Rethinking the economic properties of human capital: is human capital a private good?

Carolina Cañibano & Richard Woolley

INGENIO, CSIC-Polytechnic University of Valencia

WORK IN PROGRESS PAPER. PLEASE DO NOT QUOTE WITHOUT PERMISSION FROM THE AUTHORS

Abstract

This paper questions the conceptualisation of human capital as an aggregative commodity that mainstream economics provides and argues there are developments in the literature that provide the bases for interesting alternative developments. The paper reviews the neoclassical conceptualisation of knowledge and human capital's economic properties to point out certain inconsistencies. Human capital is conceptualised by certain neoclassical authors as bearing the properties of rivalry and appropriability that characterize private goods. Other authors however, point to its external effects and increasing returns, which make it non-rival and non-excludable to a certain extent. We argue that in neoclassical economics, the properties of human capital are addressed from two different perspectives that are not made explicit in the theory: that of the "owner" and that of the "buyer". Additionally the perfect rivalry and excludability of (scientific) human capital claimed by mainstream economics is put into question by building on contributions from sociology and evolutionary economics. Since the deployment of scientific human capital is highly context dependent as well as dependent on the availability of complementary assets, its perfect tradability (therefore transferability) in labour markets is under question. We argue that far from being perfectly private or just subject to some "external effects", scientific human capital is a "distributed" good whose economic properties are highly variable depending on the networks in which it is embedded. The discussion closes by proposing a list of fundamental characteristics of embodied knowledge conceptualised from an evolutionary economics perspective.

1. Introduction

The distribution and deployment of knowledge is assumed to be at the core of economic organisation and evolution by most schools of economic thought. Much of the knowledge that is economically relevant is embodied in human beings in the form of many different types of skills, abilities, attitudes, etc. all of which are socially deployed and constructed. Mainstream economics reduces the transformation of embodied knowledge into social and economic benefits to a mechanical allocative process that hides much of the complexity that is fundamental to understanding economic evolution. The first step taken by neoclassical economists to incorporate knowledge into their mechanical thinking was its

"commodification". Scientific knowledge and human capital were thus conceptualised as "goods", "things", susceptible to be traded or allocated. The allocation of such goods raises however certain problems since they may be endowed with specific economic properties. Scientific knowledge is conceptualised first by welfare economics and later on by the economics of science as a "public good" justifying public intervention in the production of scientific knowledge. Scientific human capital is in turn conceptualised as a private good in most economic growth models, but not in all. It is not quite clear from reading the neoclassical growth theory whether markets are going to produce and allocate human capital efficiently. In some models the accumulation of human capital is subject to increasing returns, in others to diminishing returns.

This paper is concerned with the economic properties of human capital in general and of scientific human capital in particular. We argue that the neoclassical conception of human capital falls short to understand its complexities, in particular in the scientific context. Other authors have argued the same from other disciplinary backgrounds, notably from the science and technology studies (STS). A range of contributions from evolutionary economists have also supported the same idea. We systematize and bring together these various contributions, starting by reviewing the inconsistencies that may be found in the neoclassical literature concerning human capital's properties (section 2). We review two relevant alternative approaches to scientific human capital (section 3) and key contributions from evolutionary economists (section 4) to propose a set of fundamental properties that characterize the economic deployment of (scientific) human capital. Our proposal is a conceptualisation of human capital as "distributed" and endowed with specific properties that require a conceptualisation that goes beyond the frame of welfare economics.

2. Welfare, knowledge and neoclassical economics

The neoclassical economics of welfare and knowledge

One of the earliest references to the problems raised by the economic allocation of scientific research may be found in Pigou's Economics of Welfare (1920). In the work that constitutes one of the main systematic treaties on the neoclassical economics of welfare and public choice, Pigou clearly points to scientific research as a type of good that may not be efficiently allocated by markets due to the existence of external economies. External economies appear when the value of the marginal private net product in a certain productive process and the value of marginal social net product differ (Pigou, 1920, II.II.1-II.II.6). There are activities in which the private net product of investments falls short of marginal social product (1920, II.IX.12). This is true – states he – "of resources devoted … to the fundamental problems of scientific research, out of which, in unexpected ways, discoveries of high practical utility often grow, and also to the perfecting of inventions and improvements in industrial processes. These latter are often of such nature that they can neither be patented nor kept secret, and therefore, the whole of the extra reward, which they at first bring to their inventor, is very quickly transferred from him to the general public " (Pigou, 1920, II.IX.11). In other words,

scientific research and technological innovation are among the activities that may produce larger social than private value, leaving room for governmental action for attaining an optimal level of allocation of resources that the free market could not achieve.

A few decades later, the neoclassical synthesis brought about a new economics of welfare culminated by Paul Samuelson and his theory of public expenditure (Samuelson, 1954, 1955, 1958). Samuelson develops a theory that is consistent with methodological individualism, "yet at the same time it explicitly introduces the vital external interdependencies that no theory of government can do without" (Samuelson, 1955, 350). For analytical reasons, he defines two polar cases to study the allocation of different types of goods. He distinguishes between private consumption goods and public consumption goods. The former can be parceled out among different individuals, the latter are such that "each individual's consumption of the good leads to no subtraction from any other individual's consumption of that good" (Samuelson, 1954, 387). For the purpose of this paper it is important to note Samuelson's insistence on the polarity of these to theoretical cases. He explicitly says that although he is following a method that is natural within traditional general equilibrium theories, "the careful empiricist will recognize that many … of the realistic cases of government activity can be fruitfully analyzed as some kind of a blend of these two extreme cases" (Samuelson, 1955, 350). "A mixed model that refuses to fall in [the] polar case of a pure public good will not thereby obligingly go into the other polar case of a pure private good" (Samuelson, 1958, 333).

For a good to be optimally allocated by a perfect-competition market, the good needs to be private – as defined above – and be producible at constant returns to scale. Pure public goods are such that adding an extra consumer does not imply an extra cost. They are therefore characterized by general decreasing costs. Now, given the existence of a variety of private and public goods and given a specified social welfare function, how can a society decide on the product mix that will maximize its social utility? Samuelson provides the mathematical apparatus to calculate such an optimum, which would imply the tedious work of weighing "all the different individual's utilities from each decision" (Samuelson, 1958, 336). He acknowledges the unrealistic nature of the polar case he exposes and points out the limitations of classical economics formulas to build a general theory of government (Samuelson, 1958, 336).

According to Mirowski (2007, 21) Samuelson and his colleagues at the MIT were the true progenitors of the idea that scientific knowledge showed the characteristics of a public good. There is no explicit mention however of knowledge as a good in Samuelson's published Theory of Public Expenditure (Samuelson, 1954, 1955, 1958) as there was in Pigou's welfare theory. Samuelson is in any case identified by Mirowski as "the first to envision a neoclassical science policy" (Mirowski, 2007, 5).

It is Arrow's (1962) and Nelson's (1959) works that are most commonly identified as the founding pillars of what has later been called the old economics of science (Callon, 1994, Sent, 2011, 101). The old economics of science uses the above "polar case model" of neoclassical welfare economics to argue first, that knowledge may be analytically treated as a good (a commodity). Second, that knowledge has the properties of a public good. These properties are summarized in the concepts of (non)rivalry, (non)excludability and (non)appropriability. Non-

appropriability was the main problem pointed out by Pigou, while Samuelson focused on non-rivalry and non-excludability which are partly linked to good's indivisibilities.

Nelson (1959) applies Pigou's classical external economy problem to a detailed description of "the economics of basic research". The main lines of his argument are i) scientific research is an important source of economic value and is coupled with invention; ii) the marginal social value of basic research is larger than the marginal private value. The maximization of private profits will therefore not be socially optimum. iii) Knowledge is non-appropriable and non-excludable. "The use of existing knowledge by one firm in no way reduces the ability of another to use that same knowledge" (Nelson, 1959; 163). iv) It is more efficient for societies to place the effort of conducting basic research in public institutions, which implies the provision of the necessary public funds.

Arrow (1962a) focuses on the analysis of "information". As Sent (2011, 106) points out in this early literature science often becomes conflated with knowledge and information. Arrow treats information as a commodity derived from the processes of research and invention, which by definition are risky and uncertain. Uncertainty and risk, together with non-rivalry and non-appropriability will result in an under-production of information compared to what would be socially desirable and the economic properties of the good will result in market miss-allocation. Arrow acknowledges however the difficulties of quantifying the necessary public investment in the presence of uncertainty (1962, 623).

In summary, the old economics of science built on neoclassical welfare economics to treat scientific knowledge as a pure public good that would be under-produced in competitive markets. Around the same time that scientific knowledge was conceptualised by neoclassical theory as a pure public good, knowledge embodied in individuals was also commodified and conceived as human capital. This "commodification" had been controversial in the pre-World War period as economists had rather followed the Marshallian conceptions that considered human beings as not marketable and therefore the concept of human capital as unrealistic (Savvides & Stengos, 2009, 12). Human capital theory was nevertheless developed in the 1960s mainly by Schultz (1961, 1963) and Becker (1964). Knowledge conceived as a commodity either as information, as embodied in human beings (Lucas, 1988) or incorporated into intermediate goods (Romer, 1990a; Aghion y Howitt, 1992) became the key to overcome the diminishing returns that characterized the neoclassical production function. A growing stock of knowledge endowed with certain properties inducing external economies was thus the key to growth in endogenous growth models.

As earlier discussed, scientific knowledge (information) was clearly conceptualised as a public good, which would automatically induce externalities, increasing returns and therefore growth, as described in several well-known endogenous growth models. What type of "good" was then human capital if it was also responsible for economic growth? This is much less clear judging from the literature. The economic properties of human capital seem to be ambiguous and changing according with the model. The following section these ambiguities.

Human capital and growth economics: is human capital a private good?

The theoretical treatment of human capital is highly complex. Savvides and Stengos (2009, 32) signal that the concept includes "not only the role of education and on-the-job training, but also the importance of differences in ability, attitudes and outlook that individual human beings bring to the production process as they attempt to improve their economic lot and, by extension, that of society at large". Economic models therefore normally select some of its characteristics or components. In growth models, human capital is conceptualised as contributing to the growth of total output through different channels. The type of contribution depends much on the economic properties that human capital is endowed with and therefore the type of returns that follow its use as a production input.

In the years in which human capital theory was being laid out, Weisbrod (1962) pointed out that the theory was mainly focused on the contribution of education to earning capacity, which disregarded external effects (Weisbrod, 1962, 107). He argued that the benefits of investment in the education of one student went largely beyond her. External effects affect the personal environment of the individual - current and future family – the productive system – due to interdependence in workers productivities – and society at large through various mechanisms. The benefits of human capital accumulation through education are thus distributed across space and time (Weisbrod, 1962, 119).

Endogenous growth models would also later on base the explanation of growth dynamics on external effects to the accumulation of human capital. This is the case of the Lucas (1988) models of economic development. Lucas associates an external effect to human capital accumulation that implies that human capital growth contributes not only to increase an individual's productivity (internal effect), but also other people's and physical capital productivity (external effect). He emphasizes that "human capital accumulation is a *social* activity, involving *groups* of people in a way that has no counterpart in the accumulation of physical capital (Lucas, 1988, 19). He builds two models of economic development, both with increasing returns to the accumulation of human capital. In one model human capital is accumulated over time through education and 'inheritance' and in the other through learning by doing. In the second case continuous learning is facilitated by the introduction of new (improved) goods in the economic system, as In the Arrow (1962) model. Even if there is a limit to how much one person can learn in an activity using certain goods, diminishing returns are overcome in the model by the previous assumption (Lucas, 1988, 28). In sum, there are externalities associated with the accumulation of human capital, which implies that it is conceived as non-appropriable to some extent. Additionally there are increasing returns associated to human capital accumulation which implies that it will not be efficiently allocated in competitive markets. As Samuelson had pointed out: in a context of decreasing cost in production, "ordinary pricing will be non-optimal unless it happens to be able to pick up each indirect external marginal utility" (Samuelson, 1958, 335). The non-rival character of human capital in this conceptualisation makes it non-excludable to a certain extent since its use will benefit more than one agent at a time.

Romer explicitly disagreed with the approach above. Human capital is central to the growth dynamics in his models, but is conceptualised as a private good. The key to economic growth in

Romer's 1990 (a) model is the allocation of human capital to research and development activities which in turn produce knowledge that will "spill-over" the economy due to its non-rival character, encouraging therefore increasing returns. Here scientific knowledge is conceptualised as a public good and (scientific) human capital as a private good. For Romer, human capital is rival because it is inextricably tied to a particular individual (1990b, 8). In fact, Romer (1993: 72) understands human capital as a good which is "as close to a perfect good as one can get". Romer's conceptualisation of human capital equals "a set of connections between neurons" (1993, 72), which includes "the ability to remember the commands of a word processor" (1993: 71) or the "ability to add" (1990a: 74). The person who possesses these abilities cannot be in more than one place at the same time. Additionally, the opportunity cost of reproducing such abilities is not negligible: "[t]raining the second person is as costly as training the first" (Romer, 1990a: 75). According to Romer, rivalry leads to the presumption that human capital is also excludable. He argues that a person who possesses a 'piece of human capital' can perfectly exclude others from benefitting from his or her abilities. Finally, whereas non-rival goods can be accumulated without limit on a per-capita basis, human capital cannot. Each individual can acquire a certain amount of skills. "When this person dies, the skills are lost" (Romer, 1990a: 75). Romer clearly makes the distinction between "ideas" that human capital produces – or that produce human capital - and human capital itself. He explicitly criticizes the approaches that conceptualize human capital as a non-appropriable good capable of growing without bound (1993, 71,71).

Becker (1993) also assumes diminishing returns to the accumulation of human capital but his is not quite assertive as Romer. Referring to variable H (human capital) in his model, he states that "knowledge is not subject to diminishing returns in the same obvious way as physical capital because greater knowledge raises the productivity of further investment in knowledge. However, as knowledge continuous to grow, limited human capacities tend to make it harder to pack into a person without running into diminishing returns" (Becker, 1993, 312). Becker is not including here external effects.

In summary, whereas scientific knowledge is considered in the neoclassical tradition as a public good (non-rival & non-excludable) and therefore not allocatable through markets, there is no agreement in the conceptualisation of embodied knowledge which enters some models as a pure private good and some others as one subject to diminishing production cost and a certain degree of non-rivalry and non-excludability. It is important for our purposes to note that much of the human capital the above discussed literature refers to as key to economic growth is human capital devoted to research and development activities, independently of its economic properties.

Theoretical problems in assessing human capital's economic properties

Later developments in the socio-economics of science, together with the above discussed literature illustrate how dealing with the economic properties of (scientific) human capital is anything but a simple task. According to Callon (2002: 284), the proponents of the new economics of science (Dasgputa & David, 1994) agree to consider embodied knowledge as a rival good: "A research director who recruits a scientist removes him or her from the market,

for no other *laboratory* can employ him or her". However, in a previous paper (1994) he recognises certain differences between economists on this point and refers to the skills incorporated in human beings as non-rival goods: "Mobilizing the skills and techniques of an expert does not prevent another *expert* from mobilizing the same skills at the same time" (1994: 401).

The two statements are not necessarily inconsistent for the perspective used to address rivalry is different in each case. The later (2002) approach addresses the rivalry of the good 'skills embodied in a specific person' that cannot be in two places at a time. The earlier approach considers the properties the good 'skills'. It is true that nothing necessarily prevents one person from developing exactly the same skills as another although it is extremely unlikely considering the social elements that contribute to the construction of embodied knowledge over time. Another way to think of these two approaches is to distinguish between the 'owner's perspective' - that of the person in which the skills are embodied – and the 'buyer's' (or tenant's) perspective – that of the agent that pays for its use - .

If we turn back to growth economics we also find these two distinct ways of addressing human capital's properties. Romer (1993) takes the perspective of the individual in which the knowledge is embodied – the human capital *owner* – to argue that "the set of connections between neurons" is as close to a pure private good as one can get since no one can make use of that knowledge without the owner's authorization. The perfect privateness of the good human capital derives from the fact that the owner has total control over the use of the individual's abilities: noone can use them without permission, noone can steal them. Human capital is therefore more perfectly private than other goods (i.e. a floppy disk) that can actually be stolen from the owner (1993: 72). Here, the good is again the knowledge embodied in someone's mind. However, as other economists would argue, once that knowledge is put to use in a certain productive context – that of the employing organisation – it starts benefiting other agents that interact with the human capital bearer in different forms, which is very hard to control by the employer. Although it is undeniable that the same person cannot be physically located in two places simultaneously, this is not enough to derive definitive conclusions concerning the 'privateness' of her human capital. Thus, from the human capital's *buyer's* perspective, the economic properties of the good that is being paid for are different, notably there are degrees non-rivalry and non-excludability that overcome the limiting capacities of work contracts.

Although eventually tradable in markets, embodied skills are very different to typical private exchangeable goods. The consideration of human capital's 'ownership' raises important conceptual problems that the economic literature has not addressed. When discussing excludability or appropriability in a welfare economics context a distinction should be made between the 'buyer's' perspective (the organisation that employs the person in which the human capital is embodied) and the 'owner's' perspective (the person in which the human capital is embodied). In the case of a typical private good the agent who purchases it in the market becomes the owner. In labour markets, employers acquire the right to benefit from their employees' embodied competences but they do not own the human capital that is deployed.

Is neoclassical welfare economics however the best framework to place a theoretical reflection on the properties of human capital? Since the production and diffusion of human capital is inherently social its conceptualisation as a standard marketable good falls short to address the complexities involved in those two processes. There is no agreement in the literature concerning the presence of externalities associated to its accumulation, but even if most economists agreed with Weintrod and Lucas on the external effects that turn human capital into a partially public good much would remain unknown about the process of its social deployment and its economic mobilisation.

In a neoclassical mechanical context, it is inputs accumulation that matters and assures production, or growth in the case of increasing returns. The value of economic inputs, including scientific knowledge or human capital is independent of their context of application and of the other entities to which they might relate. In a neoclassical context, human capital is basically conceptualised as a marketable aggregate easy to allocate and whose accumulation may engender – or not – some externalities which are considered to be market failures to be corrected by governmental intervention. Agents are essentially autonomous and independent of each other. Loasby describes this by pointing out that neoclassical models treat connections as problematic: “the basic model of standard economics ignores connections because they do not affect outcomes but allows for a variety of special models to explore the implications of particular deficiencies” (Loasby, 2001, 400).

In his review of the “the legacy of mechanical thinking” Dopfer (2005) summarizes the main characteristics of the mechanical paradigm. Two of these characteristics have direct implications on how human capital is generally conceptualised. According to Dopfer, “the first axiom of the mechanistic paradigm recognizes that reality refers to a ‘hard’ entity as being composed of matter-energy” (Dopfer, 2005, 12). The hard entity that encapsulates human capital in the neoclassical paradigm is the human body, which implies a theoretical conflation between human capital and human resources. This conflation enables economic calculations in which individuals and human capital are effectively equivalent, which has consequences for instance on the assessment of the economic implications of migratory movements (Cañibano & Woolley, 2012, 12).

A second axiom recognises the mutual independence of entities, as pointed out above, “an individual entity does not change its behavioural mode by enriching its informant agency with ideas from other entities, nor does it offer any export of information” (Dopfer, 2005, 12). This axiom implies the mutual independence of human capital units and respectively, the independence of human capital with other type of economic entities, unless a deficiency appears in the form of ‘external effect’.

In the case of human capital as will be later argued, it is connections that make it a valuable economic good. Acknowledging this implies necessarily going beyond the neoclassical mechanical paradigm. The concept of externalities allows very limited consideration of the social construction and deployment of human capital and its economic effects. One needs to go beyond the mainstream economic paradigm to reflect on the “extra-individual” attributions of human capital, which will determine its economic characteristics and therefore its tradability. In the following section we review some fundamentals of the evolutionary

economic paradigm. We argue that evolutionary economics may accommodate a necessary distributed conceptualisation of human capital that is incommensurable with mechanistic neoclassical approaches.

3. Evolutionary economics and embodied knowledge

A systematic theory of embodied knowledge or human capital has not yet been proposed within the evolutionary economic literature. However, the necessary conceptual tools for such a theory are available in a theoretical paradigm in which the organization of knowledge and learning in uncertain environments are the central key processes explaining economic development and evolution (Boulding, 1966, 1973, 1991 [1956]). In a theoretical context that acknowledges constant change as the main characteristic of capitalist economies (Metcalfe, 2000) the mere definition of an inherently static concept like 'capital' becomes problematic.

In his review of what evolutionary economics is, Boulding defines capital as "those things existing at a moment of time on which some kind of an economic value can be put. This will include human capital, that aspect of human bodies and minds which can be evaluated in these terms, though this evaluation is often difficult" (Boulding, 1991,9-10). We may now turn back to Dopfer's axiomatic description of economic paradigms, in particular to his proposal of the characteristics of the evolutionary ontology (Dopfer, 2005, 12). "Axiom 2 recognizes existences as relations and connections." Matter-energy entities are conceived as carriers of information that are connected with each other. Informational relations and physical connections constitute associations that will build up structures that evolve over time. "Axiom 3 recognizes existences as processes"; as structures in time. Processes are self-caused or spontaneous (Dopfer, 2005, 17-18).

Human capital resides in human bodies as suggested by Boulding's quote above but, understanding human bodies and minds as necessarily connected with other 'matter-energy entities' (other bodies, minds, artifacts, institutions) implies recognizing that connections will also be bearers of such capital. Again, in an earlier discussion on the 'brain drain' phenomenon Boulding recognized that "human capital even more than physical capital is a structure, rather than an aggregate" (Boulding, 1968, 113). Boulding stresses the fact that the productive capacity of a society is not necessarily increased through aggregation or accumulation of human capital units, as implied within the neoclassical paradigm. Trained people need to fit properly into production structures and in what Boulding refers to as the "matrix of information flows" (Boulding, 1968, 113). Similarly, Loasby argues that "[e]ach individual and each established connection between individuals may be regarded as a bearer of capital, but the effectiveness of each unit of capital depends on the structure in which it is embedded" (Loasby, 2008, 50). Loasby stresses the fact that human capital is not reducible to isolated individuals, and that its value depends on the structure of differentiated complementary and context dependent elements in which it is mobilized.

There are elements in the above quoted contributions by evolutionary economists to argue that human capital should be conceptualized as a distributed structure whose economic value depends precisely on how such structure is connected with or embedded in other economic

structures. The conflation between human resources and human capital that derives from neoclassical assumptions is here broken. In an evolutionary framework, human capital resides both in human bodies and human connections. Its economic value is not given *a priori* but derives from the characteristics of the context of its mobilization. Using Dopfer's terminology, *efficacy* is not guaranteed. The components of a certain structure need to mutually adapt to their complementary tasks. The relational nature of economic phenomena makes the problem of efficacy a central one in evolutionary economics (Dopfer, 2005, 25).

From an evolutionary perspective, human capital should thus be conceptualized as a distributed structure evolving over time. The relevant questions would then be how are human capital structures built and how is human capital constructed and transmitted over time? These questions have not been posed as such within the evolutionary literature. However, much emphasis is put in this literature on the importance of learning and on the tacit dimension of knowledge. Importance of time in evolutionary economics. Structures in time. How is HC constructed and transmitted over time : heterogeneity, uncertainty and dispersability

4. Distributed human capital structures: two illustrative approaches

Callon's socioeconomics of scientific research

Callon (1994) makes a general argument that scientific knowledge (meaning codified scientific knowledge) is not necessarily non-rival and non-appropriable, as assumed by economic theory. He states that the properties of 'codified knowledge' are not inherent to 'the good' (the codified knowledge) but are extrinsically configured. He argues that this has major consequences for the conceptualisation of the dynamics of scientific research and the replication of knowledge.

Callon (1994) addresses the question of to what extent science – meaning codified scientific knowledge – can be considered an inherently public good (non-rival and non-appropriable) as assumed by neoclassical economists. Callon argues from a position within sociological studies of science that understands the fabrication of scientific knowledge as a messy and irreducibly social process (Barnes, 1982). He argues that in order to use a codified statement produced by an agent, other agents must undertake a series of investments[1] without which the knowledge has no use. This he refers to as 'the thesis of the intrinsic inutility of statements' (Callon, 1994: 403). In other words, codified knowledge such as a scientific paper has no use in and of itself, it is useful only when it can be read and understood and deployed as part of processes of knowledge production and or dissemination.

Callon's starting point for what he terms 'a socio-economics of scientific research' is "the replication of knowledge" (2002: 287). In making the object of analysis the 'replication of knowledge', he argues that the diffusion of basic scientific knowledge cannot be subsumed under the exchange of codified statements as information "because it is not statements that

[1] Reproduction investments, investments in acquiring and maintaining complementary assets (i.e. instruments, embodied skills, know how), and investments in the mobilisation of the codified statement (Callon, 1994: 404-405)

are duplicated but laboratories: consequently basic science cannot be reduced to information" (2002: 288). In other words, whilst concepts can be circulated in the form of information, this is only part of the work of 'replication'.

The replication of knowledge depends on what Callon terms "the set [statement + instruments + embodied competences]" (Callon 2002: 289). Following the work of Collins (1974), Callon assumes that the elements of 'the set' cannot be mobilised independently of each other (1994: 403). Therefore the work of replicating knowledge is equally dependent upon the availability and transporting of the requisite material devices and on access to the competences required to set up, calibrate and use this equipment.

The degree of non-rivalry of a statement (which refers to the unlimited possibility for all agents to use it once it has been produced) thus depends on the amount of investment needed to develop the skills and acquire the instruments that make it useful in a certain context. "Non-rivalry is in no way an intrinsic property of the statements themselves: it would be better to call it an extrinsic property and to consider the variable degrees of (non) rivalry" (Callon, 1994: 406).

Callon acknowledges that 'the thesis of the intrinsic inutility of statements' can be equally applied to skills and instruments (1994: 403). Although he does not expressly extend the argument to the economic properties of human capital, he provides the theoretical bases to make this step. We may argue that the possibility of agents (organisations and individuals) using what Romer would call 'a piece of human capital' depends on the availability of the complementary assets required (instruments and statements). The artistic capabilities of a great pianist are of little use in an environment lacking pianos and sheetmusic, for example. In other words, the utility of human capital is context dependent. The amount of investment required to gain access to, and understand, codified scientific knowledge and appropriate instrumentation thus determines the degree of (non-)rivalry of scientific human capital.

If the economic properties of human capital are extrinsically determined it is the nature of the context that ascribes the degree of rivalry and excludability. Callon explains this in terms of the structure of networks in which scientific knowledge is produced. The notion of 'network' refers to 'translation networks': "a compound reality in which inscriptions…technical devices and human actors…are brought together and interact with each other. The networks vary in length and complexity" (Callon, 1995: 52). He argues that the degree of rivalry and excludability of codified scientific knowledge "is closely correlated to the form and state of the networks concerned" (1994: 313).

In 'consolidated networks' "competences and instruments have been duplicated in multiple copies and widely distributed" (Callon, 2002: 290) All the required complementary assets are available at each 'equivalent' node in the network. In such consolidated configurations a relatively extensive 'space of circulation' is elaborated, knowledge flows comparatively easily and is relatively difficult to appropriate. Callon argues that in consolidated networks the economic properties of statements are closer to those of a theoretical public good. We can apply this argument also to scientific human capital: within a consolidated network in which scientists already share a codified knowledge base, a modus operandi, types of infrastructure

and instrumentation, etc, there is an extended space of circulation for human capital which is therefore relatively non-rival (easy to circulate and reproduce).

On the other hand, in 'emergent networks' codified scientific knowledge more closely resembles a private good, according to Callon (2002). This knowledge is less easily reproducible and usable than is the case in 'consolidated configurations'. When new research findings and networks emerge, the number of actors sharing the use of common sets of skills, codified knowledge and instruments is by definition limited. Emergent findings remain easily or inexpensively appropriable within the localised setting as it is "easy to take ownership of a good that nobody understands and that has no utilitity outside its place of production" and "contrary to the traditional view, leaks and overflows are costly to organize" (Callon, 2002: 290). It is therefore more rival and excludable (Callon 2002). Again, we may apply the same reasoning to human capital. Mobility of human capital with relatively scarce (emergent) embodied competences would "presuppose the existence of a circulation space that does not yet exist" (Callon, 2002: 290). If no space for the circulation of skills yet exists, it is comparatively easy for organisations to exclude others from the overflowing of their human capital and more costly for others to try and reproduce those skills.

The economic properties of scientific human capital are also defined as extrinsically configured and dependent on the contexts in which it is deployed. Using Callon's words we may state that these properties depend on the structure of the networks involved: in emergent networks human capital resembles a relatively private good; in consolidated networks it tends to be less rival and excludable. In the following section we look at Bozeman's conception of scientific and technical human capital (STHC), to point out how in this framework the properties of human capital are similarly context dependent, but also socially and relationally defined.

Social and contextualised human capital: the 'scientific and technological human capital' approach

Bozeman and colleagues (2001) build on social and economic theory to broaden the traditional neoclassical approach to human capital. According to Bozeman et al. (2001: 721) standard human capital theory regards the human being as

> "a knowledge delivery mechanism into which inputs are added in the form of education and training and outputs are received in units of productivity, higher earnings and expanding economic growth. It is the emphasis on the value of knowledge creation, recombination, transformation and application process that is missing. The process that takes place within the black box is inherently social…and is missing from the theory".

Scientific and technical human capital (STHC) is defined as the sum of scientific, technical and social knowledge embodied in a particular individual. More specifically it is composed by internal and external resources. Internal resources are classified into three overlapping categories: cognitive skills (not determined by the context, i.e. memory, mathematical reasoning), substantive scientific and technical knowledge (basically obtained through formal scientific education and training) and context skills (gained by doing, usually tacit knowledge

acquired through design and implementation of specific research plans) (Bozeman et al., 2001: 726). External resources are the social capital that scientists bring to their work. They are embedded in network ties. Since the production of scientific knowledge is by definition collective and social, many of the skills are more social or political than cognitive (Bozeman et al., 2001: 727-728).

The human and social capital components of STHC are both important for our argument. The STHC framework classifies so-called 'internal resources' (human capital) into three overlapping categories: cognitive skills, substantive scientific and technical knowledge and context skills. According to Bozeman et al.,

> context skills are usually tacit and are obtained through experience in specific research settings. They cannot be directly brought to new scientific and technical problems, but they provide the basis for problem solving heuristics and comprise an action repertoire, which is transferable to other contexts (2001: 727).

The distinction between specific localised context skills and the generic action repertoire of science is central to understanding the economic properties of human capital. Whilst the two types of context skills are inculcated simultaneously in practice, we would argue that localised context skills are particularly rival and appropriable for they are difficult (and costly) to reproduce and transfer to different contexts. Conversely, generic skills and problem solving aptitudes are part of the "background knowledge" (Zellner, 2003) of science that is routinely and systematically reproduced and disseminated. These skills comprise an aspect of the professional habitus of scientists (Bourdieu, 1975) and are relatively non-rival and are not appropriable.

This argument seems consistent with the approach taken by Callon (2002). If we consider 'context skills' in relation to Callon's description of emergent and consolidated networks, it seems reasonable to assume that in a 'consolidated configuration', where scientists share a common knowledge base and action repertoire (including the use of a set of instruments and statements), a relatively extensive space of circulation exists. From the 'buyers perspective' the properties of human capital being circulated are relatively non-rival and non-appropriable. Alternatively, localised context skills seem comparable to emergent embodied capabilities for which there is a restricted circulation space. Human capital in such emergent configurations or localised contexts is a relatively rival and appropriable good.

However, STHC also includes the additional component of "social capital", here conceptualised "as the cooperative glue that binds collaborators together in knowledge exchange", (Bozeman et al., 2001: 723). Social capital includes the resources that connect scientists with their colleagues, funding agencies, other laboratories, firms, etc. Unlike human capital as traditionally conceptualised by economic theory, which resides in the 'connection between neurons' within the brain of its owner and is therefore explicitly individualized, Bozeman et al. argue that 'social human capital' "inheres in relations between people and therefore cannot itself be owned" (Bozeman et al., 2001: 723).

In other words and following Bozeman's statements we could say that 'social capital' is embedded in external relationships and therefore inherently inappropriable. Furthermore,

Bozeman et al. (2001: 723) argue that "the interplay between social and human capital is so fundamental, intimate and dynamic that neither concept is fully meaningful by itself, making it nearly impossible in the end to pinpoint where one leaves off and the other one picks up". There is thus an inherently inappropriable component of STHC which is not easily distinguishable from the other components.

The social dimension of STHC is thus by definition inappropriable (non-excludable) and embedded in network ties. It is logical to derive from this that the degree of inappropriability of the STHC associated to a certain scientist will depend to some extent on the characteristics and configuration of these social networks. There is thus an important difference between Callon's and Bozeman's conceptualisation of 'networks'. However, these differences do not have major implications in terms of our argument, as both analytical frameworks permit us to derive the conclusion that the degree of appropriability of scientific human capital is externally (extrinsically/socially) and not internally (intrinsically/individually) determined.

One of the major contributions of the STHC framework is the categorisation of embodied scientific skills into different types, which are closely and dynamically linked to each other. Moreover, the theory states that the composition of an individual's STHC is constantly reconfigured over time (Bozeman et al. 2001: 727). We may thus derive some conclusions concerning the economic properties of STHC. On the one hand, these properties will depend on the individual's composition of STHC at a certain analytical instant: for example the more important the social skills and relationships, the less appropriable her STHC will be. On the other hand, we may argue that the more important localised context skills are during a particular period, the more rival and excludable the STHC will be. The balance of these components is dynamic and transforms over time in the course of a scientific career. The economic properties of STHC are therefore not constant over time.

According with Callon's and Bozeman's conceptual developments the economic properties of scientific human capital change over time depending on its skills-type composition. These properties are extrinsically determined by the characteristics of the networks in which scientists deploy their activities. The economic properties of human capital are thus argued to be context dependent and distributed.

5. Distributed human capital: towards an evolutionary conceptualization (to be completed)

This paper argues that the main theoretical fundamentals for an alternative theory of human capital may be found in the evolutionary literature, notably in early contributions from Boulding (1968, 1981) and more recently in Loasby (2007, 2008, 2010). An alternative conceptualisation of human capital is, in our perspective, a necessary step to further the understanding of its contribution to economic and social welfare and of the consequences of its geographical mobility. The six conceptual fundamental building blocks for such a theory that we find in these authors' writings are the following:

- Structure: Human capital is conceived as a structure (a system composed of elements and connections among them), not as an aggregate.
- Heterogeneity: Human capital structures are heterogeneous; each structure is particular and unique in its own form.
- Context: Human capital is not automatically transferrable between contexts; the structure is developed and located in particular spatial and temporal contexts.
- Complementariness: The context is partly determined by the complementary assets that make human capital valuable in certain circumstances or for certain purposes, such as instruments and physical capital, information or complementary skills.
- Uncertainty: The human capital structure acts in a context of uncertainty, which is at the basis of its expansion potential as it provides freedom of imagination.
- Dispersability: This is an ambivalent category in the sense that it refers to dispersion as diffusion and diversification of the human capital structure, but also to dissipation in the sense of loss or redundancy. A human capital structure may grow and be diversified and expanded as a result of interactive learning or may stagnate or deskill, for example in extremely stable environments.

The above fundamentals have in one way or another been addressed in the literature, but to our understanding have not been yet comprehensively systematized into an explicit theory of embodied knowledge. Further research needs to address these properties meaning and implications. The opposite happens in the 'socio-economics' of science, in which significant contributions have been made to improve and systematize theoretical understanding of *scientific and technical human capital* (Bozeman and colleagues, 2001) and techno-economic networks (Callon, 1994, 2002), without explicitly revealing some of their underlying fundamentals. The above listed evolutionary fundamentals can be applied to these approaches. Scientific and technical human capital, as defined by Bozeman can be conceptualised as a specific case of an evolutionary human capital structure that plays a fundamental role in the (re)production and distribution of scientific and technical knowledge.

A structural evolutionary conception of human capital takes us closer to reconciliation between 'the individual character of knowledge and its intrinsic social nature' and takes us away from traditional aggregative understandings of human resources.

References:

Aghion, P y Howitt, P (1992) A model of growth through creative destruction. Econometrica. Vol.60, n.2, Pags: 323-351

Arrow, K. (1962a) Economic Welfare and the Allocation of Resources for Invention, in P. Mirowski P & E-M. Sent (Eds.) *Science Bought and Sold: Essays in the Economics of Science,* The University of Chicago Press. Chicago & London; Chapter 4: 165-180.

Arrow, K (1962b) The economic implications of learning by doing. *Review of Economic Studies*. June, n.29, 155-173

Becker, G. ([1964] 1993) *Human Capital. A theoretical and empirical analysis, with special reference to education.* National Bureau of Economic Research. New York.

Boulding, K. (1968) 'The "National" importance of human capital', in Adams, W (Ed.) *The Brain Drain,* Chapter 7: 109-119

Boulding, K. (1981) *Evolutionary Economics.* Beverly Hills, Sage.

Boulding, K. (1991) What is evolutionary economics? *Journal of Evolutionary Economics*, 1: 9-17

Bozeman, B., J. Dietz & M. Gaughan (2001) 'Scientific and Technical Human Capital: An Alternative Model for Research Evaluation', *International Journal of Technology Management*, 22(7/8), 716-740

Callon, M. (1994) 'Is Science a Public Good?' *Science, Technology and Human Values*, 19(4): 395-424.

Callon, M. (2002) From Science as an Economic Activity to Socioeconomics of Scientific Research: The Dynamics of Emergent and Consolidated Techno-economic Networks', in P. Mirowski P & E-M. Sent (Eds.) *Science Bought and Sold: Essays in the Economics of Science,* The University of Chicago Press. Chicago & London: 227-317

Cañibano, C. and Woolley, R. (2012) Towards a Socio-Economics of the Brain Drain and Distributed Human Capital. *International Migration*. First Published Online Nov, 29. DOI: 10.1111/imig.12020

Dasgupta, P. & P. David (1994) Toward a New Economics of Science. *Research Policy*, Vol. 23: 487-521

Dopfer, K (2005) 'Evolutionary Economics: a theoretical framework' In Dopfer, K. (ed) The Evolutionary Foundation of Economics. Cambridge University Press: 3-55

Loasby, B. (2010) Human Capital, Entrepreneurship and the Theory of the Firm. *Oxford Handbook on Human Capital*. Forthcoming.

Lucas, R (1988) On the mechanics of Economic Development. *Journal of Monetary Economics*. Vol.22, n.1, pags: 3-42

Loasby B.J. (2008) Los microfundamentos de las capacidades organizativas. In Cañibano, C.; Encinar, M.I. & Muñoz, F. (eds.) *Economía del Conocimiento y la Innovación: nuevas aproximaciones a una relación compleja*. Pirámide, Madrid: 35-58

Mirowski, P. (2004) *The effortless Economy of Science*. Durham: Duke University Press

---------- (2007) The Mirage of An Economics of Knowledge. Version 3.0. Mimeo. http://economix.fr/pdf/workshops/2007_history_economics/Mirowski.pdf

Nelson, R. (1959) The Simple Economics of Basic Scientific Research. Journal of Political Economy, Vol. 67: 297-306.

Nelson R. and Winter S. (1982) *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge MA

Pigou, A.C. (1920) *The Economics of Welfare*. Library of Economics and Liberty. http://www.econlib.org/library/NPDBooks/Pigou/pgEW.html

Polanyi, M (1967) *The Tacit Dimension*. Routledge and Kegan Paul, London.

Romer, P (1990a) Endogenous technological change. *Journal of Political Economy*. Vol.98, n.5, part.2 Pags: 71-102

Romer, P (1990b) Human capital and growth: theory and evidence. Unit Roots, Investment measures and other essays. Carnegie Rochester Conference Series on Public Policy. Vol.32 Spring. Pags: 251-286

Romer, P (1993) Two strategies for economic development: using ideas and producing ideas. Proceedings of the World Bank Annual Conference on Development Economics. Pags: 63-91

Savvides, A. & T. Stengos (2009) *Human Capital and Economic Growth*. Stanford University Press, Stanford.

Samuelson, P.A. (1954) The pure theory of public expenditure. *The Review of Economics and Statistics*, Vol.36, No.4: 387-389

---------- (1955) Diagrammatic Exposition of a Theory of Public Expenditure. *The Review of Economics and Statistics*, Vol.37, No.4: 350-356

---------- (1958) Aspects of Public Expenditure Theories. *The Review of Economics and Statistics*, Vol.40, No.4: 332-338

Schultz, T (1961) Investment in human capital. *The American Economic Review*. Vol.51. N.1: 1-17

Schultz, T (1963) *The Economic Value of Education*. Columbia University Press.

Sent, E.M. (1999) Economics of Science: survey and suggestions. *Journal of Economic Methodology*, Vol. 6, No.1: 95-124

Weisbrod, B. (1962) Education and Investment in Human Capital. *The Journal of Political Economy*, Vol.70, No.5: 106-123