'The knowledge economy, the crash and the depression'

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1. Introduction

The knowledge economy is generally invoked as the key to progress, development and prosperity. Since the work of Schumpeter (1934; 1942), knowledge production and innovation have been identified as distinctive features of market economies, crucial to overcome societal inertia and, as later recognized by Abramovitz' (1959) and Solow's (1960) seminal contributions, more relevant than capital accumulation to explain growth. A recent strand of research has, however, emphasized that the present institutions of the knowledge economy, far from being infallible engines of economic growth, embody features that may lead to their own demise, resulting in stagnant growth.

The key to understanding why the endgame of the knowledge economy may be crash and depression is the analysis of the dynamics leading to a reduction of investment opportunities as a consequence of the escalation of knowledge enclosures associated to the strengthening of the intellectual property (IP) system and the weakening of the traditional institutions of 'Open Science'. The progressive monopolization of intellectual resources gives rise to both virtuous and vicious feedback effects between the distribution of intellectual assets and incentives to learn and develop new knowledge. Even where virtuous cycles are at play, however, the more the share of non-privatized knowledge shrinks in favour of intellectual monopolies, the less global investment opportunities tend to be available and therefore the less the knowledge economy is able to keep its growth promises.

The ongoing reduction of the share of publicly available knowledge resources is compounded by the political economy of IP protection and public funding of Open Science. At the national level, large firms' rent-seeking activities and corresponding decision makers' capture may explain many aspects of the evolution of national IP systems and innovation policies. However, this is not the end of the story. At the international level, many forces are at play that conjure up to increase the extent of knowledge enclosures.

Contemporary international IP treaties such as the Agreement on Trade-Related Aspects of Intellectual Property Rights (henceforth, also TRIPs Agreement) involve reciprocity rules such as that of 'national treatment': to obtain IP protection for their nationals in signatories to the Agreement, countries have to grant foreign inventors the same treatment as they grant to domestic inventors. Once rules of this type are in place in the international IP domain, countries' incentives to (upward) harmonize their IP rules are magnified and an excessive degree of IP protection tends to result, not just for the majority (of nations) but arguably for all.

More generally, the global commons nature of knowledge resources creates scope for free-riding phenomena whereby each country has an incentive to use the public knowledge of other countries and to over-privatize the knowledge that it is producing, leading to a one-way ratchet of increasing IP protection. Both at the national and at the international level, the problem is reinforced by ubiquitous feedback effects: once IP institutions are in place, firms (countries) find themselves in a prisoner's dilemma situation whereby patenting (strengthening patent protection and reducing the scope of publicly available knowledge) is a dominant strategy for all even if choosing a strategy of greater openness would be consistent with joint welfare maximization.

In this paper, we propose that the existence of these forces endogenous to the knowledge economy and with self-reinforcing features should be conceived of as a new rationale and foundation for science policy, and particularly for a *global* science policy. Since there is no spontaneous antidote to the progressive drift towards excessive knowledge privatization, public policies expressly recognizing the risks inherent in over-privatization of intellectual resources are sorely needed. Moreover, these policies require efforts at international coordination, so as to avoid the inevitable distortion of incentives to invest in public research following from uncompensated cross-border externalities.

Our perspective suggests not only that neoliberal prejudices against direct public investments in research should be abandoned, but also that the issue of whether to fund public research should not be considered separate from the question of the appropriate form of diffusion of publicly-funded research results. Absent explicit policies aimed at redressing the balance between private and publicly available knowledge, the knowledge economy will hardly be able to meet its growth-enhancing promises.

The paper is organized as follows. Section 2 illustrates the reasons put forward to explain why the endgame of the knowledge economy may be crash and depression. Section 3 engages with the issue of the political economy of knowledge enclosures. Section 4 articulates the rationale for a new (global) science policy. Section 5 concludes by summarizing the main questions for future research.

2. Why may the endgame of the knowledge economy be crash and depression?

The widespread faith in the growth-enhancing features of the knowledge economy and of the underlying pillars of scientific and technological research and innovation has gone, in the past few decades, hand-in-hand with a similarly widespread belief that private property-like institutions may deliver in the realm of intangibles exactly the same sort of benefits they deliver in the tangible domain. This intellectual position has coalesced with the more mundane interests of the large corporations of the developed world (most of which are highly IP-intensive), leading to an unprecedented strengthening of intellectual property protection at the global level (on which more will be said in section 3).

The pervasiveness of the propertisation of intellectual resources has also been sustained by extraordinary technological developments that, on one side, underline the extension of patentable subject matter and, on the other side, increase the scope for global copy and imitation of inventions and intellectual creations; both of which then lead to further tightening of IP laws. Advancements in information and communication technologies as well as the growing complexity of interactions across different scientific disciplines (e.g., in the realm of nanomaterials, bioinformatics etc.) are increasingly blurring the once much clearer distinctions between basic and applied science, leading to a significant expansion of so-called "Pasteur's quadrant" (Stokes, 1997), i.e. of the scope of scientific research that is simultaneously basic and applied.

Products, production processes and entire industries are characterized by ever greater complexity and draw on inherently intertwined and cumulative innovations that are typically related both to numerous prior basic and applied research results and to parallel technological developments. With blurring lines between the realm of technology and the realm of pure science and the definite dismissal of the linear model of innovation (see Edgerton chapter), the *scope* of patentable subject matter has thus increased considerably. At the same time, the pervasive global diffusion of ICT technologies has broadened the *global reach* or *scale* of

technical knowledge and innovations, simultaneously expanding the scope for their misappropriation.

These scientific and technological developments also hint at some of the reasons why the analogy between property and intellectual property that underpins many policy discourses (in the domain of trade policy, industrial policy as well as science policy) is misleading and dangerous for the knowledge economy itself. Unlike tangible property, intellectual property involves a much greater scope for overlap of "exclusive" rights. This makes it difficult to securely identify the owner of a given intellectual resource, gives rise to costly and unproductive conflicts in enforcement and, most importantly, may hamper its productive exploitation.

The root cause of this is the inherent (quasi) 'public good' (see below) features of knowledge ([ref]). This gives rise to a mismatch between the legal relations defined by private property and the intrinsically unbounded nature of knowledge and information as productive resources (Arrow, 1996, p.651). Non-rivalry of knowledge – meaning many people can use this 'good' at the same time without incurring additional marginal costs – entails that the artificial exclusion of third parties associated to intellectual property comes at the cost of an inefficiency. This inefficiency is usually accepted as a necessary evil in exchange for greater incentives to produce the underlying knowledge. However, non-rivalry also entails that the size and potential extent of the exclusion associated to intellectual property is of an order of magnitude that is incomparable to that of private property. As argued by one of us elsewhere: "*the full-blown private ownership of knowledge means a global monopoly that limits the liberty of many individuals in multiple locations*" (Pagano, 2014, p.1413).

Contributions from many intellectual backgrounds and with different research agendas have started to recognize these tensions and to highlight reasons why the undeniable trend of propertisation of knowledge resources may be excessive from the social standpoint and may end up undermining the functioning of the very engines of knowledge production.

A first strand of the literature focuses on the drawbacks of the current intellectual property institutions, with special regard to the patent system. Contributions belonging to this category typically delve into the link between patents and innovation and highlight the existence of effects standing in contrast with the claim that greater patenting necessarily entails greater innovation. Sceptical views have been expressed by many legal scholars, especially by those that have been most directly exposed to the real-world mechanics of the intellectual property regime (e.g., Lemley, 2005; Benkler, 2002; Samuelson, 2006). However, there is by now also a consistent body of economics literature (well represented, for instance, by the books by Bessen and Meurer, 2008; Boldrin and Levine, 2008 and Jaffe and Lerner, 2006) advancing the view that patents may actually have in many instances a detrimental effect on innovation. This view has, especially after the inception of the 2008 crisis, been taken up in the broader policy discourse even by mainstream voices such as *The Economist*.

A number of contributions has long shown theoretically that, when research is sequential and builds upon previous innovations, stronger patents may discourage follow-on inventions (Merges and Nelson, 1990; Scotchmer, 1991) and that overlapping patent rights may give rise to the so-called "anticommons tragedy", an instance of underexploitation of intellectual resources due to the excessive proliferation of veto rights over their use (Heller and Eisenberg, 1998).

Similarly, from the empirical standpoint, it has long been known (at least since the 1980s) that in most sectors, patents are at best of limited usefulness and that firms often deem formal protection mechanisms less effective than the alternatives (Mansfield, 1986; Levin et al., 1987; Cohen et al., 2000; various editions of the Community Innovation Survey), yet their

propensity to patent remains high. A number of studies has pointed out that firms may be patenting *because other firms are patenting* rather than for the intrinsic usefulness of patents. A 'patent paradox' may be at play: the patent system may be creating incentives to patent rather than to invest in R&D (Hall and Ziedonis, 2001), especially as firms refine their use of patents as a strategic tool to pre-empt competitors' innovative investments, to improve bargaining positions in licensing and/or to defend themselves from patent litigation (see, e.g., Arundel et al., 1995; Duguet and Kabla, 1998; Reitzig et al., 2010).

Other research has uncovered the distortionary effects patents may have on innovation, by inducing costly duplications of research efforts (inventing around), by distorting firms' technological trajectories, forced away from areas with greater risks of third party IP infringements, and by discouraging altogether the undertaking of those innovative projects that are most likely to incur problems due to patent overlaps. These problems are compounded in areas where products are technologically complex and firms' patent portfolios can reach a substantial scale – an instance often referred to as the problem of "patent thickets"[1].

Lerner (1995) finds early evidence that new and small biotechnology firms that have high litigation costs refrain from patenting in areas where they are more likely to infringe on existing patents, particularly where ownership belongs to (large) firms with low litigation costs. Cockburn et al. (2010) provide evidence of the fact that the need to licence-in patents reduces firms' innovative performance, by performing a survey of German innovating firms. Noel and Schankerman (2013), in a study focused on the patenting in the computer software industry between 1980 and 1999, find that companies facing a high concentration of patent portfolios of their main rivals refrain from investing in R&D in those areas where rivals' patent portfolios are stronger.

A contiguous domain of research is that considering academic patenting. The 1980 U.S. Bayh-Dole Act has allowed the patentability of federally funded research results, opening the way to a trend of increasing propertisation of publicly funded science that has rapidly expanded into many OECD countries (and increasingly beyond – e.g. see Suttmeier chapter on China). The purported rationale for this shift in science policy is many-fold: to ease commercialization, to counteract the effect of shrinking public funding for science and, more generally, to re-orient academic and Public Research Organizations' (PROs) research towards directions suitable to better contribute to the growth-enhancing promises of the knowledge economy. In this regard, research has mainly focused on a double link: between patenting and speed of scientific advancement; and between academic patenting (particularly of research tools) and diffusion of research results (for a concise survey, see Franzoni and Shellato, 2011).

Three main results of this literature are relevant for the purposes of the present paper. The first is that Universities and Public Research Organizations appear not to be very good at the patenting game, both if one looks at the share of their patents over total patenting (about 5% of active patents in the US, according to Thursby and Thursby, 2007, and a similar share in Europe according to Lissoni et al., 2008) and at the amount of revenues they are able to raise (Geuna and Nesta, 2006).

In addition to raising doubts about the effectiveness of academic patenting in promoting commercialization, this should be sufficient to raise the question whether, from the PROs' standpoint, the prospective benefits of patents outweigh the certain restriction to the freedom of research involved by the inevitable curtailment of the research exemption[2]. Indeed, while

[1] Shapiro (2001) refers to "patent thickets" as to dense webs of overlapping patent rights, mostly belonging to multiple firms' large patent portfolios.

[2] In the United States, the key judicial decision sanctioning the curbing of universities' research exemption is considered to be the Federal Circuit Court of Appeals' decision *Madey v. Duke University* (307 F.3d 1351, 1362 (Fed. Cir. 2002). In this decision, the Court has held that the exemption "does not apply to activities conducted in

universities have traditionally enjoyed a relatively wide exemption from infringement of patent protection for the purpose of scientific experimentation, as academic patenting and overlaps between public and private research increase, it remains to be seen whether PROs activities will continue to be considered entirely part of scientific experimentation and thus shielded from liability.

Second, evidence exists that academic patenting hampers diffusion of research results. One particularly interesting paper considers the 'natural experiment' given by the release into the public domain of patents related to a genetically engineered mouse (Murray et al., 2009). The authors find that the extent of research in the area significantly increased and became more diversified, with the opening of new research trajectories that were not pursued when patents were in place. With a different methodology, Franzoni and Scellato (2010) find significant delays in publication in scientific journals when results are patented. Finally, Campbell et al. (2002) and Walsh et al. (2007) find evidence of the withholding of information, data and materials on which research is based.

Third, not much can be said on the effect of patenting on the speed of scientific advancement. While simple trade-offs between publishing and patenting do not seem to be at play if one looks at the productivity of single researchers (e.g., Azoulay et al. 2009), there currently is no research addressing the key issue, from a broader systems perspective of the productivity of science more generally, of whether substantial negative externalities for other researchers in the same field are associated to patents (Franzoni and Scellato, 2011).

While the contributions so far mentioned have focused on direct causal links between patenting and innovation or patenting and scientific advancement, the authors of the present chapter have, in previous works, proposed the view that the links between IPRs and innovative investments have a self-reinforcing nature, which is at the root of both patterns of unequal distribution of intellectual resources and chances for growth and of a global progressive reduction in investment opportunities. This, in turn, points to the existence of a mechanism endogenous to the knowledge economy that may be part of the explanation of its crisis.

The starting point for the recognition of the self-reinforcing relationships existing in the intellectual property domain is the mentioned difference between the property of tangibles and intellectual property. The key efficiency argument underlying the existence of private property institutions is linked to the incentive effect property is able to generate. Owners have incentives to maintain, improve and productively use their tangible property. Most importantly, they have incentives to invest in specific and value-increasing human capital, as recognized by proponents of the new property rights approach (e.g., Hart, 1995). Pagano and Rossi (2004) have highlighted that this incentive effect is much stronger for intellectual than for physical property because IP owners enjoy a right not just to use but to *exclude* that has a much broader scope, as it entails a restriction of the liberty of third parties to replicate similar means of production. This, in turn, is at the origin of important feedback effects: while owners have heightened incentives to invest in IP-specific learning and human capital and to further acquire intellectual assets, non-owners are disincentivized from investing in the acquisition of intellectual capital. Both virtuous circles of accumulation and vicious circles of exclusion from intellectual capital ensue, with evident self-reinforcing properties.

This perspective makes a step further from the mentioned analyses focusing on the effects of firm and patent portfolio size on R&D investment and patenting patterns by highlighting the

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the contest of the normal "business" of a research institution, either for-profit or not-for-profit". It is clear that the more PROs engage in patenting, the more their activities will be considered part of business, unworthy of a research exemption. In Europe, acts "done privately and for purposes which are not commercial" and acts "done for experimental purposes relating to the subject matter of the invention" have traditionally been shielded from liability.

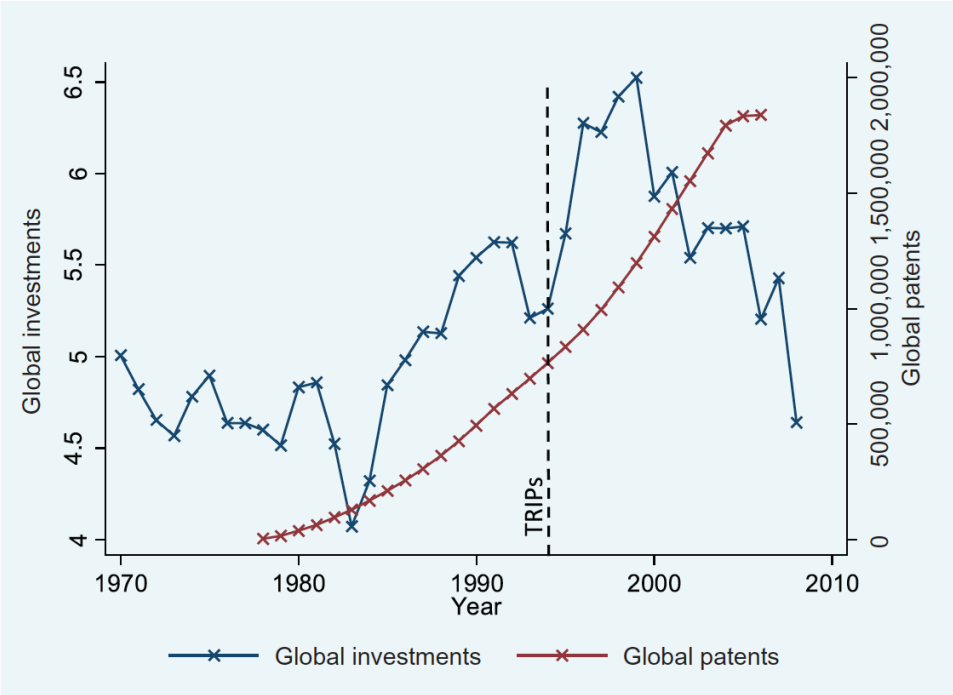
self-reinforcing nature that these effects may have at both firms' and countries' level. At the firm's level, ever-increasing knowledge propertisation has the effect of preventing the development of more democratic forms of organization of production. This is paradoxical, considering that the higher knowledge content of contemporary production would appear *prima facie* to enable greater democratization of production (Pagano and Rossi, 2011; Pagano, 2014). When monopoly rights are in place and much knowledge relevant to production may be codified, disembodied and legally protected, capitalist firms enjoy a cost advantage with respect to workers-owned firms because their size and the artificial excludability induced by IP feeds into a dramatic form of (firm-level artificially restricted) increasing returns.

The self-reinforcing effects of intellectual ownership are even more profound at the country level. IPR endowments tend to be at the origin of new forms of comparative advantage in the 'knowledge economy' (Belloc and Pagano, 2012): given pervasive and global IPRs, countries find obstacles in specializing in those productions that depend heavily on IP-protected knowledge held by other countries. This gives rise to patterns of forced specialization that feed into global trade, constituting a novel cause for increased international exchange, along with the classical explanations provided by trade theory. What is most relevant is that these patterns of forced specialization tend to perpetuate in time, giving rise to trajectories of development *and underdevelopment* associated to the unequal initial distribution of IP endowments into IP-, and hence rent-, rich and poor worlds.

Pagano and Rossi (2009) and Pagano (2014) have argued that this sort of feedback effects do not impact only on the relative gains and losses of asymmetrically endowed countries, but also on the overall availability of investment opportunities, and thus, on growth at the global system level. The overall effect of the global strengthening of IP protection may, indeed, have been a global contraction of the chances for productive investment, which may be considered to underlie the recent crisis. The lack of good investment opportunities, together with abundant capital and lax financial regulations may explain why capital was redirected away from productive uses, thus giving rise to the housing bubble and the ensuing subprime crisis (Pagano and Rossi, 2009; on financialisation, see also chapters by Lazonick et al. and Birch). Moreover, knowledge propertisation contributes to the financialisation of the economy, as it turns intellectual resources into securely owned and tradable assets that, having no value defined in a competitive market, are easily exposed to the vagaries of speculative expectations (Pagano, 2014).

The evolution of global investment appears coherent with the view that global IPRs are progressively curtailing investment opportunities. As can be seen from figure 1, after the major event triggering the global strengthening of IPRs (the 1994 Agreement on Trade-Related Aspects of Intellectual Property Rights - TRIPs) (e.g., May and Sell, 2006), global investment rose for about five years and then started a continuous decline. Our contention is that this global decline is to be attributed to the progressive erosion of the availability of non-privatized knowledge.

Figure 1. Global patents and global investments



Source: Belloc and Pagano (2012)

Thus, the uneven distribution of knowledge is an important cause of overall economic inequality and a brake to global growth. In a much acclaimed book Piketty (2014) has emphasized how a rate of profit greater than the rate of growth must necessarily lead to a growing relative impoverishment of the majority of the population. Piketty attributes the origin of the phenomenon to over-accumulation of capital. However, a careful reading of the evidence suggests that a more convincing explanation must be found in the under-investment of real capital goods (Rowthorn 2014), which has characterised the recent decades. This under-investment is consistent with the increase in wealth of the firms because the latter has been often due to an increase in their monopoly rents (and also of the overall profit rate earned on their capital). As argued by Stiglitz (2015 p. 24): "[i]f monopoly power of firms increases, it will show up as an increase in the income of capital, and the present discounted value of that will show up as an increase in wealth (since claims on the rents associated with that market power can be bought and sold."

Knowledge propertisation, although so far disregarded, may be an important part of the explanation for the puzzling simultaneous occurrence of under-investment, wealth accumulation, high profit and low growth. When much knowledge moves from the public to the private sphere the increased monopolization is likely to increase profits and to decrease growth. And, moreover, almost by definition, subtracting from public knowledge resources increases inequality: everyone has equal rights of access to a public good. By contrast, the privatization of knowledge involves that only the monopolistic owner has full access to it. Thus increased rents (including also those that do not arise from the monopolization of knowledge) are likely to cause both declining growth and increasing inequality. The actual dismal economic record of recent years thoroughly corroborates these theoretical expectations.

3. The political economy of knowledge enclosures

As mentioned in passing in the previous paragraph, the turning point in global IPRs protection is given by the 1994 TRIPs agreement. This is the first international agreement on IP-related matters that, in addition to (upward) harmonizing an almost all-encompassing range of aspects of the legal protection of intellectual creations at the global level, explicitly foresees a mechanism of enforcement, under the oversight of the World Trade Organization (WTO). Since the TRIPs agreement, a number of less comprehensive but equally relevant agreements have contributed to further strengthening global IP protection. TRIPs-plus provisions (meaning those even stronger than TRIPs) have been introduced in countries such as Australia, Chile, Peru, countries of the Middle East and others as part of the negotiation of Preferential Trading Areas (PTAs) with the United States and the European Union. Horizontal agreements among developing countries (e.g., within members of ASEAN) have also raised their harmonized IP standards and procedures. IP-reinforcing provisions are also common in many bilateral investment treaties and international investment agreements (Maskus, 2014).

The rent-seeking activities of large (and IP-endowed) firms in developed countries have been an important trigger of these developments. This is particularly true for US firms who, at the onset of the Uruguay Round of negotiations, were perceived as falling behind their German and Japanese counterparts and were eager to increase the extent of monopoly and oligopoly rents they could appropriate in international markets. These private interests may have translated into industry capture of trade negotiators (Lanjouw and Cockburn, 2001).

However, countries' policy makers may have excessive incentives to strengthen global intellectual property protection even assuming away problems of politicians' capture. Scotchmer (2004) suggests that harmonization of IP protection leads to broader IP protection than would be chosen if choices were independent and to stronger protection than would be optimal from a social standpoint. In addition, she also shows that, under the requirements of reciprocity (national treatment) embodied in the TRIPs agreement, countries have an incentive to tilt the policy mix in favour of IP and away from public sponsorship of research and innovation because the former, unlike the latter, allows to internalize cross-border knowledge externalities.

More generally, the fact that knowledge is a global commons and is therefore exposed to the usual free rider problems that plague this sort of good may contribute to explain why each country has an incentive to use the public knowledge of other countries and to over-privatize the knowledge that it is producing, even more so if globally harmonized protection is in place. Hence each country is pushed towards a portfolio of instruments for intellectual property management that increases the weight of patenting well beyond what would happen in a closed economy and beyond the socially efficient level. This, in turn, amounts to a form of national free-riding on the global knowledge commons that can be seen as an instance of unfair competition. Seen from this angle, it is thus striking that this form of unfair competition goes unnoticed at the WTO level, while the forms of unfair competition associated to IP violations are severely sanctioned, even by allowing retaliation through trade restrictions (Pagano, 2014).

This free-riding-based incentive to favour privatized knowledge over Open Science (Dasgupta and David, 1994) has gone hand-in-hand with the substantial changes public research systems have been undergoing since the mid-nineties. The more knowledge has been recognized as a key ingredient of growth, the more universities and PROs have been oriented towards serving the training and research support needs of the economy. Reforms have been made to strengthen and intensify public-private collaborations, actively to promote patenting and patent-backed technology transfer with the institution of specialized technology transfer offices (TTOs), and to direct research efforts towards specific societal needs through the increased competitive allocation of funds (Geuna and Rossi, 2015). These developments are changing

the overall attitude of publicly funded science institutions as well as of individual researchers and profoundly affecting the set of norms conventionally associated to Open Science.

This tends to extend to public research the sort of feedback effects that appear at play for firms and countries alike: once IP institutions are in place, producers of knowledge (be they researchers, firms or countries) find themselves in a prisoner's dilemma situation whereby patenting is a dominant but sub-optimal strategy even if choosing not to patent would be consistent with joint welfare maximization.

Thus, also if seen from the political economy angle, the present (international) institutions of the knowledge economy appear to embody an endogenous mechanism that tends to perpetuate their very existence as well as their negative implications for learning, growth and inequality. Most importantly, with the once Open Science-oriented public research institutions ever more active at the IP game, there currently seems to be a lack of endogenous antidotes to the ever-increasing enclosure of public knowledge. In the next section, we argue that the pressing need for such antidote should be conceived of as a new rationale and foundation for science policy, and particularly for a *global* science policy. Absent such antidote, the knowledge economy will hardly be able to meet its growth-enhancing promises.

4. A new rationale for a global science policy

The economic literature has pointed to the existence of a multiplicity of rationales for science (and technology) policy. In the neo-classical approach (Arrow, 1962; Dasgupta and David, 1994) the main foundation of science policy is the existence of market failures linked to the public good nature of the knowledge that constitutes basic science. While technology can be privately appropriated through IPRs, fundamental research creates maximum spillover effects, which motivate public investment in their production to make up for lacking private incentives.

The literature on systems or networks of innovation (e.g., Freeman, 1995; Lundvall, 2007), by contrast, identifies the justification for public intervention in science and technology in the existence of innovation system failures. Since innovation depends on the complementarities and the links between multiple actors and resources, which may be subject to coordination and incentive alignment problems, there may be a role for public policy in helping to address these problems.

Evolutionary thinkers (e.g., Nelson and Winter, 1982; Dosi, 1988) highlight an additional role for science policy, residing in the need to promote knowledge diffusion and generation of diversity, so as to redress the consequences of path-dependent evolutionary trajectories.

Finally, proponents of the knowledge-based approach (e.g., Cohendet and Meyer-Krahmer, 2001) emphasize the collective nature of knowledge production, sharing and distribution and the importance of learning processes, finding in the existence of learning (cognitive) failures the justification for science and technology policy.

The perspective we propose in this paper (and in previous related work) offers a new rationale for (global) science policy. We have advanced so far two main contentions. The first is that excessive knowledge privatization should be considered responsible for the squeeze and distortion of investment opportunities and, ultimately, for hampering growth and increasing global inequality. The second is that the political economy underlying international global IP protection and investment in public research tends to magnify the effects of knowledge privatization, leaving "intellectual monopoly capitalism" (Pagano, 2014) with no endogenous mechanism to redress the imbalances caused by knowledge propertisation. From these two contentions we draw three main conclusions for science policy.

First, the (quasi) public good nature of knowledge should not only be interpreted as a rationale underlying the need for public funding to substitute for private incentives, thus addressing a market failure. An even more pernicious failure of the system itself derives from the excessive reduction of the domain of non-propertised knowledge, due to the fact that knowledge ownership gives rise to the self-reinforcing positive and negative dynamics and to the overall squeeze in investment opportunities highlighted in the previous paragraphs. Open Science, intended as scientific knowledge that preserves its public good features, is thus key to unlock the growth-enhancing features of the knowledge economy.

Second, and relatedly, it is necessary to broaden the set of tools of science policy with more openness-preserving tools. Mazzucato (2013) has convincingly shown that substantial public investment in science underpins many of the most successful privately appropriated innovations of our time. This certainly backs the claim that public funding of research should be preserved and enhanced. However, given the present institutional framework skewed in favour of privatization of the results of basic research, increasing public research funding may not be enough. In other words, we propose that the question whether and how much public research should be funded should not be considered separate from the more fundamental question whether privatization of public research results through IP should be encouraged. The efficiency-enhancing features of publicly funded research reside in the broad range of externalities it is able to propagate throughout the economy. Absent these features, it is unclear why public research should be funded at all.

Third, the global dimension of knowledge production and its associated political economy dynamics should be explicitly taken into account as a foundation for science policy. Differently from the case of IP, in the domain of Open Science there are not (yet!) international institutions that ensure harmonization of public sponsorship policies so as to address the disincentive effects of cross-border externalities (Schotchmer, 2004; Pagano and Rossi, 2009). Undeniable difficulties notwithstanding, ways should be found to devise science policies with a global dimension. International coordination is sorely needed to ensure that the main engine of growth – knowledge production – does not run out of its indispensable fuel: freely accessible scientific knowledge.

A few possible tools have been already proposed in this connection. Stiglitz (1999) has suggested that it would be justified on both efficiency and equity grounds for the international community to "*claim the right to charge for the use of the global knowledge commons.*" One way to achieve a similar outcome could be to foresee a minimum investment requirement in open science (e.g., 3 per cent of GNP) to all the countries that are members of the WTO organization (Pagano, 2014). Alternatively, funding of international knowledge institutions and internationally-backed patent buyouts may be part of the set of tools (Pagano and Rossi, 2009). There is certainly a dearth of creative policy solutions in this important domain: the search for ways to overcome the negative consequences of excessive knowledge privatization should be a necessary part of the agenda of a political economy of science.

5. Conclusions and questions for future research

In this chapter, we have proposed the existence of a new foundation for a (global) science policy: the need to counteract the nefarious consequences of excessive knowledge privatization. The growth-enhancing promises of the knowledge economy may never be realized due to its endogenous tendency to drift towards excessive knowledge privatization. Excessive exclusion and blockage in the utilization of knowledge resources has already manifested its effects not only in the patterns of international production specialization and

unequal growth, but also in the curtailment of the growth potential of the countries that enjoy the best endowments of privatized intellectual capital. In addition, the political economy of global intellectual property protection and of investments in public research suggests that this squeeze in investment and growth opportunities does not find easy antidotes.

This also suggests a range of new questions for a political economy of science. First, the mechanisms underlying the virtuous and vicious feed-back effects existing between the distribution of intellectual assets and learning and knowledge investment should be further explored, with the purpose of identifying ways to break vicious circles and unlock the potential of the knowledge economy. Second, more research is needed to understand fully the global consequences of the changing attitudes and practices of publicly funded research that are progressively moving away from the norms of Open Science to embrace norms of 'closed science'. To what extent open access movements and policies promoted by some universities and research groups may be an appropriate solution? What alternatives are available (see chapters by [])? Third, a further crucial question concerns the identification of ways to overcome the ingrained resistance to devise global solutions for the production of Open Science and, more generally, of publicly available knowledge.

These questions by no means exhaust the range of issues relevant to the research agenda of a new, global, political economy of science policy. We believe, however, that they are a necessary starting point if further crash and depression of the knowledge economy are to be avoided.

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