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The fourth mission of hospitals and the role of researchers as innovation drivers in the public healthcare sector

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Abstract: This article explores the role of researchers as innovation drivers in the public healthcare sector. The Triple Helix model is proposed for the analysis of the role of public hospitals in innovation processes. We discuss the role of public hospitals in innovation and in economic and social development, and identify this role as a 'fourth mission' of hospitals in addition to their widely recognized threefold function of healthcare provision, education and research. We discuss the evolution of hospital administration from healthcare towards the 'entrepreneurial hospital' model. More specifically, we investigate the extent to which the incorporation of full-time researchers can help to foster innovation at research and healthcare centres affiliated with the Spanish National Health System. Data were obtained through a survey of researchers, research group leaders and heads of departments and centres where these researchers worked, as well as through content analysis of researchers' annual reports.

Keywords: Health innovation; biomedical research; full-time researchers; hospitals; public healthcare sector; R&D&I programme evaluation.

La cuarta misión de los hospitales y el papel de los investigadores como promotores de la innovación en el sector sanitario público

Resumen: Se estudia el papel de los investigadores como promotores de la innovación en el sector sanitario público. Se propone el modelo de la Triple Hélice para el estudio del papel de los hospitales en los procesos de innovación. Se identifica la innovación y la contribución al desarrollo económico y social como la 'cuarta misión' de los hospitales públicos, adicional a su triple misión asistencial, docente e investigadora. Este enfoque aboga por una evolución desde el modelo asistencial tradicional hacia el modelo del 'hospital emprendedor'. A través del Programa FIS/Miguel Servet, se investiga en qué medida la incorporación de investigadores contribuye a fomentar la innovación en los centros del Sistema Nacional de Salud español. Los datos proceden de sendas encuestas a los investigadores y a los responsables de los grupos y de los distintos departamentos y centros a los que éstos se incorporaron, así como del análisis de contenido de sus informes anuales.

Palabras clave: Innovación en salud; investigación biomédica; investigadores; hospitales; sector sanitario público; evaluación de programas de I+D+i.

1. INTRODUCTION

One of the dogmas of the economics of innovation is that companies generate innovation, whereas the public sector suffers from what Potts and Kastelle (2010) call an innovation deficit or challenge. Nevertheless, recent years have seen a growing awareness that innovation is not restricted to the private sector, with public sectors such as education and healthcare, among others, also considered sources of innovation (OECD/Eurostat, 2005; Djellal and Gallouj, 2005; Koch et al., 2006; Petty and Heimer, 2011; Hughes et al., 2011).

Innovation is basic for the maintenance and improvement of healthcare provision and has evident, well-documented benefits for the healthcare system (Cutler and McClellan, 2001; Brach et al*.,* 2008; Font et al*.,* 2008; Pons-Ràfols, 2010). "Understanding how innovations […] can be effectively introduced in health systems and how these innovations interact with health system variables to influence health outcomes" has been identified as a challenge for health systems in order to achieve good health efficiency (Atun, 2012). However, measuring innovation and evaluating its impacts in the health sector is a field in a relatively incipient phase of development (Koch et al., 2006; Weiss, 2007; Fung et al., 2011).

Research and innovation are closely related. Although it is true that many innovations are not based in scientific knowledge, some authors consider research and technological development as instruments for attaining innovation (Commission of the European Communities, 2003). Many authors have found science and technology to be linked to both technological and non-technological innovation (Carpenter et al., 1980; Narin and Olivastro, 1992; Petty and Heimer, 2011). According to Friedman (2002), winner of the Nobel Prize for Physics in 1990, "innovation is the key to the future, but basic research is the key to future innovation", and symbiotic research, understood as the synthesis of basic research, applied research and product development, plays a crucial role in the creation of new technologies.

In this regard, researchers in the healthcare sector can play a significant role as innovation drivers and fosterers. Nevertheless, the existing literature on innovation in hospital-based healthcare has failed to investigate the role of actors involved in innovation other than medical staff (Djellal and Gallouj, 2007).

The present article is part of a research project one of whose aims is to investigate the role of researchers as innovation drivers in the public healthcare sector. Using the Triple Helix model as a framework for the analysis of the role of public hospitals in knowledge generation and innovation processes, we discuss their role in innovation and in economic and social development, and identify this role as a 'fourth mission' of hospitals in addition to their widely recognized threefold function of healthcare provision, education and research. We discuss the evolution of hospital administration from healthcare towards the 'entrepreneurial hospital' model. More specifically, we investigate the extent to which the incorporation of full-time researchers can help to foster innovation at research and healthcare centres affiliated with the Spanish National Health System (NHS).

2. BACKGROUND. INNOVATION AT THE SPANISH NHS AND THE FIS/MIGUEL SERVET PROGRAMME

Earlier analyses found the Spanish NHS to have shortcomings in the transfer of the research-based knowledge to clinical practice. The Spanish NHS is involved only rarely in the generation of research returns such as diagnostic tools, applied health treatments and new technologies, and has generated few patents (Meneu et al., 2005; de Pablo and Arenas, 2008). In addition, the Spanish model of biomedical and technological innovation is characterized, according to Bigorra (2010), by the limited role of hospitals, which are mainly restricted to providing services for clinical trials and enabling doctors to contribute to the dissemination of knowledge about therapeutic novelties. Oteo-Ochoa and Repullo-Labrador (2005) identified, among the factors that hinder innovation in the Spanish health sector, the insufficient number of institutionally supported R&D programmes, and the technical obstacles derived from the shortage of qualified personnel with technological skills. Moreover, the system of research evaluation neither encourages nor rewards innovation, except that which results in patents.

The generation of scientific and technological capacities at NHS hospitals constitutes a strategic action of prime importance in Spanish health public policies. In this regard, together with the creation, in recent years, of research centres of excellence and international prestige, public policies are making substantial efforts to enhance the research activity of public hospitals, as institutions with a threefold function: healthcare provision, education and research (de Pablo and Arenas, 2008; Gomis, 2009). Improving the capacity of Spanish NHS centres as generators not only of scientific knowledge but also of innovation is one of the challenges of the Carlos III Health Institute[1]. Its commitment to innovation has been explicitly manifested in the statement of programme objectives, and through initiatives currently underway within the framework of the Strategic Health Action[2]. To this end, the FIS/Miguel Servet Research Contract Programme constitutes one of the most important strategic actions. This programme was created in 1998, and in 2008 it was renamed after Miguel Servet, the illustrious 16th century physician, scientist and humanist. Previously it was known as the FIS (*Fondo de Investigación Sanitaria* [Health Research

Fund]) Programme, and the researchers it funded were known as FIS researchers. Hereafter, we will refer these actors as the FIS Programme and FIS researchers, respectively.

The programme's objectives are to incorporate researchers with excellent training within the Spanish NHS in order to improve the health system's research capacity, to provide research units and groups at healthcare establishments with multidisciplinary capacity, and to promote the creation of stable research groups within the Spanish NHS. Researchers are supported with a three-year contract which can be renewed for three more years if their work is evaluated favourably.

Innovation is among the goals of the National Research, Development and Innovation (RDI) Plan. By incorporating basic researchers into research at Spanish NHS hospitals and centres, the programme may contribute to this aim of the RDI Plan. As other authors previously noted, we are aware that the path from basic research (the production of knowledge) to innovation is a complex one that, as noted by De Pouvourville (2001), "is far from being straightforward". Nevertheless, considering that scientific research can be an instrument to attain innovation, our aim was to determine the contribution of these researchers not only to research, but also to innovation.

3. TOWARDS A CONCEPTUAL FRAMEWORK FOR THE ANALYSIS OF THE ROLE OF PUBLIC HOSPITALS IN KNOWLEDGE GENERATION AND INNOVATION PROCESSES

In this section we review the main theoretical approaches and conceptual frameworks used in previous research about innovation. As a theoretical grounding for our empirical study, we discuss the potential applicability of previous theories to the study of innovation in the healthcare area.

Current empirical studies and academic discussions on innovation are eminently multi-disciplinary. Theoretical and methodological contributions have come from many different areas, and have given rise to a broad corpus of knowledge which will not be reviewed in depth here; readers are referred to recent publications for further information (Fagerberg and Verspagen, 2009; Bhupatiraju et al., 2012; Fagerberg et al., 2012; Fernández-Esquinas, 2012; Martin, 2012).

The concept of innovation and the traditional linear model

The concept of innovation draws from the Schumpeterian tradition, according to which innovation has a basically economic purpose. This initially led to a linear conception of innovation (Godin, 2006) that some authors have called Mode 1 of knowledge production (Gibbons et al., 1994). In short, the traditional linear model of innovation postulated that "innovation starts with basic research, is followed by applied research and development, and ends with production and diffusion" (Godin, 2006).

This view of innovation began to be questioned by authors who were interested in the roles of different actors in the innovation process (in addition to the business sector) and in different forms of innovation other than technological innovation (Hochgernet et al., 2011; Echeverría and Merino, 2011). Thus, the new paradigm takes into account public sector organizations, public authorities, civil society organizations, trade unions and consumers (Commission of the European Communities, 2006; Hughes et al., 2011). Moreover, it also considers non-market-oriented processes such as hidden innovation[3] (for example, social innovation[4]). Within this new explanatory context, innovation in healthcare and in the hospital setting is clearly related to these different agents and forms of innovation.

The 'Innovation Systems' and the 'Triple Helix' approaches to the study of innovation. Their application to the study of innovation within health systems

As a result of this shift and some important considerations regarding the concept of innovation, a series of proposals have been made from an interactive or dynamic standpoint (Etzkowitz, 2003). Their main precursors were the Innovation Systems approach from the 1980s and the Mode 2 approach from the 1990s. The starting point that these two approaches share is their critique of the linear model of innovation along with their emphasis in interactivity among all agents involved. In the newer conceptualization, innovation is understood as a social system. The Mode 2 approach concentrates on the description of a new system of production of flexible, dynamic, trans-disciplinary and socially distributed knowledge (Gibbons et al., 1994), whereas the Innovation Systems approach focuses on the economic and sociological aspects of innovation and gives greater prominence to the role of institutions. This approach was introduced by Freeman's (1987) and Lundvall's (1988, 1992) work in National Innovation Systems. Their proposals intrepret innovation as a process in which actors and contextual factors are "important elements of any given system for the creation and use of knowledge for economic purposes" (Sharif, 2006).

This initial work subsequently gave way to other variants that shared the same systemic vision while emphasizing other levels of organization in addition to the national setting. Notable among these variants are the systems of innovation based on clusters (Malmberg and Maskell, 2002), sectors (Malerba, 2002), technologies (Carlsson et al., 2002) or regional settings (Doloreux and Parto, 2005).

Nevertheless, authors such as Edquist (1997) have pointed out a theoretical shortcoming in some of these non-linear proposals, and have recommended that they be used as framework models rather than closed theories with full explanatory capacity. In addition, some authors have criticized the excessive importance given to companies compared to other agents involved in innovation (Etzkowitz and Leydesdorff, 2000). A further potential limitation is that these approaches have tended to prioritize the level of analysis (e.g., national, regional or sectorial) at the expense of the view that research and innovation policies must be developed on a multi-level governance basis, including the national, transnational and regional levels (Edler et al., 2003).

Although innovation is not currently one of its principal objectives, different institutions within the NHS (e.g., hospitals and their associated research centres) can be considered part of national (and regional) innovation systems, understood as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse technologies" (Freeman, 1987), as well as "the system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies" (Metcalfe, 1995). The relationship between the National Health System and the National Innovation System can also be characterized from the approach proposed by Arnold and Kuhlman (2001). In their model, hospitals and other NHS centres may play a role in the education and research sectors. At the same time, they can be viewed as intermediaries between these sectors and the industrial system, whereby they assume the role of intermediate organizations with the capacity to provide extramural R&D services to industry (e.g., the pharmaceutical sector). In addition, the NHS, as a designer and co-ordinator of health and research policies, can be considered an element in the political system, as described by Arnold and Kuhlman, or in the institution sector, as proposed by Fisher (2001). On the other hand, the role of hospitals as entities that request and use innovation cannot be disregarded.

Nevertheless, some authors have drawn attention to the fact that innovation is dependent on other conditions in addition to scientific, technological, industrial and financial support (López Cerezo, 2004). It also requires social agents not directly involved in R&D activities or not directly tied to the business and finances world, i.e., agents that are not considered by the Innovation Systems model. Given their threefold function in healthcare, education and research, NHS hospitals can be considered one of these social agents. In addition, the social context is a determinant for innovation to succeed, but is frequently overlooked in analyses of innovation systems. As a result, the role of social agents (e.g., consumers or other direct beneficiaries of innovation, and people affected by or interested in innovation) is disregarded. Given that "the success of innovation depends on the favourable or at least non-hostile reaction of these and other social agents" (López Cerezo, 2004), in the healthcare arena it is essential to consider health professionals themselves as innovation users and patients as the ultimate beneficiaries of innovation. This is a drawback in the Innovation Systems approach to the study of innovation in healthcare.

A model that appears better suited to our analysis of the roles of public health service hospitals is the Triple Helix approach (Etzkowitz and Leydesdorff, 2000), which brings together the main contributions from earlier dynamics-based approaches. The Triple Helix proposal focuses "on the network overlay of communications and expectations that reshape the institutional arrangements among universities, industries and governmental agencies", and interprets innovation to be increasingly based upon the 'Triple Helix' of university–industry–government interactions (Etzkowitz, 2003: 293).

Considered in these terms, this approach may appear unlikely to be useful in attempts to analyse innovation at NHS institutions. However, the model is usually expressed in terms of interactions between academia (rather than simply universities), industry and government (Etzkowitz and Leydesdorff, 2000). In this model, academia includes universities and other knowledge-producing institutions, which are seen to play a new role in society (Etzkowitz, 2003). When formulated in these terms, the model offers a better conceptual fit to our purposes, provided that university hospitals are assumed to be knowledge-producing institutions where education and research take place as academic endeavours.

Healthcare institutions can be viewed as a different strand in the Triple Helix model. This is possible because the model is not a rigid framework, but rather allows new elements to be incorporated into the framework when one element is missing and another has appeared (Etzkowitz, 2003). Other essential characteristics of the Triple Helix are "the recognition that institutions may perform multiple missions", the corollary that "the secondary functions performed are the primary functions of the other spirals in the Triple Helix", and the recognition that "it is possible for an institutional sphere to play multiple roles without the original role being degraded or harmed" (Etzkowitz, 2003). This characteristic of the model allows hospitals to be considered as Triple Helix partners that take on some of the capabilities of other agents while maintaining their primary role and distinct identity (Etzkowitz, 2003). In this Triple Helix model of institutional relationships with a role in healthcare, the core mission of university hospitals continues to be that of healthcare provision, while at the same time these hospitals also assume a role canonically

ascribed to one of the other strands in the helix, i.e., the education and research roles of academia.

The 'fourth mission' of hospitals. From healthcare to the entrepreneurial hospital

Within the Triple Helix framework, a two-stage revolution has been identified (Etzkowitz and Leydesdorff, 2000**)** through which universities have been transformed from "a support structure for innovation, providing trained persons, research results, and knowledge to industry" into organisms that are increasingly "involved in the formation of firms, often based on new technologies originating in academic research" (Etzkowitz, 2003). In the first stage or first academic revolution, universities took on the function of research, evolving from teaching institutions into centres that combined teaching with research. The so-called second academic revolution comprised the change from research university to entrepreneurial university through the integration of economic and social development with teaching and research. This process has occurred at universities that successfully embraced the third mission – contributing to the economy and society – in addition to the two traditional roles of education and research (Martin, 2012).

In the context of the NHS, hospitals can be seen as institutions with a broader role than the widely recognized threefold function of healthcare provision, education and research. Just as a third mission has been identified for universities, a 'fourth mission' of hospitals can be seen to consist, in general terms, of innovation and knowledge transfer. This mission is understood to include innovation in health technologies and healthcare services, such that the outcomes can be transferred to society and thus contribute to economic and social development. In order to be compatible with the Triple Helix model, this mission can be considered to complete the circle by imbricating with healthcare to constitute the 'third mission' of healthcare institutions. Ultimately, this third mission of hospitals, which includes healthcare and the translation of research and innovation to healthcare provision and patient care, becomes their main, fundamental mission. This mission can transform hospitals, in Zawdie's (2010) words, into "power-houses of innovation, and hence strategic agents of sustainable development" in addition to healthcare providers.

In countries whose national health systems are troubled by the disconnect between healthcare provision and research, and where research is not well developed at public hospitals (as is the case in Spain [FECYT, 2005a; Bigorra, 2010]), the 'research revolution' is still in progress. At the same time, however, hospitals in these countries are preparing to face the 'innovation and transfer revolution'. At Spanish public hospitals the first revolution has been characterized by the change from healthcare institutions to healthcare and teaching hospitals (i.e. university hospitals), as a result of successful education and training activities[5]. Spanish public university hospitals are now in the midst of a second revolution – a process whereby their research function is being fully incorporated into the centres' usual activities. This 'second healthcare revolution' from teaching hospital to research hospital can be considered equivalent to the 'first academic revolution' described above. In addition, hospitals face the challenge of a third revolution in which they are taking steps to integrate innovation and economic and social development with healthcare, education and research.

Thus university hospitals face the challenge of evolving, as universities have done, to become 'entrepreneurial hospitals'. Like the entrepreneurial university, the entrepreneurial hospital can be defined as a hospital "that encompasses the conservation and passing on of knowledge, integrating [in addition to healthcare] education and research, as well as supporting innovation" (Etzkowitz, 2003). Like the entrepreneurial university, the entrepreneurial hospital**,** although it has "a considerable degree of independence from the state and industry", also requires a "high degree of interaction with these institutional spheres". The entrepreneurial hospital is closely linked to industries (e.g., the pharmaceutical industry) which produce goods and services; at the same time, the entrepreneurial hospital carries out research and provides training in their particular areas of expertise. Hospitals that operate according to this model are also linked to government, the ultimate arbiter of the rules of the game and potential provider of funding to support research and launch new enterprises. Like the full-fledged entrepreneurial university (Etzkowitz, 2003), a characteristic of the full-fledged entrepreneurial hospital is that research goals are defined by outside sources in addition to hospital experts in different scientific disciplines, in a two-way flow between research on the one hand and economic and social activities on the other. Within such a framework, translational research, i.e. knowledge flow from bed to bench and from bench to bed, remains a distinctive feature of the entrepreneurial hospital. As hybrid organizations emerging at the interfaces between the different institutional spheres in the Triple Helix model, research hospitals and entrepreneurial hospitals may give rise to spin-offs and other hybrid organizations. These arrangements, as stated by Etzkowitz and Leydesdorff (2000), are often encouraged, but not controlled, by governments through new "rules of the game", direct or indirect financial assistance or new actors[6].

In contrast to classical models that view institutions according to their traditional functions (such as the national Innovation Systems model, which considers industry as the primary institutional sphere and focus of innovation analysis, with government and university playing only supporting roles), the Triple Helix model focuses on new

activities "as a potentially productive innovation in innovation" (Etzkowitz, 2003). Classical models may thus be more appropriate to analyse "classical" healthcare-provision hospitals, whereas the Triple Helix model is better suited to the analysis of entrepreneurial hospitals involved in the missions described above.

Our approach to the study of innovation in Health Systems is consistent with the structural and procedural perspective that contemplates not only market- and profit-oriented innovation but also innovation that addresses social needs. We consider innovation as embedded in the science-technology-society system, rather than in the science-technology-industry system. In the former, industry forms an important part of society although the system also comprises other agents (López Cerezo, 2004), including health services.

We approach the study of innovation as the sociology of innovation, which we view as a hybrid discipline stemming from the sociology of science and the sociology of economy. Studies in the sociology of innovation thus set out to understand innovation as a social process. Our approach uses the sociology of science to analyse innovation, because it "provides the keys to study scientific communities and organizations that generate the knowledge that gives rise to innovations with a broad social impact" (Fernández Esquinas, 2012). These communities include universities, research centres, and, as in the present study, healthcare institutions. There were two main reasons for choosing this perspective to study innovations derived from scientific research and based on scientific discoveries and applied technology: first, the role of the healthcare sector in the generation of innovation, and second, the fact that innovation is rooted in the structure of society and culture.

The study of the interphase that arises as a result of the incorporation of basic researchers within the NHS environment entails looking beyond the traditional Innovation Systems approach, because – as noted by Fernández Esquinas (2012) – this approach "limits the observations to those sets of rules that affect the interrelation of organizations". It is therefore necessary to consider different sets of rules that condition the work of researchers and healthcare personnel in scientific institutions in general, and in NHS institutions in particular. In addition, the set of norms and values governing scientific research and the production, diffusion and consumption of scientific knowledge need to be considered. The approach based on the sociology of innovation makes it possible to observe the manner in which particular values and norms typify particular institutions. This correspondence is interesting when basic researchers – who learn a set of norms and values at laboratories at R&D centres – join hospital-based research groups where a different set of values and norms is likely to apply.

The notion of social structure, although not usually considered in innovation studies, is nevertheless essential to understand innovation at Health Systems. Social structure, as noted by Fernández Esquinas (2012), is the sphere of individual and collective interests backed by variable amounts of power and resources. The social structure is composed by people who play different roles according to a hierarchical scale, and the components of this structure are formed by the skills and resources that give the actors the ability to act or force others to act. Within the scope of the present study, the integration of basic researchers into hospitals places them in a social structure very different from that of the research laboratories most of them came from. The social structure at Spanish public hospitals is characterized by marked hierarchization, a traditional prevalence of clinical research, a disconnect between healthcare provision and research, and the absence of an established research career path within the Spanish NHS (Rodés and Mayor, 2003; FECYT, 2005b; Bornstein and Licinio, 2011). These features may act as determining factors in the production, implementation and diffusion of innovation, and may also provide keys to understanding to what extent hospitals and other healthcare institutions may be considered innovative organizations.

4. METHODS

A detailed description of the methodology used in this research was published previously (Rey-Rocha and Martín-Sempere, 2012). In that article we explained the population and sample studied, the research instruments used for data collection, the data analysis and statistical procedures. However, to facilitate comprehension of the present article, the most relevant aspects of this methodology are summarized below.

The universe to be studied consisted of the different stakeholders in the FIS Programme. This included, on the one hand, the population of 192 FIS researchers funded by the first four calls of the Programme (1998–2001) who worked at 60 different hospitals and five research centres of the Spanish NHS. In addition, the universe included the population of 277 leaders of research groups and heads of the different departments and centres where FIS researchers worked (referred to hereafter as FIS hosts).

We used a web-based survey to obtain data from the population of FIS researchers. In addition, a detailed structured questionnaire was administered face-to-face to FIS hosts. The overall response rate was 70.8 % (136 valid answers) for researchers and 52 % (144 individuals) for hosts. In addition, an initial attempt was made to assess innovation quantitatively by examining data on patenting activity obtained from FIS researchers' final activity reports.

We asked FIS researchers whether the research work they carried out during their contract helped produce or implement innovation. To facilitate the identification of innovation, the concepts of innovation used in the survey were explained together with the relevant item. In accordance with the OECD/Eurostat Oslo Manual guidelines (1997) 'technological innovations' were defined as those related to the introduction or use of technologically new or substantially changed products (goods or services) and processes. 'Non-technological' innovation covered all innovation activities that did not meet the definition of technological innovation, including organizational and managerial innovations. An innovation was considered to have been 'implemented' if it had been introduced on the market (product innovation) or used within a production process (process innovation).

Meaning analysis of the responses to open questions was approached by both 'meaning condensation' and 'meaning categorization'. First, significant information was extracted from texts and condensed into briefer, more succinct formulations, and the constructs implied by the data were identified. These constructs were further categorized and coded. Quantitative data were analysed with the Statistical Package for Social Sciences (SPSS) for Windows, version 15.0.

5. RESULTS

In order to better understand their role as innovation drivers, it is worth recalling some of the researchers' main characteristics along with the activities they carried out during their contract. Under the FIS Programme, postdoctoral researchers from different academic backgrounds joined research groups working at Spanish NHS centres. Most FIS researchers held a doctorate in biology, and some held a doctorate in medicine and surgery, pharmacy or another academic field (Rey-Rocha et al., 2012). FIS researchers mainly undertook basic research exclusively or in combination with clinical research. They collaborated mainly with clinical researchers at their own centres, whereas extramural collaborations most frequently involved basic or basic + clinical researchers (Rey-Rocha and Martín-Sempere, 2012). The survey results showed that most FIS researchers (60%) worked full-time in research, whereas two fifths of the participants alternated research with other activities, mainly administrative and management tasks, teaching, and science communication. Less than 24% worked in development activities (rather than research activities) or healthcare provision.

Around three quarters of the scientists surveyed considered that during their FIS research contract, their group did not produce or implement any technological innovation, or did so as a result of other research lines different from their own. This percentage was even higher (more than 90%) for non-technological innovation. The contribution of the small group of researchers who answered affirmatively was focused mainly on technological (product and process) innovation, as well as on the production of innovation in organizational structures and corporate strategic orientations (Table I).

On the other hand, 80.9% of the respondents felt that their research work did not directly help their group to produce or implement any technological process innovation (Table I). Initially, this may appear to contradict the fact that 92.7% believed they had helped their group to apply new techniques, and 89.7% felt they had helped their group to develop new techniques (Table II).

Table I. Do you think the research you carried out during your FIS contract helped to produce or implement any innovation?

% of researchers surveyed (n=136)	My group did not produce or implement any innovation during my stay	Yes it did, but as a result of research lines other than mine	My research helped to PRODUCE innovation	My research helped to IMPLEMENT innovation
Technological innovations				
Technological product innovation	74.3	3.7	12.5	9.6
Technological process innovation	75.0	5.9	14.0	5.1
Non-technological innovations				
Implementation of advanced management techniques	91.9	1.5	4.4	2.2
Introduction of significantly changed organizational structures	84.6	1.5	10.3	3.7
Implementation of new or substantially changed corporate strategic orientations	83.8	2.9	8.1	5.1

Table II. Do you think your incorporation as a FIS researcher helped to apply or develop new techniques by the host group or department?

% of researchers surveyed (n=136)	APPLICATION of new techniques	DEVELOPMENT of new techniques
Yes, my incorporation has been a determining factor	59.6	51.5
Yes, my incorporation has contributed to some extent	33.1	38.2
No, my incorporation had no effect	4.4	8.1
No new techniques have been applied or developed	2.9	2.2
Total	100	100

Most techniques applied or developed by FIS researchers fall into the fields of molecular biology and communication and image engineering. Examples are given below:

> *Basic molecular and cell biology techniques such as real-time thermocycler, flow cytometer, cell cultures, gene overexpression and silencing, protein interactions, tissue arrays and cDNA* (FIS researcher who led a newly created research group at a hospital pathology research unit, and who carried out basic and clinical research)

> *Molecular genetics techniques such as [testing for] loss of heterozygosity, promoter methylation, gene expression, etc*. (FIS researcher who led a newly created research group at a hospital molecular oncogenetics laboratory, and who carried out basic and clinical research)

> *Confocal microscopy, various molecular biology techniques such as recombinant DNA, electrophoretic mobility shift assay, real-time polymerase chain reaction, gene transfer into cells by transfection or adenoviral agents* (FIS researcher who led a newly created research group at a hospital bone metabolism laboratory where she carried out exclusively clinical research)

But even if the respondent specifically mentioned having developed a new technique, he or she did not consider that it contributed to innovation, or did not regard this development as an innovation. This situation is well reflected by the comment by one of researchers surveyed who, despite reporting that work contributed to the development of many techniques, stated that none of his work led to the production or implementation of innovation.

> *In our laboratory we perfected animal models and cell culture, molecular biology, gene transfer and flow cytometry techniques. […] In the future our research line may lead to products or processes that reach the market, but at the moment our main objective has been and continues to be knowledge generation, i.e., to answer questions.* (FIS researcher who led a newly created research group at a hospital blood and tissue bank, and who carried out exclusively basic research)

The view expressed above contrasts with that of researchers who, regardless of whether their results reached the market or not, identified a wide range of both technological and non-technological innovations. These include not only innovations of economic value (i.e., those which helped improve productivity and competitiveness), but also social innovations that facilitated the availability, quality and efficiency of healthcare, and healthcare innovations such as care centres that increased efficiency in the use of human and financial resources and improved the management of demand pressures. Examples of these technical and non-technical innovations are given below:

> *We patented, together with a pharmaceutical company, products with anti-tumour activity against colorectal cancer which we are extending to other tumour types.* (FIS researcher who led a newly created research group at a hospital gastrointestinal research laboratory, where he carried out basic, clinical and pharmacological research)

> *Commercialization of the sperm chromatin dispersion (SCD) test by two national companies. We patented a new siRNA anti-CD40 molecule (product innovation) and created a new process to incorporate it into kidney tissue (process innovation) that consists of injection via the renal artery and immediate organ electroporation.* (FIS researcher who created a sub-group within a research group on experimental nephrology and transplantation, and who carried out basic, clinical and pharmacological research)

> *We originated and developed molecular diagnosis procedures with high-performance and highly reliable techniques for research and molecular diagnosis tasks. [These procedures] were not available before I joined the group. Thanks to these techniques, a Molecular Diagnosis Service was established oriented towards molecular diagnosis for the pathologies of interest, where samples are currently processed from many national and international centres.* (FIS researcher who led a newly created research group at a hospital endocrinology department, and who carried out basic and clinical research)

Participation in the Strategic Plan at my Centre and in the Mental Health Plan of the Autonomous Region. (FIS researcher who led a newly created research group at a hospital research unit, and who carried out basic and clinical research)

The contribution of these researchers to innovation at the hospitals and research centres where they worked was further investigated from the point of view of the heads of their administrative units and research group leaders. They were asked to rate the extent to which the Programme fostered innovation within the Spanish NHS. The average rating was a mid-range value (3.1) on a scale from 1 (not at all) to 5 (a lot) (Table III), reflecting a remarkable consensus among informants in all categories.

Even more informative is the distribution of responses: around one third of our informants felt that the FIS Programme had contributed a lot or quite a lot to innovation. Particularly noteworthy was the proportion of positive responses from healthcare professionals closest to the researchers: 31% of research group leaders and 37% of hospital research managers felt that the programme researchers had helped to foster innovation.

Professionals more directly related with medical services (heads of clinical services) were more divided in their opinions, the largest proportion (42%) having a positive perception of the importance of FIS researchers as catalysts of innovation processes. However, this group also accounted for the largest percentage of informants who felt that programme researchers had helped only slightly or not at all (39%). For their part, only 18.5% of hospital administrators, who a priori are the actors most removed from research and FIS researchers, felt that the latter had played a large role in facilitating innovation, most of them indicating that the Programme had contributed 'to some extent'.

As we have seen, FIS researchers reported that most of their work involved basic research. FIS hosts confirmed this and considered this to be one of the reasons why FIS researchers were not more focused on innovation. Two of the informants at a large hospital that hosted many FIS researchers highlighted this point from the perspective of a research director and a research group leader:

[FIS researchers] have brought in a breath of fresh air and have incorporated basic research, which may eventually be applicable at the hospital, sooner or later. (Hospital research director)

Innovation is not transferred to the [Spanish] NHS. Thanks to the programme, clinicians are brought closer to basic research, but FIS researchers 'do not push', do not translate innovation to the System. (Research group leader)

FIS hosts emphasized time as the main reason why the incorporation of these researchers did not contribute significantly to strengthening innovation within the Spanish NHS: 8.3% of them were of the opinion that six years is not long enough for their contributions to materialize, as the following quotations indicate:

It is too early to talk about innovation. We haven't reached the 'I'. (Head of a hospital service and research group leader)

I don't think they had enough time. Innovation needs research first. Research is part of the innovation process. And they haven't had enough time yet. (Hospital administrator)

Innovation is a long-term concept. Six years is not long enough. (Hospital administrator)

An open question we put to FIS hosts solicited their opinion about the main effects the incorporation of FIS researchers had on hospitals and research centres, and on their different units, departments and groups. Only two of them, the

Table III. To what extent do you think the Programme has helped to strengthen innovation in the National Health System?

(% of FIS hosts)	HA (n=27)	RM (n=46)	HS (n=36)	GL (n=35)	Total (n=144)
5 = a lot	7.4	8.7	8.3	11.4	9.0
4 = quite a lot	11.1	28.3	33.3	20.0	24.3
3 = to some extent	40.7	23.9	5.6	40.0	26.4
2 = slightly	22.2	23.9	25.0	17.1	22.2
1 = not at all	3.7	8.7	13.9	2.9	7.6
No response	14.8	6.5	13.9	8.6	10.4
Total	100	100	100	100	100
Average ± standard deviation (range) median	3.0±1.0 (1-5) 3	3.1±1.2 (1-5) 3	3.0±1.3 (1-5) 3	3.2±1.0 (1-5) 3	3.1±1.1 (1-5) 3

HA = hospital administrator; RM = research manager (includes: managers of research foundations, hospital research directors and heads of research centres); HS= head of hospital services and units; GL= research group leader.

administrator and the research manager of middle-sized hospitals with strong research capacities, expressly mentioned the researchers' capacity for innovation and their contribution to the increase in the hospitals' capacity for innovation. The hospital manager noted their effect on human capital, while the research manager mentioned their influence on the hospital's technological capital.

Although FIS hosts rarely mentioned innovation explicitly as one of the effects of the incorporation of FIS researchers, they did implicitly mention technological innovation. According to 19.4% of them, the main contribution of FIS researchers was their methodological training, i.e., the incorporation of new technologies and techniques to the host groups, units or hospitals (Rey-Rocha and Martín-Sempere, 2012). These technologies and techniques, once incorporated into the groups, formed part of their technological capital, and by extension became part of the technological capital of the hospitals and research centres. Some respondents (9.7%) considered this to be one of the main added values provided by FIS researchers:

> *Innovation in medicine is more complicated. In any case, the incorporation of FIS researchers allowed us to apply techniques already in existence, but that we had not applied before. This does not make it possible for you to innovate, but it does make you aware of innovation that takes place.* (Head of a hospital service)

> *There are technologies that we would not have incorporated without the FIS researcher.* (Research group leader)

According to the leader of a productive research group of recognized national and international prestige, these researchers:

> *…bring in new techniques that allow the work to take a giant leap forward, and for some groups I know this has marked a turning point in their work.*

This is the case, for instance, in a cancer research group, whose leader noted:

> *We are haematologists and physicians, and we admit our weakness in research. The FIS researcher set up all the techniques. Without him we could not have set up the arrays.*

This is an aspect that is especially relevant from the point of view of research group leaders, and is one of the two effects they mentioned most often (34.3%).

Innovation is not produced exclusively in the field of new technologies, but also covers the areas of institutional management, organization and strategic orientation. Along these lines, the effects on the organizational capital of hospitals, specifically in the organization of hospital research (a clear example of non-technological innovation), is another innovation-related aspect that was identified by FIS hosts as one of the effects of the incorporation of FIS researchers. This particular was mentioned by 7.6% of the hosts, and 5% considered it one of the main added values provided by FIS researchers. Organizational innovation is essential in the health sector. One of the hospital administrators we surveyed summed up how essential organizational innovation is in the healthcare sector:

> *The introduction of technological innovation has to involve organizational change. If we incorporate computed axial tomography and use it as just another technology, this is an additional expense; if we do not use it selectively for only some patients rather than for just any patient (organizational change) it is an expense. Research lines that investigate the technological–organizational–attitudinal innovation triad should be favoured.*

Nevertheless, organizational innovation was rare, as indicated by the survey data (Table I) and as some FIS hosts noted:

> *I do not think that research carried out by FIS researchers has changed clinical practice at their host centres. They did not have the time. I haven't seen them create any spin-offs either.* (Research group leader)

> *Innovation means the ability to do what we do in a different way. In this regard, I do not think this has been achieved. We are at a quantitative stage (we have more grants and more papers), but haven't reached the qualitative stage yet. Innovation is not only technology. It is organizational innovation and attitudinal innovation.* (Hospital administrator)

Our analysis of the final reports from FIS researchers at the end of their contracts showed that an average of 0.3 patent applications were filed per capita, and an average of 0.1 patents per capita were awarded (Table IV). These are absolute numbers that should be considered not in themselves, but rather in comparison with figures for other researchers in the fields of Biomedicine and Health Sciences, both in the healthcare sector and in the academic and university sector. Studies that have appeared to date usually present data on a macro or meso scale, and few data are available on technological productivity at the micro scale of groups or individuals.

The study by Rey-Rocha et al. (2006) on the individual productivity of members of research groups in the Biology and Biomedicine area of the Spanish Council for Scientific Research (CSIC) provides some data on technological productivity by individuals, which can be compared with the findings reported here. CSIC researchers were awarded an average of 0.4 patents per capita during the period from 1998 to 2002 (Table IV), a much higher figure than FIS researchers during their six-year contracts. Nevertheless, this comparison should be considered as merely exploratory because of the different characteristics of the two samples. Among other considerations, the data for the population studied here refer to technological productivity resulting exclusively from work done

during the six-year FIS contract, and do not take into account results based on work done during previous postdoctoral training. In contrast, the analysis of CSIC researchers' productivity was based on patents granted during the five-year period from 1998 to 2002, and some of the results obtained during this period may have been the fruit of work done before 1998. Moreover, this difference in the rates of successful patent application was very likely influenced by the different professional contexts in which these researchers worked: academic and purely research-oriented in the case of CSIC employees, versus mainly hospital-based (therefore aimed mainly at providing healthcare) in the case of FIS researchers.

6. DISCUSSION AND CONCLUSIONS

This paper has explored the role of researchers as innovation drivers in the public healthcare sector. To this end, we have first reviewed the main theoretical approaches and conceptual frameworks used to study innovation, and have discussed their suitability and relevance to research such as ours, which aims to understand innovation in healthcare. We have then considered the role of public hospitals in innovation as well as in economic and social development, and have identified this role as the 'fourth mission' of hospitals in addition to their widely recognized threefold function of healthcare provision, education and research. We have argued in favour of the evolution of healthcare hospitals towards a type of operation termed the 'entrepreneurial hospital', and have suggested that this process requires a 'research revolution' and an 'innovation and transfer revolution', in accordance with the terms used in the Triple Helix model. More specifically, we have used the FIS/Miguel Servet Research Contract Programme as the basis for a case study to explore the extent to which basic researchers can contribute to this shift by fostering innovation at research and healthcare centres affiliated with the NHS in Spain.

Our findings indicate that the role of researches as R&D-based innovation drivers was limited, as evidenced by participant's assessments and the hosts' views. The FIS researchers contributed to innovation mainly by providing research groups with new techniques and technologies. This represented a type of intra-organizational innovation based on the incorporation of technologies developed elsewere. In this regard, the incorporation of these researchers does not seem to have surpassed the model of innovation based on the extension of foreign innovation, which Meneu et al. (2005) considered predominant in Spain.

Although most FIS researchers felt they had helped to apply and even develop new techniques, few of them identified this contribution as an innovation or were aware that it can be considered as such. Their attitude may be considered evidence that many researchers who participated in the Programme assume that innovation is defined according to the 'Oslo conception' (Echeverría, 2008) based on the Schumpeterian tradition according to which innovation primarily concerns economic and business values.

The incorporation of FIS researchers helped few Spanish NHS research groups and centres to make substantial progress toward becoming innovation generators or increasing their innovation capacity. As Font et al. (2008) pointed out, "although innovation does not always guarantee better results in the short term, it almost always facilitates the development of new models to achieve them, new techniques and approaches that redefine the limits of what is possible". Taking into account the importance for contemporary research of access to and opportunities to use advanced technologies, along with the knowledge of these techniques, the acquisition of new techniques by some research groups and healthcare centres could reasonably be assumed to start them down the road to new lines of action leading to better results in the middle and long term.

In this regard, research-based innovation must be understood as a long-term output. Innovation in the healthcare public sector resulting from R&D activities must be seen as the result not of single discrete changes, but as the result of (as stated in the third edition of the Oslo Manual

Table IV. Patent applications and patents awarded to FIS researchers during their contracts. Comparison with CSIC researchers in the Biology and Biomedicine area

Average ± standard deviation (range) median	CSIC researchers Biology and Biomedicine (1998-2002)*	FIS researchers
Patent applications per researcher	No data	0.3±0.8 (0-4) 0
Patents awarded per researcher	0.4±0.9 (0-6) 0	0.1±0.4 (0-3) 0

Includes all patents (domestic, foreign and international)
* Source: Rey-Rocha et al. (2006)

[OECD/Eurostat, 2005]) "a series of incremental changes, provided those changes together amount to a substantial improvement" (Bloch, 2007). Thus, time is needed to undertake these changes and see innovations resulting from research. Insufficient time was identified by our informants as an important reason why the incorporation of FIS researchers did not contribute significantly to strengthening innovation in the Spanish NHS, as six years was considered too short a period for their contributions to materialize. Consequently, further research will be needed to investigate whether the activity of researchers at public healthcare centres will result in innovations and transfer processes throughout their subsequent research careers after completing work under the terms of their FIS contract. Ultimately, the study of FIS researchers' career paths will provide an opportunity to obtain empirical evidence to corroborate Friedman's (2002) claim that "basic research is the key to future innovation".

As we have seen, most of the work done by FIS researchers involved basic research, and FIS hosts confirmed this point as being one of the likely reasons why FIS researchers were not more focused on innovation. Moreover, most of the groups FIS researchers joined for the duration of their contract were groups that worked in mainly clinical research. As a result, most techniques applied or developed by FIS researchers fall within both basic-oriented and more clinical-oriented fields such as molecular biology and communication and image engineering. This is consistent with Bigorra's (2010) new model of biomedical and technological innovation resulting from advances in the knowledge of the molecular basis of diseases and the convergence between biology and engineering thanks to new communication and imaging technologies. This kind of collaboration may be able to foster innovation through the promotion of interactions between basic researchers, clinical researchers and healthcare professionals, e.g., by favouring translational research. As we reported previously (Rey-Rocha and Martín-Sempere, 2012), policy actions intended to enhance human resources in R&D within the hospital environment may play a valuable role in promoting translational research, which may in turn result in innovation and transfer.

In line with the FIS Programme objectives and evaluation criteria, which assess researchers' activity and performance on the basis of their leadership capabilities and scientific productivity (articles published in journals that have been assigned an impact factor), FIS researchers focus their efforts on scientific publications[7] rather than patenting, commercial or entrepreneurial activities. Consequently, FIS researchers obtain fewer patents, at least compared to other researchers such as those employed by CSIC. A challenge for further research is to analyse patenting activity at hospitals as an indicator of R&D-based innovation, and to identify the factors that influence this activity.

Although an overall objective of the present study was to investigate researchers' opportunities to become drivers of innovation in the hospital setting, we also wished to further identify the likely effects of science-based innovation on the Spanish NHS. The FIS/Miguel Servet Research Contract Programme provides opportunities for further research to answer a number of questions. i) Which factors influence the capacity to produce and incorporate innovation in the public health arena? ii) Which types of activities, resources and social relationships are involved in these processes? iii) Which contexts favour innovation? iv) How receptive to innovation are healthcare centres and their associated R&D centres? v) What is the role of healthcare institutions and institutions that manage public healthcare services and R&D programmes? vi) Which types of people are likely to become innovators? vii) How might the development of the foregoing factors foster the innovation capacity and enhance performance at these institutions? viii) What are the organizational and social effects of innovation in healthcare?

Some limitations in the data and their interpretation need to be recognized. Our findings cannot be generalized to other populations of researchers or to contexts other than the Spanish NHS. It is important to consider that Spanish NHS hospitals, in general, are characterized by a traditional prevalence of clinical research, deficits in the transfer of the research-based knowledge to clinical practice, a limited role in the innovation process, a shortage of qualified personnel with technological skills, and the absence of an established research career path. Moreover, the validity of the results of our study will ultimately rest on replication in other populations and settings, further research with different analytical techniques, public discussion and debate by other researchers and actors in other study populations, and the response of decision-makers and information users to our analysis.

As emphasized in the introduction, among the factors that hinder innovation in the Spanish health sector are the insufficient number of institutionally supported R&D programmes and technical obstacles arising from the shortage of qualified personnel with technological skills (Oteo-Ochoa and Repullo-Labrador, 2005). In this connection, stronger human resource programmes to support the incorporation of highly qualified basic researchers into hospital-based research efforts may help support the 'fourth mission' of hospitals within the Spanish NHS system.

In the line with the Publin Report on Innovation in the Public Sector (Koch et al., 2006), Spanish NHS healthcare and research centres face the challenge of developing "learning strategies needed to find, understand and make use of competences developed elsewhere". According to the concept first introduced by Cohen and Levinthal (1990), centres should develop their absorptive capacity,

i.e., their ability to "recognize the value of new information, assimilate it, and apply it" not only "for commercial ends" as stated by these authors, but for the benefit of healthcare provision. But these centres should also be capable of identifying and appreciating intra-organizational innovation within their own operations. For public hospitals and health research centres to create and maintain an innovation baseline, they will need to recognize the innovation cycle, opportunities for innovation, innovative ideas and ultimately the innovations generated within the organization itself.

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NOTES

[1] The Carlos III Health Institute is the public organism responsible for funding and managing most biomedical research in Spain.

[2] Resolution of 22 February 2010. Boletín Oficial del Estado number 58, 8 March 2010, pages 23295-377.

[3] The concept of hidden innovation was originally developed by Hansen and Serin (1997). It has been defined by NESTA (2007) as "innovation activities that are not reflected in traditional indicators such as investments in formal R&D of patents awards".

[4] 'Social innovation' is a notion that considers "the innovative activities and services that are motivated by the goal of meeting social need and that are predominantly developed and diffused through organizations whose primary purposes are social" (Mulgan, 2007).

[5] In Spain this has been accomplished through an internal resident physicians training programme known as the MIR Programme, which started in 1998 (FECYT, 2005b).

[6] Examples of such arrangements at the Spanish NHS are the creation of Research Foundations at public hospitals (FECYT, 2005b) or the more recent actions and programmes of the Health Research Fund (FIS) and the Carlos III Health Institute, e.g. the Thematic Networks for Cooperative Research (RETICS), the Biomedical Research Networking Centres (CIBER), the Programme for the Promotion of Research or the Human Resources on R&D programmes, including the FIS/Miguel Servet Programme, among others (Font et al., 2008; Gomis, 2009).

[7] Compared to patent data, it is of note that almost all researchers who completed their contract published at least one article in a Web of Science-indexed (ISI) journal. On average, they published more than fourteen articles per capita during the six-year duration of their programme contract (Rey-Rocha et al. 2012).

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