Knowledge ecologies and ecosystems? An empirically grounded reflection on recent developments in innovation systems theory

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Abstract

Since the development of the national systems of innovation theory in the early 1990's there has been a succession of attempts to research the systemic dimension of innovation at many different levels of economy and society. More recently, there has been some shift in the academic and policy debate on innovation from a more traditional systems approach to ecologies and/or ecosystems. The latter are concepts transferred from the world of biology to the social world in order to explain the evolutionary nature of interrelations between different individuals, their innovative activities and their environment. This paper evaluates the concept of knowledge ecology and the related implications for innovation systems theory on two fundamental grounds: firstly, on the grounds of theoretical plausibility and conceptual consistency; secondly, on empirical grounds of the case of public-private interrelations of biotech innovation in Cambridge. The paper argues that the concept of knowledge ecology and the associated version of innovation systems theory can lead to problems of reductionism and functionalism. This is due to its development in abstraction from more grounded analysis of historical processes of capitalism. Knowledge and innovation need to be looked at in the context of historically founded processes of economic and social development.

Keywords: Knowledge Ecology; Innovation System; Public-Private Interrelations; Biotech

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1. Introduction

Since the development of the national systems of innovation theory (NSI) in the early 1990's (Lundvall, 1992; Nelson, 1993), there has been a succession of attempts to research the systemic dimension of innovation at many different levels of economy and society. The rationale of these attempts has been stated by Edquist (1997: 2) as follows: '…to describe, understand, explain – and perhaps influence – processes of innovation, we must take all important factors shaping and influencing innovations into account'. The NSI theory mainly takes into account national-level factors. Thus, for instance, Cooke (1992) and Braczyk et al (1998), by criticising the relative generality of Lundvall's and Nelson's concepts of NIS, have stressed the need for new and detailed empirical research of innovation interactions at a regional level. According to them, research should take account of developments within regional science and economic geography and they point out the existence of heterarchical networks and bottom-up economic processes which effectively constitute regional innovation systems (RIS). Other scholars within the neo-Schumpetarian tradition of economics such as Malerba (2002; 2004) have paid more attention to internal dynamics of the evolution of industries, specifying knowledge linkages and informal networks at sectoral level. Their theoretical and empirical investigations have resulted in the introduction of yet another concept of innovation system, namely the sectoral innovation system (SIS).

More recently, however, there has been a crucial shift in the academic and policy debates on innovation from the systems approach towards ecologies and/or ecosystems. The reason for this is that the systems approach tends not to capture the distinction well between innovation events and innovation structure. Therefore concepts of ecologies and/or ecosystems are transferred from the world of biology to the social world in order to capture better the evolutionary nature of interrelations between different individuals, their innovative activities and their environment. According to neo-evolutionary economists[1] such as Metcalfe and Ramlogan (2005: 18-19), knowledge or innovation ecology refers to '…the set of individuals, usually working within

organisations, who are repositories and generators of existing new knowledge'. For neo-evolutionary economists, that is something distinct from '…the *system making* connections between the components that ensure the flow of information whether in general or directed at specific purpose' (ibid; italics added).

The aim of this paper is to critically evaluate the concept of knowledge ecology and the theory of innovation system on two fundamental grounds: firstly, on the grounds of theoretical plausibility and conceptual consistency; secondly, on the grounds of empirical case of public-private interrelations of biotech innovation in Cambridge (UK). In what follows, it is argued that the concept of knowledge ecology and the theory of innovation system that derives from it can lead to problems of reductionism and functionalism. The reason for this is their conceptual development in abstraction from the historical processes in the development of capitalism. Our argument is empirically supported by the case of public-private interrelations of biotech innovation in the region of Cambridge. This case suggests that knowledge and innovation are nothing but historically founded processes of uneven economic and social development.

The paper is structured as follows. Section 2 begins by questioning the plausibility and consistency of the concept of innovation ecology and its implications for innovation system theory. Section 3 presents the methodology of empirical research. Section 4 examines the case of public-private interrelations of biotech innovation in Cambridge. Section 5 builds on empirical evidence to point out that, in fact, knowledge and innovation are historically developed social processes that include internal contradictions and conflicts. Section 6 concludes that knowledge ecology and innovation system are concepts which have to be more critically used in the analysis of social and economic development through biotech innovation at regional level.

2. Questioning the concepts: knowledge ecology and innovation system

The term 'ecology' is derived from the Greek 'οίκος' (ecos), which means household, and from 'λόγος' (logos), which means discourse. Therefore, ecology can be translated as the discourse or discussion of the household of nature. Indeed, ecology is today a branch of biology that studies living organisms and their interactions with the environment. Such interactions constitute an ecological system or ecosystem. According to Miller (1975: 77), an ecosystem implies that '…everything is connected to everything; everything feeds back through the ecosystem on itself. The interconnectedness preserves the overall system'. Ecosystems evolve through adaptation of the living organisms to their environment. This means that there is no need for external intervention. Ecosystems have an internal dynamic that reproduces interrelations between individuals of different species and their environment.

Two questions arise here. Firstly, whether the concepts of ecology and/or ecosystem can be used as an analogy to analyse the socially dynamic environment of knowledge and innovation? Secondly, are biological metaphors such as 'knowledge ecology' and/or 'innovation ecosystem' theoretically plausible and conceptually consistent with the Schumpetarian tradition of thought? To answer these questions, one needs to take a closer look at the theories of neo-evolutionary economists such as Metcalfe and Ramlogan. Specifically, one of their arguments is that knowledge ecology includes '…those organisations that store and retrieve information as well as those that manage the general flow of information in multiple formats but the principle actors are usually for-profit firms, universities and other public and private specialist research organisations. They exhibit collectively a division of labour that is characteristic of the production of knowledge and this is reflected, for example, within and between the academic specialisms in universities and public and private research activities that are major components in any modern knowledge ecology' (Metcalfe and Ramlogan, 2005: 19). For key and basic reasons, this argument appears to be theoretically unconvincing. First of all, despite the fact that eco-thinking is

taking place in an attempt to open up innovation systems thinking, it is not there yet. That is to say, it does not adequately capture the distinction between innovation events and structures, going beyond them to integrate innovation activity in companies and organisations. Secondly, although, there may be abstract similarities between ecology, in the biological sense of the term, and an environment of knowledge and innovation, the latter includes complex social interrelations and networks (Powell et al, 1996) which are historically developed. This implies on the one hand that the division of labour as such is not biological but social and on the other that a historically developed environment of knowledge and innovation does not evolve through a functional process of adaptation but through an uneven and contradictory process of both co-operative and conflicting relations generated by the separations of the social division of labour.

Although Metcalfe and Ramlogan recognise the social character of the division of labour, they conceive evolution in analogy with biology rather than in concrete historical terms. Therefore, they seem to get close to the view that 'Biological tropes encourage us to see how innovation resembles a living organism that must struggle to grow in changing, historically contingent environment. An innovation's success will depend critically upon the specific 'fitness criteria' of its environment – that is the attributes that are rewarded by the process of natural selection' (Bollier, 2000: 4). This view reduces the evolutionary phenomenon of innovation into a socio-biological process of adaptation. Thus, it might be argued that Metcalfe and Ramlogan tend to move away from Schumpeter who, in his *Theory of Economic Development*, criticised the reduction of evolutionary thought into social Darwinism (Schumpeter, 1983). Indeed, they seem to be closer to thinkers such as Polanyi (1951) and Hayek (1978) who conceived the social environment as a spontaneous order in analogy with the growth and form of plants and animals. For those thinkers, evolution was a matter of cultural selection and unconscious adaptation to spontaneously generated rules of conduct. Although Schumpeter recognised the importance of spontaneity in economic development, he insisted that change is a discontinuous and uneven historical process that involves both economic and social elements. In doing so, he

addressed all forms of uncritical evolutionism, including the socio-biological evolutionism of the third generation of the so-called Austrian School of Economics.[2] Schumpeter clearly urged that 'We must get away from such things. Then two facts still remain: first the fact of historical change, whereby social conditions become historical 'individuals' in historical time. These changes constitute neither a circular process nor pendulum movements about a centre. The concept of social development is defined by these two circumstances, together with other fact: that whenever we do not succeed in adequately explaining a given historical state of things from the preceding one, we do need to recognise the existence of an unsolved but not insoluble problem' (Schumpeter, 1983: 58).

Schumpeter's argument does not seem to provide foundation to any notion of knowledge or innovation ecology. Rather it seems to point towards the same direction that Smith (1976) and Marx (2000) had pointed to, namely the development of capitalism as a particular social system of division of labour and knowledge that leads to technological innovation and thereby to economic progress. This development is by no means socio-biological. Therefore, it is incompatible with the idea of harmonious innovation ecology. Neo-evolutionary economists who endorse this idea do not seem to provide adequate explanation of the origins of certain knowledge or innovation ecologies. Why is it, for instance, that in some areas and in some industries there are rich innovation interrelations at the level of 'Triple Helix'[3] and in some others poor? If it is not a matter of historical development of the social division of labour and knowledge then what is it? As Freeman and Soete (1997) point out, the historical dimension cannot be excluded from our understanding of innovation and progress. This dimension has been proved crucial as the stage of development of a technology and industry is one of the principle determinants of the contribution of individuals and organisations (labour force and firms) to innovations (Freeman and Soete, 1997: 193). History friendly models like those of Malerba et al (1999) and Malerba and Orsenigo (2001; 2002) pay attention to the historical evidence and the specific institutional dynamics of the development of industries such as the pharmaceutical industry and biotechnology.

By contrast, concepts of innovation ecology and/or ecosystem miss the concrete historical dimension of particular knowledge and innovation environments. Therefore, innovation ecology and/or ecosystem used as a conceptual foundation leads to an abstract theory of innovation system. According to Bollier (2000: 10; italics added) '…in adopting the notion of an *ecology of innovation* a key premise is the organic integrity of the whole'. This means that interrelations and networks between different actors are integrated into a holistic systemic framework. In fact, proponents of innovation ecology and/or ecosystem build on their reductionism a functionalist systemic analysis. Thus, they argue '…any innovation ecology is the basis for a system but it is not a system of itself until subsets of the actors are connected with the intention of promoting innovation. Furthermore, the purpose of the connections is to combine multiple sources of knowledge and innovative capability through the flow of information' (Metcalfe and Ramlogan, 2005: 19). Whilst this argument is useful in highlighting dynamics between particular innovation events and broader systems, it is functionalist because it overlooks discontinuities and conflicts that take place in the transition process from innovation ecology to innovation system. Metcalfe and Ramlogan (ibid) stress that '…barriers to information flow, barriers to converting information flow into knowledge, lack of appropriate resources of the requisite information, all fit under the umbrella of connecting ecologies into systems'. In this theory, everything appears to be an internal component of a dynamic system that is self-functioning. In some respects, this is not surprising since all evolutionary economists reject the neo-classical notion of static equilibrium and understand innovation systems as dynamic processes of 'restless' capitalism. However, as a recent study by Tait (2007) demonstrates, there are components such as regulation external to the system, in its environment, influencing and controlling it. Metcalfe and Ramlogan do not seem to take into account the underlying systemic concepts of the boundary and environment of the system.

Metcalfe and Ramlogan also do not seem to explain how we move from the stage of non-teleological situation (innovation ecology) to the stage of teleological system (innovation system). Thus, for instance, they (ibid: 20)

suggest that 'Innovation systems do not occur naturally, they self-organise to bring together new knowledge and the resources to exploit that knowledge, and the template they self-organise around is …the problem of sequence that defines innovation opportunity. Hence, innovation systems are emergent phenomena, created for a purpose, they will change in content and pattern of connection as the problem of sequence evolves and they are constituted at micro scale'. This argument implies that innovation ecologies are spontaneously transformed into innovation systems when an innovation problem sequence arises at a micro scale. Take for instance the example of emergence of intra-ocular lens (IOL) invention and innovation system. Metcalfe et al (2005: 1298) say that 'This invention and innovation system did not exist naturally, it had to be instituted and the focus for its construction was the emerging problem sequence'. Here, they move from their correct initial supposition to a narrow focus on innovation-problem sequence at micro-scale which seems inconsistent with the views of authors such as Lundvall, Cooke and Malerba who contributed to making the concept of innovation system widely known. Those authors study innovation from a neo-institutionalist perspective e.g. in terms of historically formed networked-relations among institutions (Leydesdorff and Meyer, 2006: 1442). Therefore, they focus on the wider meaning of innovative activities, directing their research either on NIS or RIS or SIS '…through an orientation (that) is not limited to the behaviour of firms at the forefront of world's technology, or to institutions doing the most advanced scientific research, although in some countries the focus is here, but is more broadly on the factors influencing …technological capabilities' (Cooke et al., 1997: 477).

At the core of the argument about the innovation-problem sequence is the role of the market. Proponents of innovation ecology conceive innovation systems as being embedded in market processes. Therefore, they appear critical of neo-institutionalists who, within the wider innovation system approach (e.g. NIS or RIS or SIS) place more importance on the role of non-market institutions and processes in fostering innovation. Thus, according to Metcalfe and Ramlogan (2005: 15) '…knowledge of market opportunity is crucial to innovation…much innovation relevant knowledge is generated by experience

and awareness of the market process…Consequently, a supply oriented theory of innovation systems misses half of the story'. Whilst other innovation systems theorists might agree that in many contexts the market is extremely important, they might also point out that if one looks at the historical development of capitalism, one can realise in some areas and industries the role of the market institutions has been less important for innovation than the role of the state at national, regional and sectoral levels (Freeman and Soete, 1997). Metcalfe and Ramlogan seem to downplay the role of non-market values such as cultural and moral values, and regional and territorial identities in forming connections and fostering co-operation between different actors within the innovation system. However, as Nelson and Winter (1977) have early pointed out, a 'useful theory of innovation' can never neglect such values and the variety of institutional structures supporting innovation in different areas and industries.

As will become clear in our empirical study of Cambridge innovation system, the historical development of the social division of labour and non-market values, including culture and identity, play a crucial role in public-private interrelations of biotech innovation. This supports Hickie's (2003: 56-57; italics added) explanation of the most important and internationalised regions, what he calls *islands of innovation*, as '…those with either a long industrial history, a long history of academic scientific research, or both'. Furthermore, our argument is in line with Cooke's position that 'The elements of shared culture, territory and devolved administrative and/or political organisation provide important dimensions of the institutional setting for innovation and other policy development' (Cooke et al., 1997: 477). Proponents of innovation ecology conceive the institutional setting for innovation as predominately market based. Thus, they tend to identify innovation with the market and suggest that '…the state works with the instituted grain of the market process' (Metcalfe and Ramlogan, 2005: 18). Their identification does not seem to be correct. Although the relationship between innovation and the market cannot be denied, it is clear that not all innovation is market-led. There are number of (product and process) innovations which are led by the state. This is so especially in markets which are characterised by weaknesses or even failure.

3. Empirical case study methodology

The empirical research underpinning this paper focuses on public-private interrelations of biotech innovation in the RIS of Cambridge. As is well known, biotech innovation depends on new bio-scientific knowledge and complex interactions between various public and private actors. For this reason, the activities of dedicated biotechnology firms (DBFs),[4] research laboratories, venture capitalists, consultants, accountants, hospitals and other actors have historically clustered (Porter, 1998)[5] in particular geographical and political units (Cooke, 2001), forming RIS. More recent research (Cooke, 2004a; 2004b) into this phenomenon indicates the rise of bioscience mega-centres in several university-focused locations, including Cambridge. In the socio-economic context of these centres, proximate business interactions for knowledge generation and commercialisation take place among DBFs, public research organisations, venture capital firms and public policy institutions. As a result of it, researchers such as Cooke (2004c) already argue that 'traditional pharmaceutical industry' (Pharma) has been 'forced' by small DBFs to become supplicants of the knowledge capabilities of small university spin-out companies.

Independently of whether Cooke's argument is correct, a systematic study of Cambridge's historical development and the interrelations between different public and private actors within its bio-cluster can provide the grounds for demonstrating empirically the reductionism and functionalism of the neo-evolutionary theory of knowledge ecology or ecosystem, revealing, at the same time, the role of social division of labour and non-market values in regional innovation and development.

Our case study of public-private interrelations in the Cambridge biotech cluster is based on two methods of data gathering. Firstly, documentary analysis that includes academic journal articles, policy papers and reports, DBF websites, company brochures and press articles, including historically relevant materials from a previous study (Massey et al, 1992). Secondly, in

depth interviews with a range of public and private actors, including high level managers of biotech companies and industry stakeholders, policy makers and scheme managers, scientists and life science consultants.

Since August 2005, recent relevant documents have been collected and 14 face-to-face interviews have been conducted in the region of Cambridge. Textual representations of these qualitative data have been analysed and interpreted in such a way that provide an in-depth understanding of historically formed interrelations between public and private actors in biotechnology.

4. The Case of public-private inter-relations of biotech innovation in Cambridge

The wider innovation system in Cambridge is constituted by a number of interrelations between high-tech clusters of firms,[6] including DBFs, public sector organisations and policy institutions, reflecting a long process of historical development of the social division between mental and manual labour (Massey et al, 1992). This process cannot be seen only in terms of the social distribution of occupations in the economy but also in terms of the spatial divides between 'North-South' and 'West-East' in the United Kingdom. Thus, the social division between direct production and academia, originated from the industrial revolution, seems to be the main reason why '…up to about the mid-nineteenth century Cambridge was a university and market town and more recently in the period, a regional centre' (SQP, 1985: 15).

In contrast to industrialised regions such as Manchester and Birmingham, Cambridge started growing in the second half of the nineteenth century as a result of the expansion of the university itself (ibid: 17). Indeed, the division of labour within scientific disciplines led departments such as physics and biochemistry to become top research centres world-wide. This, however, did not have substantial impact on the industrial development of the region. The gap between academia and direct production remained unabridged up to the 1960's not because there was no need for economic development in Cambridge but because of separations of the social division of labour. The

latter included certain elements of elitism and ideological justifications which found expression in Holford's report, published in 1950. According to that report, '…Cambridge should remain predominately a university town, of national importance and international reputation. While the broader role of Cambridge as a sub-regional centre was recognised, the explicit concern was that continuation of the post-1930's pace and pattern of growth would irrevocably damage those qualities that made Cambridge such a special place' (ibid: 18). The Holford report proposed reduction of the rate of growth of Cambridge and discouraged large-scale direct production activities. The report was endorsed by the conservative government in 1954 and led to policies of tight planning controls in Cambridge. As a result of those policies, a number of high-tech industry investments were disallowed. Among the famous ones were the Tube Investments R&D laboratory that was disallowed and instead it was set up in Hinxton Hall, just outside Cambridge, and IBM that was refused permission to establish its European laboratory in Cambridge.

It might be argued that these ideological and political interventions to maintain the traditional separations of the social division of labour in Cambridge were against the national dynamic of British capitalism towards information technology (Freeman and Soete, 1997: 67) and resulted in the uneven development of regional environment of entrepreneurship and innovation. As one interviewee put it, 'When we started [in the 1960s] there was no culture of entrepreneurship in Cambridge. It was not an entrepreneurial area' (Extract 1). Another interviewee stressed that '…the idea of big companies moving into Cambridge is a very recent idea. Historically, that's not been the way that the Cambridge cluster has evolved at all, quite the opposite' (Extract 2).

This implies that the Cambridge social environment of knowledge and innovation, part of which is bioscience and biotechnology, did not come about smoothly as an adaptive ecology or ecosystem like, for instance, a heath (Aubusson, 2002). Rather, it was historically formed as an uneven process of the social division of labour and political and social actions which resulted in new institutional development. Indeed, as Massey et al (1992: 7) point out

'…the gap between direct production and academia has been interpreted, from the 1960s of Harold Wilson to the recent decade of Margaret Thatcher, as a crucial problem which it is essential to resolve'. This interpretation was also supported by the university. Therefore, it might be argued that the 1960s were a period of two breakthroughs in the development of Cambridge's knowledge and innovation environment. Firstly, big government investments in science and technology took place in and around Cambridge, including the building of the Medical Research Council (MRC) laboratory of molecular biology. Secondly, it was realised that the university's own vitality would depend on its outside links and the benefits of technological revolution. Therefore, it was the university that set up a sub-committee to produce the so-called Mott report. The report was published in 1969 and '…addressed directly the need to strengthen the interaction between teaching and scientific research on the one hand and its application in industry, medicine and agriculture on the other' (SQP, 1985: 19).

The Mott report had a crucial impact on scientists' attitudes and the county planning authority towards having a science-based industry in Cambridge (ibid: 60). Thus, it led to policies of industrial development and the formation of new high-tech firms, especially in computing. In 1979, a number of these firms founded the Cambridge Computer Group while earlier formations such as the Cambridge Consultants (ibid: 26; Athreye, 2001: 8) played an important role in transferring knowledge from the university to companies and in spinning out new ventures.

In addition to all these developments, that resulted in the accumulation of new high-tech and managerial knowledge in Cambridge, the lending policies of financial organisations such as Barclays provided seed capital for start-ups and young companies in high-technology. As one interviewee said, 'What Barclays did was to provide effectively equity through overdraft in a number of cases for which [bank] managers would have been sacked today …and the number of companies grew from twenty in 1978 to around three hundred sixty in the mid 1980s' (Extract 3). Although most companies at that time were in electronics, engineering and software, there were also a few bio-techs

emerging (for instance, IQ Bio and Cambridge Life Sciences). However, a number of these new high-tech companies grew because of their interrelations with the university and research laboratories such as the MRC laboratory of molecular biology. Some interrelations were clearly formed in the environment of the Cambridge Science Park (CSP). The creation of the CSP was a political decision backed by the Mott report. As Massey et al (1992: 175) point out, this decision was taken in response to the university needs for 'science-based' industry, the city council needs for more jobs and the local employers needs for housing. The creation of the CSP can be seen as a crucial initiative towards constructing a RIS in the area of Cambridge. Other initiatives include the creation of St John's Innovation Centre in the 1980s and the formation of networks such as the East Region Biotechnology Initiative (ERBI) and the Cambridge Network in the 1990s. In fact, as Athreye (2001: 7) observes, the whole '…period since the late 80s has been marked by a growing thickness of institutions in the Cambridge area'.

Certainly, all these institutional initiatives, which had a crucial impact on the formation of Cambridge biotech cluster, cannot be seen in abstraction from the wider economic and political context of the 1980s. Due to neo-liberal policies of the Thatcher governments, the 'Numbers of wholly university-financed full time academic staff…dropped from 33,695 in 1978-9 to 30,621 in 1988-9' (Massey et al, 1992: 130) while the numbers of unemployed in the private sector grew dramatically[7] due to the fact that a lot of big traditional companies such as Cambridge Scientific Instruments were acquired and down-sized (Garnsey and Heffernan, 2005). For the Cambridge region this meant a pool of highly qualified individuals with both the scientific and managerial know-how to start-up new science-based firms. It can be argued that the development of the Cambridge bio-cluster is due to those individuals as well as to facilitators (both individuals and organisations) of network connections. As one individual facilitator said, '…the thing we had to do was to try help create a culture of entrepreneurship and we did that by identifying and promoting role models…and also by doing a lot of press releases and going around and talking to encourage people, as I say using role models about the benefits of entrepreneurship …This corresponded in the 1980's

really with the down-scaling of a lot of companies closing down…in Cambridge so there was a lot of opportunity to help people start business and Mrs Thatcher also, her philosophy…was extremely helpful promoting the idea of standing on your own feet and doing it yourself…' (Extract 4). The idea of entrepreneurship was also central in the New Labour philosophy. Thus, the Blair government in the end of 1990s introduced a number of policies to promote entrepreneurship. For instance, as the interviewee pointed out, '…with the advent of the Blair government there became a competition to set up entrepreneurship centres so all universities were allowed to bid in this competition…' (Extract 5).

However, it becomes clear that the bottom up development of the Cambridge bio-cluster was not spontaneous. Rather it was a combination of the social division of labour that strengthen the university R&D and the wider economic and political situation of the 1980s and 1990s, including neo-liberal ideology and New Labour politics. As another interviewee put it '…Cambridge is a research cluster, its not so much a production cluster and that's a very important difference, its research-based research and when production eventuate its often done elsewhere under licence or whatever, not done here' (Extract 6).

Today, there are more than 200 biotech companies in the Cambridge area and 350 biotech expertise service providers. Also there are more than 30 research institutes and universities, 20 multinationals in pharmaceutical, agro-bio and food, and 4 hospitals involved in biotech research (ERBI, 2005). The University of Cambridge remains at the centre of this cluster mainly because '…twelve different university departments were the source of forty two companies in biotech recognised by the university as spin-outs' (Garnsey and Heffernan, 2005: 22). As many interviewees recognised 'Clearly, the university's existence has been vital to the growth of high-tech and biotech in the Cambridge area' (Extract 7). Our empirical study indicates three reasons for this: firstly, highly respected scientists; secondly, brand name; and thirdly, skilled graduates. Specifically, Cambridge is well known for its 14 Nobel Prize winners in sciences, especially in medicine and chemistry. Also, there are

over 3,500 students and 350 research groups within life sciences (ERBI, 2005). As many interviewees stressed, in Cambridge '…you have got a lot of very bright intelligent people …' (Extract 8). This in combination with '…a lot of innovations …from cross over technologies, convergence of divergent technologies …' (Extract 9), results in maintaining Cambridge as a brand name of science and technology. This becomes clear in the following extract: '…brand is probably the biggest thing, if you say are a bioscience company from Cambridge I do not think there is anybody in the world who won't sit up and take notice…' (Extract 10). Indeed, a number of small DBFs try to be associated with Cambridge while public or non-profit organisations such as St John's Innovation Centre and Babraham Bio-concepts increasingly offer rent and address facilities. This gives new companies credibility, providing, at the same time, a platform for developing connections with various public and private actors of RIS in Cambridge. As one interviewee put it '…because you develop in an attractive location with right environment of people and R&D and universities and so on, you develop a kind of momentum, I suppose. What happens is a series of processes come into play which tend to disseminate ideas and knowledge and know-how, sometimes in random ways but in ways which through combination, and sometimes collaboration by individuals, result in a growth of know-how within a pool of know-how within a region' (Extract 11).

In this pool of know-how, graduates, PhDs and post-doctoral researchers probably play the most important role. They not only provide mental labour to DBFs, transferring knowledge and skills, but also they function as knots between the university or research institutes and private firms. Therefore, it might be argued that from both employment and networking perspectives, spatial proximity matters. This is supported by the following extract: '…being close to the university, for a lot of companies is good from an employment perspective because they have got highly skilled people on the door step. So if they are in Cambridge, it's easier to make contacts with the good people and try and employ them' (Extract 12). The size of the Cambridge region is also very important for informal networking. Such networking presupposes face-to-face contacts with relevant individuals. This becomes clear in extract

13: '…Cambridge train station for instance is an extremely good place to network if you wanted to, it does happen, you know you are going to the sandwich bar, these are all places where things happen because Cambridge is not a big place and there is a high concentration'. Also, consider extract 14: '…informal networking opportunities for meetings between people so that ideas can be spun-off can get together, a lot of that. Again, that's where the small size of the region is very handy and it's quite easy for that sort of thing to happen'.

Certainly, these ongoing and continual informal relationships in Cambridge are not necessarily facilitated by individual interests of survival like in ecologies or ecosystems. Rather, they are social relationships formed upon the social division of labour. This is clear in extract 15: '…if you have got a very large university with multiple departments, multiple research bodies and in addition companies then in fact people can stay together in the same part of the world and I think that's one of the things that we found in our company, that not only you might end up employing a husband, their wife has continued to work in the university or vice versa and sometimes actually they both come to join…when they realise actually its rather fun …'. Social relationships formed upon the division of labour are facilitated by non-market values such as mutual trust and regional identity. Specifically, mutual trust appears to be a relatively strong value within informal networks. This is suggested in a number of our interviews. For instance, one interviewee said, 'You get to know somebody, you meet them, your children go to the same school; its sensible and you find you have something in common, you can phone that person up and say, can I, he might put you in touch with a venture capitalist who would not even consider seeing somebody in a similar company' (Extract 16). Another interviewee stressed that, '…a lot of social networks are about trust' [Extract 17].

Mutual trust is a less important factor within formal networks due to their structural processes of connectivity. In any case, it might be argued that this non-market value is also presupposed of any successful collaborative arrangement. As it becomes clear in extract 18: '…if you are entering the

collaborative arrangement…it is the quality of that relationship that will determine how well the project progresses…so [you] have to trust the firm…and…the key person as well'. It might be said that the value of mutual trust is influenced by another non-market value, namely regional identity. Our empirical data suggest that people do not identify with the region in general but with the city, the university and the culture of academic excellence. For instance consider extract 19: 'There is a strong identity with Cambridge and people like it …there is a lot of heritage and culture around now as well as in terms if being an ongoing centre of excellence…'. This implies that people become symbolically embedded[8] and therefore they are more likely to trust people associated with Cambridge than any other substantial region.

However, despite the various public-private interrelations in Cambridge, there are fragmentations, discontinuities and conflicts. These social phenomena take place in the context of more formal interrelations, not within but between different professional networks, the university and/or research institutes and companies. For instance one interviewee said that '…because Cambridge is such a big university historically, and has a global international context, people in the university will know other people in the university but they are so busy doing their academic work that they do not necessarily have lots of contacts in the town, in the labour market. They will have links with government in London, going up and down to London all the time or round the world but locally, in the commercial business world, often not a lot of connections' (Extract 20). Although in Cambridge there are a number of individuals and organisations that play the role of network broker (ERBI, The Cambridge Network, St John's Innovation Centre, etc.), the problem of fragmentation cannot be easily resolved, due to conflict of public-private interests and different agendas. According to one network broker, 'Academics tend to have little interaction with the network, there are a few, literally a small number, who get involved…It is always an issue trying to get academia and industry together, generally speaking if you really look at it, the majority of events that do that are either academic …events that attract industrial people or industry events that attract a few academics'.

This fragmentation at the level of 'Triple Helix' implies certain discontinuities and contradictions at the level of RIS. Such discontinuities and contradictions mainly concern the spread of new knowledge and information across the system. Conflicts of public-private interests determine who actually benefits from the new knowledge and information. It might be suggested that this uneven process takes the form of conflicts for intellectual property (IP), especially patents. [9] Such conflicts appear in the formal relationship between the university, individual scientists or group of scientists and companies, including DBFs and multinational pharmaceuticals (big pharma). In the case of the University of Cambridge, it is well known that its IP policy has traditionally acted in favour of commercialisation by scientists. That is to say, although from 1986 all UK universities were accorded with intellectual property rights in research funded by the Research Councils, the University of Cambridge allowed this entitlement to its academic and research staff. As one interviewee said '…in fact the university had a completely laissez-faire policy towards commercialisation; they did not stop people from commercialising …unlike universities which claimed IP in their employee's work, Cambridge invested IP in the inventor of the discovery' (Extract 22). Although such a policy provided incentives to scientists, it also threatened the university interests.

For instance, consider the following case described by one scientist: '…in this department a company called [C] was started-up and the academic concerned, Dr [X] paid the university or paid the department for the use of the workshop and the technicians' time, he produced some lab equipment which he sold to the lab [L]…But when [C] was started-up, the university had no IP in [C] and it was sold for a lot of money and the university never got anything for it' (Extract 23). In order to avoid dealing with similar cases, the University of Cambridge has attempted to change its laissez-faire policy on IP but this clearly conflicted with the individual interests of scientists: '…the attempt to change the IP regulations were voted down by the academic senate and I think they are still trying to find new formula…(Extract 24). Certainly, other public research organisations and institutions have developed IP policies less sympathetic to laissez-faire. In order to protect their interests, they have also

developed technology transfer offices to deal with all IP issues in detail. Therefore, IP tensions between public and private interests are increasingly resolved through negotiations between technology transfer offices and scientists. Sometimes, the outcome of negotiations is that scientists have to develop a company to buy the IP from the research organisation. In any case, as another scientist said, '…you just have to be willing to argue your corner and to be reasonable…' (Extract 25). An interviewee also stressed that '…there is a conflict between protecting IP for an individual who's made a discovery and giving the universities, or universities demanding full IP control over research that is going on by their members, whether they are postgraduates or PhD students or whoever' (Extract 26).

In fact it might be said that IP policy and regulations facilitate negotiations in power relations between the university or research institutes, scientists, DBFs and big pharmas. In many cases, DBFs collaborate with scientists for producing new IP but eventually it is powerful big pharmas that acquire DBFs and often take IP away from the region.[10] This brings out another serious contradiction within the system, namely the contradiction between bioscience and regional development: bioscience innovation depends on IP regulations which do not necessarily promote the growth of new biotechnology firms in the region. This is illustrated in a number of statements: '…the Americans have ripped out the IP and have got the business going on a continuous basis and there is no business in Cambridge' (Extract 27). Also consider extract 28 '…the risk is they [big pharmas] come in and buy the IP and they are not really interested in the company and they take that away…'. Undoubtedly, it is the regional innovation policy that tries to deal with that particular problem of IP in Cambridge. Part of this policy is information campaigns. For instance, as one policy maker said, 'I have been going around deliberately and quite provocatively, saying that it is very bad thing …to have angels investing because the first thing they do is say what is your exit strategy which puts you under pressure to sell your business…' (Extract 29). On the other hand, regional policy organisations, including the East of England Development Agency (EEDA), facilitate connections between different public and private actors with the aim to expand the Cambridge innovation system to other less

developed areas of the region such as Luton. As the policy maker put it, 'One of the things we are looking to do at the moment is look at how we can put in what might be called a super hub…' (Extract 30).

This effort towards expansion of the Cambridge RIS is combined with another policy initiative to connect regions in the South and East of England, co-ordinating innovation and strengthening new-technology based companies. According to one policy maker 'Obviously what we want to do or we need to try and do is make sure that not only do we grow these companies but we retain these companies; the risk is that we become an incubator for the US' (Extract 31). However, although it is true that the 'Cambridge phenomenon' was never top-down, the last ten years regional policy has become more visible, due to the global challenges that the RIS faces, especially the strategies of multinationals such as big pharmas. In addition to this, regional policy has been increasingly challenged to address regional constraints on firm growth, including obsolete infrastructure, insufficient transport and housing. As one interviewee observed, '…the region has become quite expensive, housing in Cambridge is prohibited for most people these days, the road structure is appalling and you are starting to develop satellite towns like Cambridge…but you have got a small town that cannot physically develop to support the needs of those industries' (Extract 32).

5. Knowledge and innovation as historically developed social processes of co-operation and conflict

The case of public-private interrelations of biotech innovation in Cambridge suggests that the neo-evolutionary concept of knowledge ecology and the subsequent theory of innovation system cannot be empirically verified. That is to say, knowledge and innovation are not harmonious processes of natural adaptation to the changing conditions of the environment but uneven social processes of co-operation and conflict founded upon the historical development of the social division of labour. This suggestion is in line with both Schumpeter and Marx who agreed that '…there is an internal economic development and no mere adaptation of economic life changing data'

(Schumpeter, 1983: 60n). In the case of Cambridge, internal economic development was a process dependent on both the socio-spatial division of labour and political decisions aimed to deal with the gap between direct production and academia in different ways. As Schumpeter stresses, 'Because of this fundamental dependence of the economic aspect of things on everything else, it is not possible to explain economic change by previous economic conditions alone. For the economic state of a people does not emerge simply from the preceding economic conditions but only from the preceding total situation' (ibid: 58).

Indeed, the historical metamorphosis of Cambridge from a predominately university town to a knowledge and innovation intense environment (Roberts, 2005) in which biotech is the most important high-tech cluster took place as a result of the total economic, social and political situation. The data presented in the previous section suggests that nothing happened spontaneously as an unintended consequence of human action. Cambridge did not evolve through the natural evolution of individuals and organisations that managed to adapt to the environment and somehow knew how to respond to it (Aubusson, 2002). Thus, one might argue, differently from Cooke (2005: 332), that the use of evolutionary economics terms like 'variety' and 'selection' are highly abstract and problematical to the analysis of evolving regional innovation/science systems such as Cambridge. The Holford and Mott reports demonstrate that there were conflicting ideologies and teleologies in the region as well as institutions and people who successfully facilitated the consequences of the socio-spatial division of labour, especially the growth of scientific knowledge and the development of interrelations between public and private actors on which the biotech innovation process could draw.

The case of Cambridge bio-cluster shows that co-operation for knowledge takes place within formal and informal networks. This verifies Powell et al. (1996) conclusion that 'knowledge is in the networks'. Also, the importance of spatial proximity for biotech networking and face-to-face contacts empirically supports the Marshallian argument of knowledge spillover. Indeed, the case of Cambridge bio-cluster suggest that it is true that being spatially close to other

DBFs, firms can access new ideas and knowledge more easily (Dahlander and McKelvey, 2005). However, knowledge flows in Cambridge also depend on whether different individuals share similar professional interests and mutually trust each other. According to Garnsey and Heffernan (2005: 4) 'Social networks, like other social structures, are formed through patterned interactions reproducing the shared values, norms and beliefs that shape further action'. Indeed, as has been suggested in the previous section, non-market values such as mutual trust facilitate co-operative social relationships within informal networks. The same holds for the values of regional and cultural identity that help interactions between various public and private actors in the region. It might be said that these non-market values create a notion of community (Taylor, 1989) that moderates individual competition within informal networks.

However, co-operation does not necessarily take place in the relationships between different professional networks and communities. As has been pointed out there are fragmentations and conflicts at the level of 'Triple Helix'. This can be explained in terms of the social separations of the division of labour. Specifically, before the 1960s, the historical development of the division of labour socially separated academia from production and policy. After the 1960s, the three sectors of social labour came together due to successful social and political facilitations. Nevertheless, they never managed to integrate at the level of 'Triple Helix' in such as way that common interests could be pursued. Therefore, conflicts of public-private interests are generated with regard to the appropriation and exploitation of new bio-scientific knowledge and information.

The case of Cambridge bio-cluster indicates that IP problems are complex. Therefore, such problems are more likely to be resolved within the cluster through informal negotiations. As has been said, IP regulations facilitate power relations between different actors in bio-tech innovation especially DBFs and multinational pharmas. According to Cooke (2005: 3; italics added), '…under *knowledge economy* conditions, globalisation evolves from *Globalisation 1*, which was orchestrated by multinational corporations and

multilateral trade institutions, to *Globalisation 2*, which is driven by the quest by multinationals for exploitable knowledge in *knowledgeable regions*, regions often quite dependent on public funding resources'.

Given the existing IP regulations, the threat of multinational pharmas to regional development through IP acquisitions seems to be real. The fact that big pharmas buy DBFs before the latter start growing seems to contribute to the paradox that Cambridge, on the one hand, succeeds in getting a significant amount of new DBFs but on the other there is not much in the way of success in a firm-growth sense or in a firm-number that make a big national contribution (Athreye, 2001: 2).

Therefore, current regional policy faces a number of dilemmas. Firstly, should regional policy makers encourage the formation of new DBFs with public money through enterprise hubs, given that they might sell off before they become big businesses or should they invest the money to other sectors? Secondly, should they attract multinational companies to locate in and how should they treat them in order to become part of regional networks and build local synergies between big and small DBFs? Thirdly, 'Should they encourage spatial concentration to achieve global excellence or should they encourage the development of such facilities in less favoured regions too?' (Cooke, 2004b: 629). Fourth, should they address problems of regional infrastructure, transport and housing or should they exclusively focus on social capital improving people's entrepreneurial skills? As regards the first dilemma, the position of regional policy does not seem to be entirely clear. Even so, on the grounds of empirical findings presented in this paper, it might be predicted that policy will continue to support the formation of new DBFs, creating, at the same time, better conditions for firm-growth and sustainability. As regards the second dilemma, the answer of regional policy seems to be the following: the more multinationals located in the region and integrated in regional networks the less likely it is for them to take IP away from the region. As regards the third dilemma, the answer of regional policy seems to be directed towards encouraging the development of innovation facilities to less favoured areas and extension of RIS. Finally, on the fourth dilemma, regional

policy seems to prioritise people's skills over infrastructure. As one policy maker put it '…infrastructure matters but isn't a colossal amount you can do about it and you have just got to do the other things…so I think I'd focus on people first rather than the physical infrastructure' (Extract 33). This statement, on the one hand, reveals the knowledge-based idea of economic progress that guides regional policy and on the other the limits of that policy in resolving collective problems.

5. Conclusion

This paper has critically evaluated the concept of knowledge ecology and the associated variant of innovation systems theory, arguing that both can lead to problems of reductionism and functionalism, due to their development in abstraction from the historical process of the social division of labour and capitalist social and economic development. The tension between the evolutionary and historical perspectives has been reflected in the empirical case of public-private interrelations of biotech in Cambridge.

On the grounds of theoretical analysis, it might be said that biological concepts such as ecology and/or ecosystem fail to capture the complexity of socially dynamic environment of knowledge and innovation. Therefore, biological metaphors like 'knowledge ecology' and/or 'innovation ecosystem' provide abstract and simplistic explanations of economic and social evolution as a harmonious process of natural selection. They take less seriously historical perspectives on the development of the division of labour that results in conflicts that drive the evolution of knowledge and innovation. In this sense, the concept of knowledge ecology and the theory of innovation system founded upon it are theoretically implausible and conceptually inconsistent with Schumpeter's *Theory of Economic Development*. The latter takes innovation to be discontinuous and uneven historical process that evolves under the influence of complex economic, social and political factors. Schumpeter's critical evolutionism has nothing to do with the socio-biological writings of neo-Austrian economists such as Hayek. Yet, theoretically

speaking, proponents of knowledge ecology are closer to Hayek than to Schumpeter.

On the grounds of empirical investigation, it might be stressed that the 'Cambridge phenomenon' and especially the bio-cluster has never been a harmonious ecology and/or ecosystem. Rather, it has been a knowledge and innovation intense environment founded upon the historical development of the socio-spatial division of labour and socio-political actions aimed at bridging the gap between academia and direct production. Within this environment one can identify both processes of co-operation and conflict. Although co-operation exists within public and private networks and communities, conflict takes place between them. Co-operation in the Cambridge bio-cluster is influenced by non-market values such as mutual trust and regional and cultural identity. Conflict also exits however and is influenced by the lack of integration of public and private interests at the level of 'Triple Helix' and in relation to IP. The latter is complex and is mainly resolved through informal negotiations. The role of policy is increasingly to deal with the Cambridge paradox, extending the RIS to less favoured areas.

Overall, it might be concluded that the concept of knowledge ecology and the subsequent theory of innovation system offer little towards understanding biotech innovation at regional level. Therefore, if they are to be kept as general metaphors of economic and social evolution, then they certainly have to be carefully and critically used in innovation research.

Notes

[1] Neo-evolutionary economists reconstruct the biological model of Darwinian evolutionary theory, focusing on selection environments in terms of economic and social outputs (Leydesdorff and Meyer, 2006).

[2] The third generation of the Austrian School of Economics includes pro-market evolutionary theorists such as F. A. Hayek (1944; 1948; 1978) while the second one includes subjectivist economists such as L. V. Mises (1949). The founding father of the Austrian School is C. Menger (1963; 1981).

[3] The 'Triple Helix' model studies the complex dynamics of university-industry-government relations and their role in technological innovation. The origins of the model can be found in a workshop on *Evolutionary Economics and Chaos Theory: New Directions in Technology Studies* (Leydesdorff and Van den Besselaar, 1994; cited in Leydesdorff and Meyer, 2006).

[4] These are firms dedicated to the application of knowledge about living organisms to industrial products and processes.
[5] Following Porter (1998) but also the Sainsbury report on *Biotechnology Clusters* (1999), we define clusters as '… geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries and associated institutions' (Sainsbury, 1999: 3).
[6] Currently one can identify four such clusters: the information technology and telecommunications cluster; the technical design consultancies; the inkjet printing cluster; and the biotech cluster (Garnsey and Heffernan, 2005).
[7] For instance, the total number of registered unemployed in UK ('000; average for 12 months) grew from 1,381 in 1978 to 1,668 in 1980 (Cook and Stevenson, 1983: 196).
[8] The concept of embeddedness '…refers to the tendency for economic activity like any social action to be interwined with – 'embedded' within – networks of social relations and structures (Adkins, et al. 2007: 5).
[9] With regard to biosciences, patents constitute legal protection of biotechnological inventions that meet the criteria of novelty, inventiveness and utility (Papaioannou, 2006).
[10] Certainly, that is not to say there are no big pharmas investing in the region. In fact, some multinational companies such as Glaxo Smith Kline have already invested in the greater south east of Cambridge.

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