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Public-Private Collaboration in Genomics and Biotechnology: the Cases of Cambridge and Scotland

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Abstract: Today, bio-scientific research and commercialisation are considered to be critical for improving a number of areas of social and economic life. Especially in the sector of human healthcare, the recent developments in life sciences and biotechnology appear to constitute the main driving force of change. The most important characteristic of the new paradigm of technological change and innovation in life sciences is the close collaboration between all actors involved, including companies and research institutes, public policy initiatives and regional impacts. This paper examines in depth the complex collaborative relationships between public policy, public research and private firms in genomics and biotechnology, focusing on the cases of Cambridge and Scotland. It is argued that although these relationships are uneven and contradictory in both regions, they play significant roles in building firm-based and policy-making capabilities. Therefore, public-private collaborations in genomics and biotechnology are inevitable for regional innovation and development within the contemporary capitalist knowledge-based economy.

1. INTRODUCTION

Today, bio-scientific research and commercialisation are considered to be critical for improving a number of areas of social and economic life. Especially in the sector of human healthcare, the recent developments in life sciences and biotechnology appear to constitute the main driving force of change (Cooke, 2004a). More precisely, the shift from synthetic or fine chemistry to micro-biology and the subsequent revolution of basic and applied, medical and clinical, research (molecular, genomic, post-genomic and proteomics) and biotechnology developments (Cooke, 2004b) seem to have undermined somewhat the role of traditional pharmaceuticals industry in drug discovery and led to the formation of small and flexible dedicated biotechnology firms (DBFs). Although more research is needed in order to assess whether this statement is a statement of fact, one can recognise that DBFs, by elaborating and codifying the knowledge developed by public research organisations and other DBFs (Rosiello, 2005), now play a critical role in researching new methodologies and developing new products.

Although some researchers (Nightingale and Martin, 2004) argue that the biotech revolution has been mistakenly overemphasised, some others (Cooke, 2004a; 2004b) seem to suggest the opposite, presenting research findings which indicate the rise of bio-science mega-centres in several United States (US) and United Kingdom (UK) regions. In the socio-economic context of these mega-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, some argue that big pharma companies have already been forced by small DBFs to become supplicants of the knowledge capabilities of small university spin-out companies (Cooke, 2004a: 166). As Cooke (2004c: 1127) says 'It is …no surprise that up to 39 per cent of big pharma R&D budget are now spent on alliances with extramural partners'. Indeed, it seems that big pharma, including international players such as AstraZeneca and Novartis, is attracted to DBFs because the latter are located close to university research laboratories and therefore can access knowledge

spillovers. However, more empirical research is needed in order to prove that this is the case.

The most important characteristic of the new paradigm of technological change and innovation in life sciences is the close collaboration between all actors involved, including companies and research institutes, public policy initiatives and regional impacts. This is what Gibbons et al. (1994) predicted to be Mode-2 knowledge production, based on networking, transdisciplinarity and reflexivity. Especially in genomics and biotechnology, public-private collaboration seems to play an important role in building and expanding dynamic capabilities for innovation in both firms and policy-making organisations. In innovation theory, building dynamic capabilities is a matter of learning (Teece and Pisano, 1994; Fujimoto, 1999). According to Lundvall (1992), learning not only comes about by performing everyday routine-activities or by using particular tools in production, but also by interacting with others, including users and producers: 'It is the latter form of learning that results in product innovation' (ibid). In the biotechnology industry, as Powell (1998) stresses, firms improve their capability for interactive learning through inter-organisational collaborations. Indeed, as Hendry and Brown (2006) also confirm, '… in the early stages of the industry at least, knowledge and resources are distributed across a variety of institutions …'.

The aim of this paper is to examine in depth the complex collaborative relationships between public policy, public research and private firms in genomics and biotechnology, revealing their role in building firm-based and policy-making capabilities. The focus is on the regional innovation systems of Cambridge and Scotland. In what follows it is argued that although public-private collaborative relationships in genomics and biotechnology are uneven and contradictory in both regions, they play significant role in building firm-based and policy-making capabilities. Therefore, they contribute to regional innovation and development.

The paper is structured as follows. Section 2 describes the conceptual framework within which the public, the private and their collaboration for regional innovation in genomics and biotechnology can be adequately understood. Section 3 presents the methodology of empirical research. Section 4 examines the cases of Cambridge and Scotland. Section 5 builds on empirical evidence to highlight the uneven nature and contradictory characteristics of public-private collaborations in genomics and biotechnology in the two regions, revealing, at the same time, their role in building firm-based and policy-making capabilities. This section concludes that despite their unevenness and contradictions, public-private collaborations in genomics and biotechnology are inevitable for regional innovation and development within the contemporary capitalist knowledge-based economy.

2. FRAMEWORK OF CONCEPTUAL UNDERSTANDING

The Public and the Private

The institutional separation between public and private is rooted in the historical emergence of the social division of labour and the development of modern economic and political liberalism. Specifically, since the early seventeenth century the private has been continuously defined as an economic realm in which various actors

(individuals and organisations) are free to pursue their self-interests. By contrast, the public has been viewed as a political realm in which actors are morally and politically obliged to pursue social interests. Inevitably, the formal separation between the public and the private has been reflected in the tension between the market and the state that dominated the historical process of technological innovation and capitalist economic development in the twentieth century. Three questions have always been central with respect to this tension: firstly, what constitutes an individual self-interest? Secondly, what counts as an interest of the whole of society? And thirdly, how can conflict between individual and social interests be resolved in a socially beneficial way?

Within the context of economics and politics, one could distinguish between different traditions of thought that address these questions. For instance, utilitarian liberals from Smith (1976) and Hume (1978) to Bentham (1970) and Mill (1937) define individual interest in terms of pleasure maximisation and pain minimisation. Therefore, they understand social interest either as an unintended consequence of the advantage of individual interests (Smith) or as the sum total of individual pleasures and happiness (Bentham). Of course, contemporary utilitarians are less hedonistic and more focused on maximisation of preference satisfaction and well being (Sen, 1970, 1999). Other traditions of economic, social and political thought such as communitarianism (Taylor, 1989; MacIntyre, 1988) strongly criticise utilitarian individualism, arguing that what unites the public and the private is not individual interest but substantive conceptions of the common good, including shared culture and values (non-market goods).

In fact, utilitarian liberals and communitarians alone fail to provide adequate theories of the public and the private. Complete notion of the public (whether it is based on narrow individual interests or communitarian values) appears to be impossible. For this reason the critical theory tradition (Habermas, 1989) puts forward an alternative definition of the public as a discursive realm in which the interest of the whole of society is constituted as a public good through the communicative actions of rational-critical actors. By contrast, the private is viewed as a realm in which individuals and organisations find the economic and social means to constitute themselves as free actors. Although Habermas succeeds in restoring the discursive relationship between the public and the private through an ‘ideal speech situation’, his approach remains abstract and formal. That is to say, he does not presuppose any fundamental change in the division of labour so that the gap between the public and the private can be bridged in substantive terms.

Public-Private Collaboration

Given the institutional separation between the public and the private, the question that arises is the following: how do collaborations between public and private actors in genomics and biotechnology become possible? To put it another way, on what grounds can such collaborations be explained? To answer these questions, the aforementioned three separate disciplinary approaches (e.g. economic, sociological and political) are needed. Specifically, public-private collaborations in genomics and biotechnology can be *first* explained in terms of economics either as the result of market/government failure (neo-classical explanation) or as dynamic processes of interaction through which R&D knowledge comes about (institutional explanation). In the context of neo-classical explanation, public-private collaborations are conceived

as rational processes through which market failure (e.g. under-investment in life sciences R&D and technology) or government failure (e.g. failure to exploit new bio-scientific knowledge) are dealt with, and individual and social interests are pursued. This explanation derives from utilitarianism and considers private and public organisations (DBFs, venture capital companies, research institutes, regional agencies, etc) to be instrumentally rational actors. In the case of market or government failure, co-operation between such actors appears to be the only rational way (Hardin, 1982) towards building firm-based and policy-making capabilities. By contrast, in the context of institutional explanation, private and public organisations are considered to be actors of bounded rationality (Simon, 1957; 1979). Therefore, collaboration between such actors appears to be the only way towards bridging knowledge gaps (basic/applied research, clinical testing skills, regulatory processes, etc.) and thereby building firm-based and policy-making capabilities. It might be said that although firm-based capabilities increase product innovations, creating private value (e.g. revenues and profits), policy-making capabilities increase institutional innovations, creating both public and private values (e.g. improving the distribution of services such as health and social welfare) (Moore, 1995).

Secondly, public-private collaboration in genomics and biotechnology can be explained in terms of sociology as a social process through which public and private actors co-operate in order to pursue the common good. The forms of such co-operation are crucial for building specific firm-based and policy-making capabilities. This explanation derives from communitarianism and considers public and private organisations to be actors that have the same territorial identity and share cultural and moral values of the community. Co-operation between such actors appears to be guided by these non-market values. The aim is to build capabilities by means of which the common good (whether that is the discovery of a new drug or the economic and social good of regional development) can be successfully pursued.

Thirdly, public-private collaboration in genomics can be explained in terms of politics as a new political process of science and technology governance. According to Lyall and Tait (2005: 3) the term 'governance' implies '… a move away from the previous *government* approach (a top-down legislative approach which attempts to regulate the behaviour of people and institutions in quite detailed and compartmentalised ways) to *governance* (which attempts to set the parameters of the system within which people and institutions behave so that self-regulation achieves the desired outcomes)'. In the heart of this new mode of governance lie the concept of communication and the idea of networking (Stoker, 2004). Communication refers to information and knowledge flows at multiple levels (national, regional, local, etc.) while networking describes the process through which formal and informal interactions take place between different private and public actors. This explanation seems to be theoretically close to Habermas' model of deliberation. Therefore, public and private organisations might be seen not merely as generators of 'Mode 2' knowledge (Gibbons et al. 1994) but also as critical actors who participate in the discursive process of legitimation and regulation of new scientific knowledge and technology in the market. In this process the role of the state (central or local) is procedural. That is to say, it only guarantees the formal framework of rules in the market. It is within this framework that the discourse of science and technology takes place.

Regional Systems of Innovation

The aforementioned separate disciplinary explanations of public-private collaboration in genomics and biotechnology can be integrated into the framework of regional systems of innovation (RSI). The latter is a meso-level theory (Cooke, 1992; Braczyk et al., 1998) that bridges the gap between the theories of national systems of innovation (NSI) (Freeman, 1987; Lundvall, 1992; Nelson, 1993) and sectoral systems of innovation (SSI) (Malerba, 2002; 2004). According to Cooke (2001: 953), the theory of RSI contains five key dimensions: *region* (e.g. a political and administrative unit); *innovation* (e.g. commercialisation of new knowledge); *network* (e.g. trust and co-operation-based linkages among actors); *learning* (internalisation and externalisation of knowledge, skills and capabilities); and *interaction* (e.g. formal and informal communication focused on innovation). These dimensions determine whether a region has an innovation system or not. A RSI is formed by the industrial and productive dynamics of a given region and the set-up of socio-economic and political institutions that shape the productive and technological processes (Borrás, 2004). Our definition here directly derives from the systemic view of innovation as a social process that engages public and private organisations and institutions whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman, 1987; Howells, 1999). Indeed, as Borrás (2004: 427) stresses '…for a system to be a system, the actors must engage in a process of self-creation that is based on the social relevance they assign to the structural elements through meaning and communication'.

Certainly, the formation of a RSI does not take place in an institutional vacuum. Rather, as Papaioannou et al (2007) stress, a system of innovation is based on a historical process of institutional development through which individuals and organisations generate new knowledge, leading to technological innovation. A RSI is historically constructed, facilitating connections between different actors and ensuring the flow of information. More precisely, a RSI makes connections between different actors such as universities, research institutes, 'top scientists', technology-transfer agencies, consultants, public and private funding organisations, health centres, small and medium sized enterprises (SMEs) as well as users and other non-firm organisations. These actors are engaged in the main functional subsystems of RSI, namely the knowledge generation and diffusion subsystem, and the knowledge application and exploitation subsystem (Autio, 1998). Therefore, most public-private collaborations and linkages can be identified as '…flows of knowledge and information, flows of investment funding, flows of authority and even more informal arrangements such as networks, clubs, fora and partnerships' (Cooke et al., 1997: 478).

Formal and informal collaborations can either be vertical or horizontal. Vertical public-private collaborations take place within the same sector, say the sector of genomics and biotechnology. By contrast, horizontal public-private collaborations take place across different but interrelated sectors, say the sectors of genomics and biotechnology, and information technology and nanotechnology. Certainly, there are different qualities of public-private collaboration within RSI. For instance, some collaboration may be strong, regular and intense. By contrast, some other may be weak, irregular and relaxed. However, what seems to be distinctive about RSI is that public-private relationships are influenced by historically developed social and political elements, including wide community culture, territory and administrative

and/or political governance (Cooke et al., 1997). Thus as Cooke (ibid) observes, in Scotland and Wales, shared culture, territory and devolved administrative and political governance provide important dimensions of institutional set-up for innovation. Cooke focuses on these dimensions. In this paper, we intend to build on his work, adding our interest in communitarian values and regional conceptions of the public and private interest (or the common good). The latter are also responsible for the role of some regionally based DBFs in global processes of innovation. For instance, locations and regions which consider their public interest to be in the building of innovative clusters and regional networks, offer opportunities for alliances with big pharmas and provide opportunities for global networking.

The literature of RSI (Asheim and Isaksen, 1997; Cooke et al. 1997; Autio, 1998; Breschi and Lissoni, 2001) implicitly and explicitly distinguishes between two different types of RSI: firstly, RSI which are parts of a regionalised innovation system; secondly, RSI which are territorially embedded within a particular region. The first type of RSI is based on the so called top-down model of innovation. By contrast, the second type of RSI is based on the bottom-up innovation model (Asheim and Isaksen, 1997).

The top-down model of innovation involves actors which are mainly linked through political and power relations. This model of innovation is based on what Cooke et al (1997: 480) define as a process of regionalisation e.g. '…the delimination of a supra-local territory by super-ordinate politico-administrative body such as the state'. The top-down model of innovation is a government-centric model and therefore, it is not highly interactive. In terms of it, knowledge and regulation capabilities building are very much codified processes. By contrast, the bottom-up innovation model involves actors which are mainly networked through cultural, social and economic relations. This model is based on what Cooke et al. (ibid) define as regionalism e.g. 'political demands from below, where cultural regions … mobilise … to negotiate new institutional ordering'. The bottom-up innovation model is a governance-centric model and therefore, it is highly interactive. In terms of it, knowledge and regulation capabilities building are very much practical and tacit processes. This is the basis of Marshallian agglomeration economies in which localised knowledge spillovers (LKS) allow some companies, hospitals and universities to introduce innovations at a faster rate than others located elsewhere (Breschi and Lissoni, 2001). In specialised industrial agglomerations innovation is a matter of cooperation. According to Asheim and Isaksen (1997:12) '… cooperation is promoted by the existence of social norms and mutual trust and the innovation activity and the learning process is sustained by formal institutions such as industrial service centres, technology centres and centres for labour training'. However, Asheim and Isaksen (ibid) stress agglomerations do not always point towards the existence of RSIs. In some agglomerations, extensive RSI cannot be identified. That is to say, interaction and networking between various systemic actors focused on innovation do not take place at regional level. Nevertheless, there may be developed health and hospital systems and industry associations which can be identified. In this case the social process of innovation takes place at sectoral level.

In the literature of RSI and biotechnology, it seems that top-down/government centric innovation models implicitly correspond to what can be defined as *simple/linear* public-private collaborations in genomics. In these collaborations we have either:

- transfer of public-knowledge management to private sector and transfer of private sector value to public sector; or
- transfer of public information to private sector and transfer of private sector value to public sector e.g. health systems; or
- transfer of public data ownership to private sector and transfer of private sector value to public sector e.g. health sector.

By contrast, bottom-up/governance-centric innovation models implicitly correspond to what can be defined as *complex/interactive* partnerships. The latter are mainly due to bounded rationality and the need of bridging knowledge gaps. In complex/interactive partnerships we have either:

- mutual exchange of knowledge management and economic value between the private and public sectors; or
- transfer of information and value from the public sector to the private sector and the reverse; or
- share of data ownership and value by both the public and private sectors.

Apart from the *simple/linear* and *complex/interactive* models of collaboration, we also introduce here an alternative model, with potential to be either top-down, or bottom-up or both, or something in between – a *translational* model. The term translational research is already fairly widespread, especially in health and medical research. Narrowly, it focuses on the conflicts of interest and practice in the translation of publicly funded research to commercial application. Broader interpretations refer to the 'translation gap' between currently available financial support for early stage spin-out companies and the final stages of development for market-readiness, e.g. stage 3 clinical trials for a drug or vaccine. Significant amounts of funding from public and charitable foundations are being invested in translational research to improve their attractiveness to commercial sponsors to complete their development, with stimulus '… what "big pharm" is failing to do'. Given the importance of the 'public' in the shape of national health systems as users, it may be that existing models of scientific research and of its exploitation will require more coupling between researchers, medical practitioners and patients and thus a more hands-on approach from health services. This may affect relations between firms, regional and local health services and thus impact on regional innovation systems. Generally speaking, *translational* collaborations include processes:

- from public research to private development and from private development to public sector; or
- public-private collaboration in genomic and biotechnology development for the public sector.

It is worth posing this as another hypothesis for empirical investigation, we believe.

The general framework for empirical investigation that we proposed in this section can be summarised in table 1:

Table 1

RSI Models	**PPP Models**	**Capabilities**

Top-Down/Government-Centric	Simple/Linear	Firm-Based, Policy-Making
Bottom-Up/Governance-Centric	Complex/Interactive	Firm-Based, Policy-Making
New Model	Translational	Firm-Based, Policy-Making

3. RESEARCH METHODOLOGY

Empirical research for this paper has been carried out in the UK since August 2005. The focus has been on public-private collaborations for innovation in genomics and biotechnology in the RIS of Cambridge and Scotland. As is well known, life sciences innovation depends on bio-scientific knowledge and complex interactions between public and private actors. For this reason, the activities of DBFs, research laboratories, venture capitalists, consultants and other actors have historically clustered (Porter, 1998) in particular geographical and political units (Cooke, 2001), forming RIS.

The objectives of our case studies of Cambridge and Scotland bio-clusters have been the following:

- to examine in depth public-private collaborations in genomics and biotechnology;
- to identify the role of such collaborations in building firm-based and policy-making capabilities;
- to test the RIS theory against empirical findings.

Two methods of data gathering have been used in order to achieve our research objectives: 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 (based on a semi-structured questionnaire) with a range of public and private actors such as high level managers of biotech companies and industry stakeholders, policy makers and scheme managers, scientists and life science consultants. The core set of questions for the semi-structured questionnaire was as follows:

- the main public-private collaboration initiatives;
- the ways regional elements of culture, morality, territory, administration and politics, public and private interests influence public-private collaborations;
- the current regional context in which innovation takes place (in genomics and biotechnology) as an extension of the wider national context of innovation or as an autonomous system strongly influenced by regional elements;
- classification of the public-private collaboration initiatives in which firms and policy organisations participate (simple/linear, complex/interactive, and translational);
- firm-based and policy-making capabilities building within public-private collaborations;
- the main capabilities creating infrastructural and super-structural conditions for higher regional innovation potential;

- the main barriers (infrastructural and super-structural conditions) to higher regional innovation potential.

Since August 2005, recent relevant documents have been collected and 26 face-to-face interviews have been conducted in both Cambridge and Scotland.[1] Textual representations of these qualitative data have been analysed and interpreted in such a way that provide an in-depth understanding of the unevenness and contradictions of public-private collaborations in genomics and biotechnology as well as their role in building firm-based and policy-making capabilities .

4. EMPIRICAL WORK

The Case of Cambridge

The RIS of Cambridge has been historically formed as an uneven process of the social division of labour and political and social actions which resulted in bottom-up institutional development. In the core of this formation has been the gap between direct production and academia, originated from the industrial revolution. According to Massey et al (1992: 7) '… this gap … 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'. 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 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. These two breakthroughs were justified in the so called Mott Report published in 1969. The report '…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 report 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. As one interviewee said 'If you look back … forty five years there was nothing other than a great university … In the 1960 a bunch of courageous young men with the Columbus spirit … formed a company called Cambridge Consultants, [they] went to the University and said right … we are here to commercialise [research] … The University said thanks a lot but that's not what we do… But they kept going and they got corporate business …' (Extract 1).

Parallel to all these developments, 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 2). Some of these companies grew because of their formal and informal collaborations with the university and research laboratories such as the MRC laboratory of molecular biology. The Cambridge Science Park (CSP) also facilitated university-industry collaborations.

Certainly, all the aforementioned bottom-up institutional initiatives, which had crucial impact on the formation of the Cambridge bio-cluster, have to be seen in relation to the wider economic and political context of the 1980s. Due to neo-liberal politics of the Thatcher governments, a lot of big traditional companies such as Cambridge Scientific Instruments were acquired and downsized (Garnsey and Heffernan, 2005). This resulted in a pool of highly qualified individuals with both scientific and managerial know-how to start-up new technology-based firms. The formation of the Cambridge bio-cluster is due to those individuals as well as to facilitators of network connections. The latter promoted entrepreneurship and development of connections between different public and private components of the RIS. As one individual facilitator confessed, '…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 …' (Extract 3). Economic liberalism and entrepreneurship were also central in the New Labour philosophy. Specifically, the Blair government in the end of 1990s introduced a number of policies to promote competition and entrepreneurship. As one 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 4). However, it becomes clear that the historical development of the Cambridge bio-cluster reflects a bottom-up innovation model that is in the core of the territorially embedded RIS of Cambridge. This particular system is founded upon a combination of the social division of labour that strengthen the university R&D and the wider economic and political situation in the 1980s and 1990s, including neo-liberal ideology and New Labour politics.

Today, the Cambridge bio-cluster includes more than 200 biotech companies 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). Collaborations between all these actors appear to be both formal and informal. Formal collaborations are established for three main reasons: firstly, to support the incubation of new DBFs; secondly, to generate new IP; thirdly, to facilitate professional networking. As one bio-incubator manager said '… we started in April 2003 when we received the total sum of £750,000 of funding from the RDA and that was essentially to help start new business in biotech in the eastern region …' (Extract 5). As another manager of DBF stressed, formal collaborations depend on the needs of companies for IP generation. Thus, '…small companies may sub-contract work out to universities on needs they have …' (Extract 6). These formal collaborations are complemented by informal interactions between public and private actors. Geographical, organisational and technological proximity plays important role in this respect. According to Knoben and Oerlemans (2006), the geographical dimension of proximity has to do with the fact that small geographical distances mainly facilitate face-to-face interactions while the organisational dimension of proximity refers to public-private actors that belong to the same space of relations. Technological proximity then is based on shared technological knowledge and experiences. All dimensions of proximity are facts for

Cambridge. For instance, as one interviewee said '…Cambridge train station … 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' (Extract 7).

Most public-private collaborations in Cambridge are vertical in the sense that they take place within the same sector e.g. biotechnology. Nevertheless, as one interviewee commented, horizontal collaborations may also be possible. '… in the particular case of IT and biotech, being able to be combined in new and useful ways probably, though again I cannot quote evidence for it in the Cambridge area that has happened and has really been beneficial for the growth of particular firms (Extract 8). The quality of public-private collaborations in Cambridge depends on the organisations involved. For instance, given the historical process of bottom-up development, collaborations between regional policy organisations such as the East of England Development Agency and DBFs are not intense. According to one interviewee '…what the RDA is obviously trying to do is to make sure that the momentum is not lost and facilitate that and make it work effectively and with more efficiency…' (Extract 9). According to another interviewee, '… government agencies have really had very little, if any, direct impact on what has happened in Cambridge' (Extract 10). By contrast, collaborations between higher education institutions (HEIs) such as the University of Cambridge and biotechs appear to be strong, regular and intense. As one interviewee stressed, 'Clearly the university's existence has been vital to the growth of hi-tech and biotech in the Cambridge area in various sorts of ways …' (Extract 11). However, nothing seems to be a liner process. According to the same interviewee, '… current links between local biotech firms … and the university … are not obvious links, they are not the university develops ideas and then a local firm is created or takes them over and commercialises and develops them… This may happen occasionally but it's very occasional in my judgement. Really what happens is that individuals carry out research or commercialisation, set up firms, recruit other people to work with and for them and develop their products and develop their ideas' (Extract 12). On the other hand, very often such public-private collaborations only involve individual professors and not their departments. As one manager of DBF said '…we struck up a research collaboration with Professor A who works at the institute B because he has done some groundbreaking work on a target that we thought was interesting… (Extract 13).

Certainly, all public-private collaborations constitute social relations which are influenced or facilitated by non-market values such as mutual trust and communication culture and regional identity. As one interviewee said '… a lot of social networks are about trust …' (Extract 14). In Cambridge, a number of social networks are in fact spin-out networks. This means that '… people who have left another company, they will still have ties with their former colleagues, they will still phone them up when they have a problem, there is this continual e-mailing and phoning going on between people asking for information, asking for various contacts. And there is no better way building up trust than having worked with somebody before …' (Extract 15). Trust is above all a communitarian value and indeed as one interviewee clearly put it '… a cluster is not about the number of biotech companies, its about the bio-community that is knocking around and that's the key aspect of how that bio-community interacts … the biotech companies by themselves would fail because they need a lot of assistance and its that community which makes it work and

that's what Cambridge has … (Extract 16). Our empirical data suggests that people do not identify with the region of Cambridge in general but with the city of Cambridge in particular, the university and the culture of academic excellence. For instance, consider extract 17: 'There is a strong identity with Cambridge and people like it … there is a lot of heritage and culture around … as well as in terms of being an on going centre of excellence …'. This implies that people become symbolically embedded 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 18). 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. This fragmentation at the level of 'Triple Helix'[2] 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 IP, especially patents. 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).

From the data that has been presented so far, it becomes clear that the historically formed innovation model of Cambridge is a governance-centric model. Public-private collaborations within this model are predominately complex and interactive in the sense that they involve a number of actors and dynamic processes of knowledge transfer and value creation. For instance, collaborations established to support the incubation of new DBFs involve RDAs, research institutes, commercial training companies, research councils and small biotechs. Through such collaborations private firms build both capabilities of managing IP and technical capabilities. As one manager of publicly funded incubator said '… we provide mentoring, both commercial mentoring and technical mentoring, and for that package then we negotiate a portion of equity in the new economy…' (Extract 19). By contrast, public organisations built capabilities of communication with private firms and also capabilities associated with flexibility and fast response to change. According to the same manager '…what we have got are very flexible, very fast responding situations in our bio-incubator and we can sort of move walls and move doors and that's something that other incubators do not have and it's something that we have just discovered here…' (Extract 20). However, complex public-private collaborations in Cambridge take different forms. Consider for instance the fact that a number of

private firms' representatives such as founders of DBFs and managing directors of big pharma sit in public policy advisory boards. Thus, as one regional policy maker revealed, '… we …run what's called science and industry council … we have a member of BBSRC …and… we have a director of Glaxo Smith Kline because obviously a lot of what we do in life sciences cascades into pharmaceutical' (Extract 21). Through such public-private collaborations regional policy makers appear to build capabilities of understanding the needs of private firms, balancing public and private interests. By contrast, private firms seem to gain knowledge of the policy-making process, understanding the importance of public interest. However, there is no doubt that through such public-private collaborations big pharma and powerful DBFs also try to lobby regional policy in favour of their interests.

Parallel to the complex/interactive model of public-private collaborations in Cambridge, a translational model is emerging. This is not necessarily a governance-centric model. Rather it appears to include both bottom-up and top-down relations between all actors involved. Within the Cambridge bio-cluster, there are publicly founded organisations such as Genetic Knowledge Parks (GKPs) and National Health Service (NHS) networks which actively promote collaborations for translational research. For instance, as one interviewee said '… we are … looking at what that research means in practice for NHS services and if a piece of research is likely to develop a new test for example [we are looking at] how does that get from research into the clinic …' (Extract 22). This translation process involves conflict of interests and tensions. According to one director of a translational research broker organisation, '[there] will always be tensions… between public values and commercial values. But the point is that one has got to co-operate and work through those tensions and negotiate because there is no way that government funding will produce the necessary money to make medicines. End of story' (Extract 23). On the basis of this point one might argue that the translational model of public-private collaborations in Cambridge is a direct consequence of government failure. Indeed, as another interviewee stressed '… it is not government's role to make medicines. The making of medicines is absolutely essential for public health …. Pharmaceutical companies make medicines' (Extract 24). The question of course is whether there are capabilities built through translational collaborations. Our data suggests that policy-making capabilities in this context are related to efficiency and productivity. According to one policy scheme manager '…there is a lot of benefit to the NHS in understanding how companies work both in terms of efficiency and productivity. In terms of understanding the commercial world and what a company needs in order to make success on either a particular technology or in general and … it is very useful for clinicians to understand the commercial sector' (Extract 25). By contrast, firm-based capabilities are related to understanding of the clinic. As one DBF manager stressed, companies through translational research are 'trying to get insight about the clinic because the clinic is slow and is expensive and also a failure in the clinic is a body blow to an organisation' (Extract 26).

The Case of Scotland

The RIS of Scotland has also been historically formed as an uneven process of the social division of labour. The latter is reflected not only in the gap between direct production and academia but also in the North-South divide of the UK. However, political interventions that aimed to resolve the problem of economic and social

separations of the division of labour in Scotland resulted in a rather top-down institutional development. Specifically, in the years after World War II, the region faced the decline of traditional heavy industry such as ship-building and the lack of new technology based entrepreneurial activities. Also, a number of people emigrated to England or went overseas. Thus, according to Mitchison (1982: 411) 'The industries entering Scotland tended to be either pushed in by the government or American in origin and native enterprise remained poor'. At the same time Scotland witnessed the excessive concentration of development in the South-East England. As Campbell (1980: 185) observes '…by the late 1950s further delay was no longer such an easy option. The growth of the Scottish gross domestic product lagged behind that of the UK from 1954 and seriously from 1958'.

Indeed, it might be argued that the development of Scotland's new knowledge and innovation environment began in the 1960s. According to Campbell (ibid) 'The signs of deteriorating industrial conditions, most evident once again in some of the old specialist producers, were partly responsible for an appraisal of regional policy accompanied by massive injection of government assistance to industry in the 1960s rising from £18 million in 1961-62 to over £96 million in 1969-70…'. It might be said that the crucial aspect of the 1970s government intervention in Scotland was the establishment of the Scottish Development Agency (SDA). The SDA was established in 1975 in order to attract an already developed hi-tech sector (Massey et al, 1992: 200). However, despite certain improvements in the region's knowledge and innovation environment, the SDA failed to provide a foundation for the essential change of the Scottish industrial structure and development of a critical mass of new-technology based firms. In comparison to Cambridge, Scotland lacked individual champions of entrepreneurship and network brokers as well as financial organisations which could provide seed capital for high-risk investments. In addition, the strategy of the SDA resulted in the development of a 'branch-plant economy'. This means that there was a little local ownership and therefore R&D was very restricted (ibid). Given the ideological and financial constraints of the Thatcher governments in the 1980s, R&D in Scotland was further restricted (Hickie, 2003: 66). Thus, for a number of years the Scottish economy was influenced by the role of multinational corporations (MNCs) in financial services, gas, oil, transport, electronics and utility sectors (Rosiello, 2005: 4). Nevertheless, as Rosiello points out '… the downturn of the global economy and the difficulties faced by some MNCs led to the shutting-down of some plants … with negative implications for the whole economy….As a result, in the late nineties the focus of policy interest shifted towards possible ways of stimulating entrepreneurship and the creation of locally anchored business with high growth potential'.

Certainly, the aforementioned historical developments explain why the formation of the Scottish bio-cluster only took place in the late 1990s as a clear top-down initiative of the Scottish Executive and the Scottish Enterprise (former SDA). According to Rosiello (2007) 'The adoption of the cluster approach was based on Michael Porter's work as a consultant for SE [Scottish Enterprise] during the nineties and the launch of SE's cluster strategy in November 1999. SE's Framework of Action for biotechnology originally consisted of a £40m investment and it included organisations engaging not only in advancing knowledge in bioscience and exploiting the technological outcomes, but also in producing medical devices and providing general support and supplies'. Targets of the SE's Framework of Action included substantial

increase in the number of DBFs and support and supply firms located in Scotland as well as doubling employment figures and developing international networks. These targets were in line with the 2001 integrated science strategy of the Scottish Executive. The main objectives of that strategy included: maintenance of a strong science base and international networking; increase of effective exploitation of scientific research and provision of cutting edge science (SE, 2001: 4-5).

However, in its review of the 2001 science strategy, the Scottish Executive (2006) recognised that competition in new science and technology has intensified, Scotland is today the third largest cluster of biotechnology companies in the UK while more than 550 public and private organisations are directly involved in life sciences related activities (Rosiello, 2006). The Scottish universities and research institutes (HEIs) play a central role in this cluster. For instance, according to Scottish economic statistics (SE, 2005) in 2002-03, 17 spin-off companies were established by Scottish HEIs. Also, Scottish HEIs filed 212 new patents and granted 131 licences for the use of IP. Most of these patents and licences concerned innovations in life sciences and biotechnology. Collaborations between public and private actors within the Scottish bio-cluster are mainly formal and aim either at creating new IP or at facilitating networking. In the case of new IP creation, the so called Intermediary Technology Institute (ITI) for life sciences plays a crucial role. ITIs were set up by the Scottish Executive to bridge research and development in Scotland. Within the bio-cluster, ITI operates as a broker of formal public-private collaborations which have the potential to commercialise research. As one ITI manager stressed 'We go into programmes having identified at least one Scottish route to commercialisation for a main IP output' (Extract 27). In the context of these programmes, ITI manages all collaborations between DBFs and research institutes, appropriating new IP. Despite criticisms (Rosiello, 2007), licensing out IP is one of the main functions of ITI. As another ITI manager said '… we … license and we know this is particularly true in life sciences. You are not going to invest the kind of money that is needed to be invested to bring a life science product to the market unless you can get exclusive rights. So we recognise that we will license exclusively …' (Extract 28). Apart from the establishment of ITI Life Sciences, various government bodies in Scotland, including the Scottish Enterprise, have developed organisations that play the role of collective broker of public-private networks and collaborations.

Our empirical data suggests that most formal public-private collaborations in Scotland are vertical. Nevertheless, these collaborations appear to be more diverse than those in Cambridge. According to one interviewee, 'More and more of the work … is attempting to target the biomedical arena and the biotechnology arena ... although we still … have many interactions with the agricultural community' (Extract 29). As in the case of Cambridge, the quality of public-private collaborations in Scotland also depends on the organisation involved. For instance, given the historical process of top-down development of the Scottish bio-cluster, collaborations between Scottish Enterprise, universities and DBFs are intense. Thus, as one policy maker stressed '…from … the mid 1980s, the Scottish Enterprise predecessor organisation [SDA] has worked with universities, supporting the commercialisation agenda out of the universities and in the 10 or 15 years looking at ways in which particularly SMEs can link more with universities within Scotland' (Extract 30). Certainly, it is more difficult for these kind of linkages to be established in Scotland without policy intervention. This does not necessarily imply that collaborations between HEIs and

biotech companies are weak. Rather policy minimises possible negative impacts of such collaborations. For instance, as one scientist highlights, a biotech company '… may change its priority or whatever and you are very vulnerable to that immediate stop … it might take two years to establish the credibility so there is a lot of output required from the scientists and in a world where we continually being monitored for our academic output … there are conflicting pressures there' (Extract 31). This reflects the uneven and contradictory character of the wider innovation system but also the role of policy in resolving conflicts. In Scotland, policy initiates public-private collaborations which are guided by strong values of pubic interest, mutual trust and above all strong Scottish identity. According to one interviewee, '… the aim is really to bring economic return and benefit to Scotland' (Extract 32). This strong conception of public interest constitutes a dominant criterion of collaboration and also a foundation of mutual trust. Another interviewee said '… trust is very important, that comes on this interaction … It's easier to interact with companies that are local because of things that you go to, you go to the local seminar and there is the Chief Executive Officer (CEO) of other companies and you just chat to them, you go to a dinner and there is more opportunity for interaction and since it's that one-to-one relationship which drives these interactions, that's important' (Extract 33). Strong values of public interest, mutual trust and Scottish identity have increasingly facilitated the formation of a new community e.g. the Scottish bio-community. As one CEO of a DBF recalled '… when I first came back to Scotland 7 or 8 years ago … the sort of drug discovery companies knew each other and were relatively supportive but there was not much interaction with the other sub-sectors of the life science industry so the medical device companies, the diagnostics companies and the clinical research organisations increasingly over the past 2 or 3 years all of that community has come together because we realise, we share many common policies …' (Extract 34).

Our empirical data suggests that there may be also political values which influence the Scottish bio-community. According to one interviewee 'North of the border we have traditionally as a community voted for labour government, a community such as Cambridge might not have that political orientation or at least not predominantly, there has been and behind that there is a culture of more socialistic aspirations then so yes that might be well embedded in the culture and that may well interact' (Extract 35). Certainly, whether deeply political or not, this bio-community might not always be open to international collaborations with other companies and/or bio-communities. As one interviewee said '… there is an advantage of having a vibrant community … and we have productive interactions with companies which are local versus ones which are based elsewhere in the world' (Extract 36).

However, despite the fact that public-private collaborations in Scotland are influenced by strong communitarian values such as public-interest, mutual trust and Scottish identity, there are also conflicts and fragmentations at the level of 'Triple Helix'. Although these phenomena may be marginal, comparing to Cambridge, they take place in the formal relations between HEIs, research councils, biotech companies and government initiatives such as ITIs. Specifically, as one interviewee said, '… for some of the work that the university researchers take part in, it is funded by a research council who retain their intellectual property rights over that money, if that project overlaps with money that is coming from a company, the academic then has a conflict of interest …' (Extract 37). As another interviewee confirmed 'There is a conflict on the academic pursuit of science and the production of a product that a company wants

and where we benefit is if we can be involved at the first bit, the development bit …' (Extract 38). Although our data suggests that initial contractual agreements between public and private organisations in Scotland aim to prevent such conflicts, the latter, when they arise, are resolved even with withdrawal of HEIs from particular collaborations.

From the data that has been presented so far, it becomes clear that the historically formed innovation model of Scotland is a government-centric model compared to Cambridge's more governance-centric model. This, however, does not verify the hypothesis that public-private collaborations within such model are necessarily simple and linear. Rather, the case of Scotland suggests that collaborations are also complex and involve a number of public and private actors and dynamic processes of knowledge generation, transfer and utilisation. For instance, as one interviewee explained '… we have a [collaborative] programme … that involves two commercial companies, one based in Scotland …and one based out of Germany .. we then have … a programme which involves the university of Edinburgh … and a US based company called C who then set up a Scottish subsidiary to do the research …' (Extract 39). Through such complex collaborative programmes private firms mainly build project management capabilities. For instance, as one programme manager said, '… we will insist that there is a person with project management skills for our programme and so if they do not already have a person inside their company who has those skills we will discuss with them how you get someone trained to get those skills and we may invest some proportion of the money required to train that person but we would not pay for all the training ourselves …' (Extract 40). Private firms also build learning capabilities in various areas, including media representation and marketing. As another interviewee revealed, in the context of public-private collaborations '… we have done workshops on media representation, we have done workshops on marketing, we have got a workshop being planned on kind of investment in people …' (Extract 41).

Despite the building of firm-based capabilities through public-private collaborations, in Scotland there is a shortage of high-level management skills. Scotland fails to import such skills from US or Europe due to a relatively small number of international collaborations. However, apart from firm-based capabilities building, public-private collaborations in Scotland also result in building policy-making capabilities. The latter are associated with sustaining research with commercial interest. Other policy-making capabilities are associated with learning and understanding of private firms. As one policy consultant confessed 'I will work with them [private firms] basically to help me understand what their aspirations are, what the nature of business is where they are going, where they want to get to, how they plan to get there' (Extract 42).

Parallel to the model of public-private collaborations in Scotland, there is also a translational model emerging. This model appears to be predominately government-centric. Therefore, it includes top-down relations. For instance, within the bio-cluster, the Scottish Enterprise has recently started investing money in translational research, involving a large pharmaceutical company and Scottish HEIs. The question is what firm-based and policy-making capabilities can be build through such translational collaboration. In Scotland it is very early to provide answer. According to one interviewee, 'Scottish Enterprise is investing quite a lot of money … it's a very positive thing in terms of the profile that is generated that we are engaging with

multinational pharmaceutical company in Scotland and we could potentially develop a model if you like that would involve other pharmaceutical companies to do similar things because we certainly have the capacity, we certainly have the critical capability and we certainly have the patients' (Extract 43).

5. DISCUSSION AND CONCLUSION

Our empirical work indicates that public-private collaborations for biotech innovation in Cambridge and Scotland have been uneven and contradictory developments of the social division of labour and politics. The historically founded separation between direct production and academia in both regions reflect market and government failures which came to be politically addressed in the 1960's. This, however, resulted in the social and political construction of different systems of innovation. In Cambridge, due to geographical, organisational and technological dimensions of proximity, the university's liberal culture and the role of individuals in networking, the system was constructed from the bottom-up as being territorially embedded within the region. This does not mean that policy was totally absent. Rather policy provided infrastructure and facilitated particular systemic connections at the level of 'Triple Helix' through institutional developments such as the MRC laboratory of molecular biology and the CSP. By contrast, in Scotland, due to specific economic, social, cultural and even political divides between North and South, the system was constructed from the top-down as being a regionalised system of innovation (Cooke et al, 1997). The SDA (Scottish Enterprise) played the role of institutional link between life sciences, DBFs and the Scottish Executive. According to Lyall (2007: 3) 'The Scottish Executive made a play for science, even though it is largely a reserved power and was the first of the UK devolved territories to have a science strategy. The biotechnology/life sciences sector … has been a priority area for Scottish and UK policy-makers in terms of competitiveness'.

Scottish policy-makers clearly adopted Porter's cluster approach to genomics and biotechnology. This approach emphasises the importance of established and deep clusters for national and regional competitiveness (Porter, 1990). According to MacDonald et al (2007: 40) 'Established clusters have reached a stage of development that is based on extensive local supplier chains. Deep clusters have extensive collaborative local networks between firms and supporting agencies that help to develop and maintain competitive advantage for firms in the cluster by sharing information knowledge and assets'. Our empirical work shows that the Scottish bio-cluster is neither fully established nor very deep. Rather it is based on formal public-private collaborative networks which are supported by the Scottish Enterprise. Formality is not a surprising characteristic of the Scottish bio-cluster. Given the region's government-centric model of innovation, the space for informal public-private collaborations is considerably limited comparing to that of Cambridge. The latter's governance-centric model of innovation allows the establishment of more informal public-private networks and collaborations. Despite their differences, both Cambridge and Scotland have at the very centre of their bio-clusters universities of great academic and research reputation. This implies generation of positive externalities namely 'knowledge spillovers' and skilled graduates. According to Hendry and Brown (2006: 70) ''knowledge spillovers' locally are more likely to occur between biotechnology firms and universities/private research centres than with other firms'. On the other hand, skilled graduates provide cheap qualified labour to

DBFs, developing, at the same time, networks between firms and university departments/research centres. Most public-private collaborations in Cambridge and Scotland are vertical while their quality depends on the organisations involved. In Scotland collaborations between DBFs and the regional development agency appear to be more intense than in Cambridge. On the other hand, in Cambridge collaborations between DBFs and the university seem to be stronger than in Scotland.

However, the Cambridge bio-cluster appears to be more fragmented and discontinuous than the Scottish bio-cluster. The reason for this seems to be the absence of any strong conception of public interest as a criterion of public-private collaboration for genomics and biotech innovation in Cambridge. Therefore, notions of 'joint-up' and 'holistic' government (Pierre and Peters, 2000; Flinders, 2006) of the region's bio-cluster do not apply. By contrast, in Scotland, public-private collaborations are guided by the public interest (or common good) of economic and social development of the region. This brings together different actors and networks, forming the basis of a 'joint-up' and 'holistic' regional governance of the Scottish bio-cluster. Fragmentation and discontinuity at the level of 'Triple Helix' also explain why the Cambridge RIS is more conflicting in terms of IP than the Scottish RIS. In the context of the latter, IP issues are more likely to be resolved on the grounds of public interest while in the context of the former such issues are more likely to be negotiated on the grounds of individual self-interests.

Our empirical data suggest that public-private collaborations in both Cambridge and Scotland constitute social relations facilitated by non-market values. The most important ones are mutual trust and identity. In both Cambridge and Scotland, mutual trust is built through interaction between different public and private actors. Nevertheless, within the Scottish bio-cluster mutual trust is influenced by strong national identity while within the Cambridge bio-cluster mutual trust is facilitated by regional identity. It might be argued that these values are at the centre of the Cambridge and Scotland bio-communities. Mutual trust and identity guide processes of co-operation which go beyond commercial values and individual self-interests, sustaining learning. This empirically verifies the RIS theory that assumes a shift from hierarchical relationships to heterarchical ones. According to Braczyk et al (1998: 9) 'Heterarchy is the condition in which network relationships pertain based on trust, reputation, custom, reciprocity, reliability, openness to learning and an inclusive and empowering rather than an exclusive and disempowering, disposition'. Heterarchies develop routines by which public and private actors co-operate. As has been implied, in Cambridge such routines are more informal than in Scotland.

It might be suggested that the Cambridge and Scotland bio-communities sustain regional innovation models of complex public-private collaborations. The hypothesis that only bottom-up/governance-centric models of innovation correspond to such collaborations is not verified by our empirical data. As has been shown, the Scottish top-down/government-centric model of innovation also corresponds to complex public-private collaborations. Therefore, it cannot be regarded as simple/linear. Through complex public-private collaborations firms mainly build learning capabilities in different areas of interest. These areas include IP and project management, human resources, commercialisation, marketing, media representation, etc. By contrast, policy-makers build capabilities of balancing research and commercial interest as well as capabilities of learning and understanding of private

firms, flexibility and fast response to constantly changing conditions. This sort of capabilities-building is not surprising since previous research clearly indicates that organisational and institutional learning constitute fundamental characteristics of all hi-tech clusters (MacDonald et al, 2007). The latter, given their proximity dimensions, provide important social, economic, cultural and even political conditions for knowledge sharing, knowledge transfer and acquisition of new technology (Gertler, 1995; Knoben and Oerlemans, 2006). What is surprising is that public-private collaborations in genomics and biotechnology clearly fail to resolve the problem of managerial skills at regional level. Our empirical work suggests that in both Cambridge and Scotland there is a serious shortage of managerial skills. This is one reason why DBFs do not grow to the extent that big pharmaceuticals do. Shortage of managerial skills has negative implications for regional development because achievement of policy objectives such as maintenance of high employment figures depends on the growth of DBFs. However, due to the fact that the Scottish RIS is less open to international collaborations than that of Cambridge, the latter is more likely to import such skills from US or Europe. In Scotland the lack of managerial skills and the absence of big pharmaceuticals implies that the RIS '… has not yet reached that critical mass that triggers incremental dynamics in the form of inward investments, inflow of skilled people, presence of local anchors and stable streams of revenues to be re-invested locally' (Rosiello, 2005: 5). A critical mass of firms (small and big) is presupposed of any regional cluster.

Our empirical work verifies the hypothesis of translational model of public-private collaborations. The emergence of such a model in Cambridge appears to be a consequence of government failure as regards the making of medicines for public health. By contrast, the emergence of translational model in Scotland seems to be a consequence of market failure as regards public health pharmaceutical products. In both cases translational research involves conflicts and tensions not only between public and commercial values but also between different social epistemologies (Fuller, 1988; Stehr, 2004). In order for biomedical knowledge to be translated into biomedical innovations which are legitimised and accepted in the clinic, such knowledge has to be developed through a social epistemology to include the epistemological claims and interests of many different stakeholders (Robertson, 2007). However, firms involved in translational collaborations appear to build integrated knowledge capabilities on clinical processes while policy-making organisations seem to build capabilities that make them more efficient and productive in terms of developing and implementing relevant policy schemes and programmes. Our empirical findings indicate that this is at least the case in Cambridge. Translational research in Scotland seems to be a relatively new phenomenon. As '… it often takes considerably longer than 5 years in order to translate scientific knowledge into biomedical innovations that enter the clinic' (ibid: 198), translational research initiatives in Scotland will take even more time in order for them to be evaluated.

This paper has sought to examine the nature of public-private collaborations in genomics and biotechnology, and their role in building firm-based and policy-making capabilities. The focus has been on the RIS of Cambridge and Scotland. On the grounds of our empirical investigation, it can be maintained that, first of all, public-private collaborations for biotech innovation are uneven economic, social and political developments within particular RIS. These developments are historically founded upon the social division of labour as well as the social and political attempts

to resolve the fundamental problem of social separation between direct production and academia in the UK. Secondly, public-private collaborations in Cambridge and Scotland appear to have differences but also similarities. The governance-centric model of innovation in Cambridge is territorially embedded and includes less formal interactions and more bottom-up initiatives. By contrast, the government-centric model of Scotland is regionalised and includes less informal interactions and more top-down initiatives. What is interesting is that both models are governed by similar non-market values such as mutual trust and identity. These values are crucial for the maintenance of the Scottish and Cambridge bio-communities. Thirdly, independently of innovation model (top-down/government-centric or bottom-up/governance centric), public-private collaborations in genomics and biotechnology are essentially complex. This is not only in terms of the number of public-private actors involved in such collaborations but also in terms of the knowledge generated and utilised. Fourthly, complex public-private collaborations in genomics and biotechnology result in the building of innovative capabilities. For firms these include learning capabilities while for policy-making organisations they include the capabilities of better understanding of the private sector. The emerging model of translational research also leads to development of knowledge capabilities for firms and capabilities of efficiency and productivity for policy-making organisations.

In conclusion, it might be said that public-private collaboration in genomics and biotechnology in Cambridge and Scotland reflects a shift from regional government to regional governance. Although this shift appears to be more important in Cambridge than in Scotland, it seems to define innovation and economic growth in both regions. Therefore, public-private collaborations for biotech innovation are crucial for regional development.

NOTES

[1] The first five interviews in Scotland and the first six interviews in Cambridge have been contacted by Dr Alessandro Rosiello. I am indebted to him for his important contribution to this research.

[2] 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).

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