



Exploration and exploitation in innovation systems: The case of pharmaceutical biotechnology

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Abstract

This paper develops a theoretical framework for an explanation of how exploitation and exploration build on each other, in a ‘cycle of discovery’, developed in earlier research. The framework is tested empirically, in the sense of seeing whether it can help to reconstruct and understand the emergence of the pharmaceutical industry. One of the conclusions is that whereas recent literature stresses the idiosyncratic nature of the biotechnological revolution, our analysis seems to reveal that this does not seem to be as unique as suggested. From this, we conclude that the theoretical framework we propose, serves its purpose of explanation. But there are also some lessons for improving it.

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1. Introduction

Many studies have analysed the effects of a wide range of institutions on innovation (Lundvall, 1992; Nelson, 1993; Edquist, 1997; Whitley, 1999; Mowery and Nelson, 1999; Malerba, 2002, 2004). Some institutions are industry-specific, such as systems of production, organization, distribution, supply, technical standards, training, and so on. Such institutions may be associated with ‘industry recipes’ (Spender, 1989),

‘dominant designs’ and mindsets regarding product, market and organization, in systems of ‘exploitation’ (March, 1991). Broader national institutions, beyond industries, include government, legal systems (including property rights), infrastructure, general training and education, labour conditions, financial systems (including venture capital), and the like. These have had a clear influence, e.g. on the biotechnology revolution, as documented in a range of studies (e.g. Gambardella, 1995; Orsenigo et al., 1998, 2001; Henderson et al., 1999; Jungmittag et al., 2000; Pisano, 2002; Gassman et al., 2004; McKelvey and Orsenigo, 2004). We fully acknowledge their importance, but in the present paper, we do not aim to repeat or extend the study of their effects. We are interested, rather, in the basic ‘system

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logic' of how, in a new round of radical innovation, sector-specific institutions such as dominant designs, industry recipes, and mindsets change. In other words, how exploration builds on but also shifts existing systems of exploitation. This system logic is based on a theory of learning, in the sense of discovery, developed in earlier work, which entails a dialectic process of exploitation and exploration (Nootboom, 2000), intended to explain how radical innovation and structural change arise endogenously. In this paper, we discuss this logic at a sectoral level, to understand the transition from exploitation to exploration and vice versa. On the basis of this, we analyze the effects of such sectoral dynamics on organizational forms, in particular networks of firms.

We apply this framework to the pharmaceutical industry to see whether it can help reconstruct and understand the biotechnological revolution. Recent studies on the pharmaceutical industry seem to agree on the fact that there have been, apart from firm-specific and national aspects, fundamental changes at the sectoral level (Arora and Gambardella, 1994; Gambardella, 1995; Orsenigo et al., 1998; Henderson et al., 1999; Jungmittag et al., 2000; Pisano, 2002; Brusoni and Geuna, 2003; Santos, 2003; Gassman et al., 2004; McKelvey and Orsenigo, 2004). This literature has described in great detail how the advent of molecular biology and genetic engineering yielded a profound transformation of the pharmaceutical industry and induced a new division of labour that required a new organizational form made up of networks of scientists, specialised new entrants and large pharma firms. The claim that we submit here is that our system logic helps to understand these sectoral dynamics. In this way, we aim to go beyond some of the more descriptive accounts as present in the recent literature and aim to contribute to an evolutionary theory at a sectoral level, which holds across different technologies or industries (Nelson, 1994). Apart from the sectoral developments that have taken place on a worldwide scale, we analyze how such sectoral dynamics have settled in network structures in the Netherlands. Although the literature abounds with claims and empirical evidence on the role of networks in this industry, a more in-depth understanding of how they are structured and of their inner functioning is still limited. Analyzing such networks in more detail echoes the claim by Powell et al. (1996) that networks are a more useful concept

for analyzing innovation in pharmaceuticals than firms.

This paper looks at issues of both competence (learning, innovation) and governance (management of relational risk). We propose that it is the combination of the two that yields a more complete understanding of interfirm networks (Dosi and Marengo, 2000; Nootboom, 2000). We identify two main kinds of relational risk: the hold-up risk familiar from transaction cost economics, as a result-specific investments, and risk of spillover of strategically sensitive knowledge to competitors. Specific investments may occur in other ways than recognized in transaction cost economics, in building up mutual understanding and relation-specific trust, which are both important, in particular, under the uncertainty of exploration, with the development of new knowledge. In contrast with transaction cost economics, we claim the viability, and indeed indispensability, of trust that, within limits, goes beyond calculative self-interest. The result is that we employ a range of instruments of governance that include coercion by hierarchy or contracts, incentives from dependence on unique partner value, hostages, and reputation, and trust based on ethics, shared values of conduct, and relation-specific empathy, identification and routinization of conduct (for an integrated account, see Nootboom, 2004). The paper proceeds as follows. Section 2 discusses the theoretical framework, a 'cycle of discovery', which serves as a logic of how exploration and exploitation are related and build on each other. In Sections 3 and 4, for an empirical test of our claims, we describe and analyse the transformation process of the emerging pharmaceutical biotechnology industry (Section 3), and discuss its organizational implications in the Netherlands (Section 4). In Section 5, we compare our empirical findings with the claims based on our theoretical framework and we draw some conclusions.

2. Exploration and exploitation: a cycle of discovery

Given the aim of this paper to provide a deeper understanding of the transition from exploitation to exploration and vice versa, we need a theory that explains it. For that we use a 'cycle of discovery' (Nootboom, 2000) that describes and explains how

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