The Dynamics of Technical Innovation

The Evolution and Development of Information Technology

Geert Duysters

Department of International Business Studies
University of Limburg, The Netherlands

Edward Elgar
Cheltenham, UK • Brookfield, US

Published by
Edward Elgar Publishing Limited
8 Lansdown Place
Cheltenham
Glos GL50 2HU
UK

Edward Elgar Publishing Company
Old Post Road
Brookfield
Vermont 05036
US

British Library Cataloguing in Publication Data
Duysters, Geert
Dynamics of Technical Innovation:
Evolution and Development of Information
Technology
I. Title
338.064

Library of Congress Cataloguing in Publication Data
Duysters, Geert, 1966–
The dynamics of technical innovation: the evolution
and development of information technology / Geert Duysters.
Includes bibliographical references and index.
1. Information technology. 2. Technological innovations— Economic aspects. I. Title
HC79.I55D89 1996 95–39636
338.4'7004—dc20 CIP

ISBN 1 85898 400 9

Printed and bound in Great Britain by
Hartnolls Ltd, Bodmin, Cornwall

The Dynamics of Technical Innovation

Contents

Tables

Figures

1. Introduction

Ever since Thorstein Veblen (1898: 374) proposed his famous question 'Why is Economics not an Evolutionary Science' theorists have been trying to incorporate biological concepts into economics. The introduction of evolutionary analogies into economics through the early work of influential scholars such as Marshall (1948), Schumpeter (1942) and Alchian (1950), however, did not lead to a fundamental change in economic thinking. Evolutionary ideas turned out to have only a modest impact on mainstream economic theory and did not challenge the position of the traditional neo-classical school of thought as the dominant paradigm in economic theory. Clark and Juma (1991) put forward three main factors which accounted for the observation that economic theory tends to neglect evolutionary concepts. 'first, the limited knowledge on evolutionary and human behaviour opened the way to arguments by analogy; such arguments are often fallacious. Second, social change was not obviously gradual, and therefore the theory was not particularly consistent with the observations of social historians (especially of the Marxists). Third, the rules of the hard sciences (especially Newtonian physics) combined with the Cartesian philosophy of nature as automata and the Baconian appeal to empirical rigour, had become the legitimate view of reality. And economics readily adopted this mechanical world-view' (Clark and Juma, 1991: 45). In spite of this widespread aversion against evolutionary ideas in mainstream economic theory, the 1970s showed a steady growing interest in evolutionary perspectives. This was due particularly to the difficulties of the dominant neo-classical paradigm in dealing with the growing complexity and radical changing nature of our society. In particular, the growing impact of technology was difficult to grasp in the traditional frameworks. This led a number of economists to search for alternative approaches that were better equipped to deal with patterns of change and instability. Their search soon turned to the biological sciences, which featured a promising and already well-developed framework for the analysis of dynamic change. Since Darwin published his 'The Origin of Species', biological theorists have been involved in the study of longitudinal

time-bound phenomena. The long tradition of evolutionary thought in biological sciences paved the way for economists to go beyond the static notions of neo-classical theories and enabled them to construct an inherent dynamic framework.

The search for alternative scientific paradigms in biology led to two distinct but closely related new frameworks. The first framework was sparked by the seminal work of Winter (1964, 1971, 1975), Nelson and Winter (1982) and Dosi (1984, 1988) and would eventually lead to the creation of a school of thought based on evolutionary economic theories. The second framework, thriving on work by Stinchcombe (1965), Hannan and Freeman (1977, 1984, 1989), Aldrich (1979) and Carroll (1987, 1988), constituted another school of thought which would soon be known as the organizational ecology school. As in biological theory, evolutionary and ecological approaches address different questions. Evolutionary theories are primarily concerned with the ability of species (or economic actors) to adapt to changing environments, whereas ecological theories tend to focus on the relative importance of specific species (or organizational forms) under different environmental conditions. We might say, therefore, that evolutionary and ecological theories study the same process from a complementary point of view. Although many theorists would argue that these theoretical perspectives are still in their infancy, the growing number of publications, the establishment of a journal dedicated to evolutionary economics (*Journal of Evolutionary Economics*) and the publication of seminal books on evolutionary economics by Nelson and Winter (1982) and on organizational ecology by Hannan and Freeman (1989) can be seen as indicators of a rapid maturation of biology-inspired approaches to economics and organizational theory.

In this book I will demonstrate that the use of dynamic insights which were originally developed in biology can improve our current understanding of the evolution of complex industrial systems over time. My commitment to non-conventional biology-inspired approaches does not imply that I completely ignore the important theoretical contributions made by neo-classical theorists. I, however, think that although the neo-classical framework can be extremely well suited to deal with complex theoretical problems, it is often less well suited to deal with dynamic patterns of change and instability. Although more recent neo-classical models incorporate imperfect information and uncertainty and are much more dynamic than the earlier models, Krepps (1990) has argued that incorporating all kinds of costs such as adjustment costs and search costs in a neo-classical framework seems to be an awesome

undertaking and is likely to be impossible. Instead of rewriting traditional economic theory I will therefore follow the lead of more dynamic heterodox theories that are particularly developed to study longitudinal time-bound phenomena.

This study departs from a long tradition in economic theory which studied the development of market structures, technological development and company strategies as separate entities. It tries to provide an alternative to the traditional Structure-Conduct-Performance (SCP) approach which, for a long time, has dominated industrial organization theory and industrial economics.[1] In my contribution technological development is not regarded as an exogenous variable, but is seen as an endogenous factor that is not only influenced by the existing market structure but also by the innovative actions of particular categories of companies. Following Schumpeter's notion of 'creative destruction' I will argue that technological changes are able to destroy existing industry structures and create new ones. My main argument is that the evolution of complex industrial systems is shaped by the interplay of industrial structures, company strategies and technological developments. Therefore, in order to understand the complex dynamics of industrial systems it is necessary to analyse not only the development of market structures, but we also need a thorough understanding of the nature of technological change and the role that is played by various organizational forms over time. Central to my approach is the model of natural selection. The natural selection model was addressed by Darwin and Wallace in 1858 and is based on the principle of the 'survival of the fittest' (Winter, 1964). The model argues that species which are best adapted to a specific environment survive, while other less well-adapted species die. In this study I will argue that firms better equipped to meet environmental changes than others may grow successfully, while other less successful firms decline. However, unlike orthodox theories, competitive forces are not supposed to establish a static equilibrium in which successful firms achieve their optimal size, and unsuccessful firms disappear (Nelson and Winter, 1982; Hagedoorn, 1984). My contribution proposes a more dynamic analysis in which technological changes, market structures and firm strategies constitute a dynamic interactive system.

My adherence to biology-inspired theories does not imply that I accept the complete models presented in these theories. Neither do I plea for the gratuitous reproduction of biological models into economics and business studies. As in biology, ecological and evolutionary models can be used to describe different phenomena. Evolutionary economic theories concentrate on

incremental changes over time whereas ecological theorists tend to focus on the evolution of organizations of a particular type: i.e. take a population-level view. Although both frameworks generate an adequate description of the dynamics at each level, they do not provide us with a method for integrating the distinct levels analytically (Levinthal, 1990). In this book I will argue that if I want to describe the full dynamics of organizations and market structures, it is necessary to integrate the two distinct levels of analysis into one all-encompassing framework. Describing the dynamics of industrial systems itself is, however, not sufficient. In order to understand these dynamics we need a thorough understanding of the underlying mechanisms which induce these systems to change. I will argue that in high-technology industries the main engine for change is technological progress. We therefore need a thorough understanding of the nature of these technological changes. As suggested by Rosenberg (1982), opening up the 'black box' of technology is considered to be the first step in a process which leads to a better understanding of the complex dynamics of industrial systems. For a detailed understanding of the nature of technological change I will build on the elaborated framework developed by evolutionary economists. For the study of the evolution of market structures and the importance of particular organizational types under various environmental circumstances I will take on a more ecological-inspired perspective. The integration of both theoretical perspectives enables us to cope with the interaction between the previously separate entities. Our approach is, however, not only biologically inspired. Although ecological and evolutionary approaches form the basis of my framework I take on a more eclectic approach, combining evolutionary concepts with ideas from strategic management, organization theory, industrial economics, new institutionalism and international business studies.

From an empirical perspective it is necessary to create a better understanding of the evolution of industry structures, the strategies undertaken by various categories of companies, the broad patterns of technological evolution, the internationalization tendencies that characterize today's markets and the networks of cooperating companies. The core of my empirical study will focus on the historical development of three major sectors of the information technology (IT) industry: i.e. computers, telecommunications and semiconductors. I decided to study the information technology industry because this industry can be referred to as one of the most dynamic industries of all times. Both market and technological evolution have been very rapid and competition has always been very intense. The

second reason to study IT sectors is that the underlying technology bases of these sectors have undergone strong patterns of change. Technological paradigms in this industry are strongly interacting and are likely to converge in the near future. We will try to find out whether these dramatic changes in the underlying technology base bring about important implications for both market structures and for the strategies of the companies involved. The information technology sector is also a field which is characterized by global competition among a large number of multinational corporations. This allows us to study market development and company behaviour in an international setting. A further advantage of studying the IT sector is the relative abundance of reliable corporate and technological indicators which allows us to analyse the structural and behavioural aspects of the major producers in more detail. It might be clear that most of the specific features of the information technology industry are very difficult to deal with in traditional economic frameworks. It can therefore be seen as a major challenge to deal with these complex dynamics in an alternative framework.

1.1. PLAN OF THE BOOK

In the second chapter of this book we will develop an integrated evolutionary framework for the analysis of complex industrial systems over time. Our framework proposes the integration of dynamic biology-inspired theories of technical and economic change. We will argue that the use of such a framework considerably improves our current understanding of the evolution of complex industrial system and that it allows us to study dynamic phenomena from a longitudinal time-bound perspective. In this chapter we will first describe the two basic approaches that are fundamental to our integrated framework: evolutionary economics and ecological organization theories. Then we will come up with a number of hypotheses that can be derived from our integrated theoretical perspective. The hypotheses as formulated in the second chapter will be empirically evaluated in the following three chapters. In these chapters we will study the evolution of three different industrial systems over a long period of time. The three systems have in common that they are part of the information technology industry, but they are characterized by very diverse features.

Chapter 3 studies the development of one of the most dynamic industry sectors of all times: the international computer industry. In this chapter we

will examine the history of market structural and technological changes in the computer industry from its initiation up to recent developments in the market. The international computer industry has traditionally been characterized by intense competition among a relatively small number of large international companies. At present the industry is undergoing a period of major consolidation and reorganization. We will end the chapter with a critical evaluation of the hypotheses that are put forward in the second chapter. We will then consider how well the assumed pattern of evolution of industrial systems fits the evolution of the computer industry.

Chapter 4 deals with the development of a previously strongly regulated sector: the telecommunications industry. This sector is particulary interesting because it has traditionally been dominated by so-called 'national champions' but is now challenged by new firms that are eager to grasp the opportunities that emerge as a result of both technological as well as institutional changes. After we describe the historical evolution of the telecommunications industry we will evaluate the predictions of our integrated framework under the specific conditions of the (regulated) telecommunications industry.

Chapter 5 describes the evolution of the semiconductor industry. This industry is especially important as a generator of technological progress in other IT fields. In contrast to other IT sectors, competition in the semiconductor industry has been dominated by relatively small, technology-oriented companies. Technological progress in this sector has always been extremely fast and forces of 'creative destruction' have brought about significant market structural changes.

Because the three IT sectors are marked by structural, institutional and technological differences, it is very interesting to examine the effectiveness of our integrated framework under such very diverse industrial settings. Although there are major differences between these sectors they share one very important feature: i.e. technological progress in each sector is increasingly dependent on progress in the other sectors. It will be argued that the basic design parameters that form the core of the relevant technological regimes have become increasingly similar and that the underlying technology bases are likely to converge in the near future. Chapter 6 is therefore concerned with an analysis of the effects of this process of technological convergence. The basic argument is that the convergence of technological paradigms of the three previously separate markets may lead to a significant shift in the boundaries of the markets and technologies involved. The major aim of the chapter is to examine whether the so-called convergence of

information and communications technologies has led to a growing similarity of the firms that are active in the different industry sectors. Empirical testing of the convergence hypothesis will be based on patent data and on patterns of intercompany strategic alliance behaviour.

Chapter 7 is concerned with a detailed empirical analysis of cooperative behaviour within the IT industry. In this chapter we will argue that the strategic value of alliances can be assessed only if one pays attention to the structure of the total network in which a firm is embedded. We will show that with few exceptions agreements are generally studied from a dyadic or firm-level perspective. Such a perspective seems, however, simply inadequate to study industry sectors where virtually all companies are linked to each other. The chapter will start with a general theoretical introduction on the use of strategic alliances and proceeds with the identification of historical trends in strategic technology alliances and the analysis of the developments of the basic networks over time. The structure of the networks in each IT sector and the positions of the major actors in these networks are analysed by means of a statistical technique which is known as network analysis. Network analysis enables us to examine the overall network and at the same time provides us with an examination of the role and importance of the individual players in the network.

In Chapter 8 we discuss one of the most noticeable phenomena that characterizes the present-day information technology industry, namely internationalization. We will make use of recent data in order to assess the importance of the internationalization of innovative activities during the 1980s. In this chapter we will also pay attention to the importance of national backgrounds of companies in relation to their corporate strategies. We address the question of whether large firms are gradually losing their national characteristics and becoming truly globalized companies. An empirical analysis is performed in order to understand whether firms, operating in such a dynamic and globalized sector as the international information technology industry, can still be identified in terms of their country of origin, given their structural, technological and strategic characteristics.

Chapter 9 is concerned with an evaluation of the results of our empirical studies and with an appraisal of the usefulness of our integrated biology-inspired approach. We will start with a summary of the findings of the first five chapters. We will consider how the predictions of our integrated framework have been evaluated under the diverse conditions that characterize the various industry sectors. The second part of the chapter is concerned with