting on thousands of predatory journals worldwide that charge an average APC equal to hundreds of USD (Shen & Björk, 2015). With the goal of alleviating this problem that overshadows the advantages of Open Access, most of the knowledge creating or transmitting institutions inform regularly its members to avoid them. As far as predatory practices are perfectly delimited, these institutions and their members cannot put into question their reputation and credibility. Reputation and credibility are both immediate and automatic correcting mechanisms of predatory diffusion of knowledge.

Besides this gold Open Access, there is a green Open Access. Green Open Access refers to the transmission through self-archiving, that is to say, the deposit of knowledge in open electronic archives. Currently, the self-archiving has suffered a huge development. There are open institutional repositories, repositories integrated into researchers' social networks, personal repositories, available publications through verified academic blogging platforms... These means are sponsored by public institutions, for-profit private organisations, and non-profit private institutions, such as experts and academic cooperatives.

It is time to ask what the level of acceptance of Open Access initiatives is in a real institutional framework. In surveys applied to specific university institutions that gather teaching and research

activities, a high consensus on the necessity of using Open Access has been found. However, the generalised good perception about Open Access policies does not correspond to the final percentage of published contents in this modality. The decision of employing Open Access or rivalrous/excludable means is linked to the prestige that they imply or to the necessity of congregating scientific merits. Consequently, it has been found that Natural Sciences, Health Sciences, and Technology are the disciplines that use gold Open Access the most, while Arts and Social Sciences tend to use Open Access less frequently, and when they do it, they use green Open Access. Likewise, it has been detected a lesser awareness about the possibilities that institutional repositories offer, even if they will be a key tool in the immediate future (Serrano-Vicente, Melero, & Abadal, 2016). There is, hence, an unequal quantity of Open Access knowledge among disciplines attached to a different scientific impact capacity among fields of study. In cases of study applied to less-developed contexts, Open Access has been found to be especially positive. The obstacles that knowledge provision has in these places are, mainly, the impossibility to pay the high fees to access transmitting means and the barriers that researchers find when they try to publish their results in international editorial formats, that work under the criteria of a society that is different from theirs. Actually, knowledge is usually lead by institutions located in countries with a higher development degree, leaving apart less privileged territories, even though their contributions are equally valuable. Open Access provides independence and permits that all researches reach a level of diffusion, democratising and balancing the obtaining and transmitting mechanisms of knowledge, even if there is still a long road to guarantee online open knowledge (Chan et al., 2011).

According to UNESCO, the answers that an Open Access political measure must provide in order to potentiate the social profits

and minimise the impact of mentioned problems are diverse (Swan, 2013). First, it must promote the freedom to choose among the Open Access varieties and the transmitting mechanisms available, prioritising the gold Open Access and increasing the transparency of the APC. Second, the policies must cover all types of contents: articles, books, research conclusions. . . Third, the time passed from the moment when results are obtained to the moment where these results are completely accessible must be restricted. Fourth, a stronger supervision of authorship must be put into force. Finally, these policies must gather the support from competent institutions and the power to apply effective sanctions in case of infringement.

It is essential that Internet democratisation measures and Open Access policies are applied together in every moment. On the contrary, rivalry and excludability will burden the use of the analysed technologies to provide knowledge in an efficient way coherent with its global public good nature. An Open Access Internet solves the transmitting problems explained, and also, has a substantial impact on education systems and research activities.

6 Conclusions

Once that the proposed methodology has been completed, some results have been reached to answer the questions and goals fixed at the beginning of the research.

Concerning the first and the second secondary goals, this analysis has focused on scientific and technological knowledge due to its clear economic connotations and because it is a global public good: it is a non-rival and non-excludable good with interpersonal, international and intergenerational transcendence. Nonetheless, it is a singular good: knowledge is needed to solve the provision problems of knowledge. With the aim of simplifying the analysis, a distinction has been introduced between knowledge itself, a pure global public

good, and the obtaining and transmitting means, generally rival and excludable private goods.

Answering the third goal, the rivalry and excludability that obtaining and transmitting means present are the responsible elements to cause a social non-efficient provision, generating access problems and insufficient use, a market failure. According to efficiency criteria, knowledge should be available at zero price. However, the retribution of the mentioned means in private markets causes a positive price, besides the apparition of other socioeconomic mechanisms of excludability over the international and the interpersonal dimensions.

As far as the fourth goal is concerned, it can be concluded that the proposed solutions to solve the problems of knowledge in the actual institutional framework usually appeal to a public intervention, in such a way that provision mechanisms are mixed, public and private. Such intervention goes from the minimalist practice consistent in recognising intellectual property rights to the granting of subsidies or the internalisation of activities in the public sector. Public intervention can be negative if it results in public failures. A proposal to solve the problems of knowledge does not need to be necessarily public or mixed: it must be social, that is to say, it must recognise the appearance of externalities linked to knowledge and their social impact.

Referring to the fifth goal, a solution proposal based on diffusion has been provided: the employment of the Internet and the Open Access policies, in coherence with the globalisation process partially caused by the information and communication technologies. The Internet and the Open Access policies are not perfect means of diffusion. The Internet shows congestion and excludability through price or socioeconomic conditions, all of them are problems that are suffering a decrease due to innovations and technology democrati-

sation. The introduction of Open Access policies carried out by the publishing sector has caused excludability problems when moving the economic charges from the user to the author, as well as predatory behaviours focused on the search of private profitability instead of social criteria. The Internet and the Open Access initiatives must be necessarily applied jointly to solve the provision problems. This dual solution has gathered private and public supports, from international institutions and national, regional or local administrations, as well as from for-profit private organisations, non-governmental organisations, non-profit cooperatives, and academic communities, among others. Nevertheless, a minimalist public intervention is needed to guarantee its correct functioning and to solve the interpersonal and international problems.

Knowledge is the driving force for economic and social progress. Due to its nature, it must be studied and provided according to social criteria. The current institutional framework, defined by technologies such as the Internet and initiatives like the Open Access policies in a globalised world, challenges the rivalry and excludability related to knowledge and moves its level of provision closer to the social optimum: ‘Omnibus mobilibus mobilior sapientia’.

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