The Economics of Invention

A Study of the Determinants of Inventive Activity

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First published in Great Britain in 1986 by
WHEATSHEAF BOOKS LTD
A MEMBER OF THE HARVESTER PRESS PUBLISHING GROUP
Publisher: John Spiers
Director of Publications: Edward Elgar
16 Ship Street, Brighton, Sussex

British Library Cataloguing in Publication Data

Wyatt, Geoffrey James
The economics of invention: a study of the determinants of inventive activity.
1. Inventions—Economic aspects
I. Title
338'.06 HC79.I/

ISBN 0-7450-0283-8

Typeset in 10 on 12 point Times by
Mathematical Composition Setters, Ltd, Salisbury, UK.
Printed in Great Britain by
Billing and Sons, Ltd,
Worcester

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Preface

There are not many books on the economic determinants of invention, which is rather surprising if one considers the extent to which changes in technology have affected our present standard of living, and the likelihood that they will continue to do so. Perhaps the dearth is due to a feeling that the occurrence of inventions has little to do with economics. I hope that this book will convince some readers that this need not be the case.

Though the first chapter is a rather extensive introduction and summary to the remaining chapters, and can provide the busy reader with a convenient overview, it may be useful at this point to state the general framework within which the various themes are developed. The mode of analysis is 'neoclassical', in that it assumes maximising behaviour on the part of individuals, and market-determined allocations of resources. The economics is also, in the main, positive rather than normative. It may be possible to have an economic analysis of invention which is not based on 'the neoclassical paradigm', and there are plenty of normative issues to engage economists in this area. But the emphasis here is on the determinants, rather than the consequences, of inventive activity, and I believe that positive, neoclassical economics is adequate for the task.

This book is a revised version of the first eight chapters of a thesis which was eventually submitted to the University of York in 1984. The other two chapters of that thesis comprise the essence of a monograph published by the Research Institute of the Finnish Economy (ETLA) under the title *Multifactor productivity change in Finnish and Swedish industries, 1960 to 1980* (ETLA, Helsinki, 1983).

It is my privilege at this point to acknowledge debts to various people who have been helpful to me along the way. At York in the far-off days of the late 1960s John Williamson provided the initial stimulus, and Keith Hartley carried on where he left off, probably for longer than he cares to recall. Tangible support, in the form of research employment, was initially provided by Jack Wiseman, the director of the Institute for Social and Economic Research at York, and more recently by Pentti Vartia, the director of ETLA in

Helsinki where I spent an enjoyable few months in 1982. I am pleased that ETLA is including this book in their series of thesis-type publications, and I am grateful to a number of people there for support in bringing it to publication, in particular to Pekka Ylä-Anttila who heads the industrial economics group, and to Arja Selvinen and Arja Virtanen who drew the numerous diagrams. My thanks also to Jean Roberts, who typed the manuscript in various drafts. I am also grateful to the editorial staff of Wheatsheaf publishers for their expeditious handling of this joint publication.

Geoffrey Wyatt
Edinburgh,
November, 1985

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Part I
Theoretical

1 Introduction and Overview

1.1 PRELIMINARIES AND CAVEATS

An invention is an addition to the stock of factual knowledge. It may be that some inventions 'just happen', but most do not; normally they are the outcome of a research process. Inventive activity is a form of research. This book, too, is a product of research, namely research into research. As usual, many of the insights reported here are truly the work of others: most research builds on prior research. To a large extent, therefore, these pages represent a synthesis, a pulling together, of what is known or conjectured about invention from the standpoint of economics. But it is not a comprehensive survey of the economics of invention. Rather, in order to focus on a theme, 'the economics of invention' has been interpreted in a particular way, and the first task of this introduction is to clarify how.

This book is about an aspect of the economics of technological change. But technological change has much wider connotations than the coverage here implies. Invention is construed as anything that adds to the set of known technological possibilities. Actual changes in technology may, however, also derive from a fuller or different utilisation of technological possibilities already in existence. Such changes do not require inventions. They are accordingly not discussed here. This means, of course, that the diffusion of new techniques of production, or the imitation of innovations, are ruled out. Nor is innovation itself, even to the extent that it implies the putting into effect of inventions, discussed more than cursorily.

It should be clear therefore that the present work has little to say about the consequences of invention as such. The focus is on the determinants of invention and inventive activity, on its causes rather than consequences. The upshot of this is that there are, undoubtedly, many aspects of economic life that are affected by invention which find no mention here. Thus, there is no discussion of technological unemployment, of the structure of industry and how it is affected by technological change, of the consequences for economic growth of endogenous technological change and so on.

(For a good discussion of many of these issues, the reader should refer to Stoneman (1983).)

An implication of focusing on the determinants of invention rather than its effects is that there is only limited discussion of normative or welfare issues. The bulk of the book is positive in the methodological sense of describing or theorising about what is rather than what ought to be. An exception to this is Chapter 5, on invention market organisation, where it is argued that the peculiar economic characteristics of invention imply the need for considerable regulation. There the desirability of competition between inventors is discussed, but the institutional framework within which inventions are produced, and in particular the assumption that patents can confer ownership on them, is taken as given. There is no extended discussion of the desirability of patents or of possible alternative social arrangements.

There are, of course, many factors that determine how much inventive activity is carried out and in what directions, but the basic supposition is that among these, importantly, are economic factors. This means that, for the most part, the scientific, technological, sociological, political, psychological and cultural determinants of inventive activity are subsumed in an implicit *ceteris paribus* clause. The present analysis, in other words, takes them as given. The realism of this assumption can only be judged with suitable empirical evidence. The empirical analysis of time-series data on numbers of patents for inventions presented in Chapter 6 is consistent with the view that at least a substantial element of inventing takes place in response to economic stimuli. But of course this does not imply that scientific, sociological, etc. factors are unimportant. There is, in the present work, no attempt made to assess the relative importance of all possible determinants of invention.

Thus the focus is on the economic determinants of inventive activity, and they are located specifically at the microeconomic level. It is argued theoretically in Chapter 3, with empirical support in Chapter 7, that the 'level of activity' is a major determinant of inventive activity. Here, this expression refers not to the conjunctural state of the national economy but to the size, measured by output or factor inputs, of the industry or sector to which the invention relates.

As a final caveat on the limited scope of the book, it should be

noted that what has come to be known as 'the Schumpeterian hypothesis' is barely touched on. The Schumpeterian hypothesis holds that larger firms are more progressive than their smaller counterparts, in the sense of being more able and willing to employ research inputs. The received empirical wisdom is that neither the smallest nor the largest firms in an industry are the most progressive in this sense. Investigating the validity of Schumpeter's conjecture has been a major preoccupation of economists, since it could have a profound influence on public policy towards big business. If true, it seems to imply a trade-off between static and dynamic efficiency. The topic is touched on in Chapter 3, only to the extent that market organisation has a bearing on the derived demand for invention at the industry level.

It has been mentioned that the central theme of this book is the responsiveness of invention to economic factors. This is developed in a neoclassical framework of supply and demand analysis. There are other approaches which provide their own insights. One such is the comparative institutions approach, according to which allocations of resources are determined either by decentralised markets or hierarchical organisations depending on which structure is the most cost-effective in the presence of behavioural constraints such as bounded rationality and opportunism, (see Williamson, 1975). Another, not unrelated, alternative approach is to eschew the full rationality assumption of the neoclassical framework in favour of 'satisficing' or rule-of-thumb decision-making behaviour. This has the disadvantage of seldom providing clear analytical predictions, though qualitative conclusions can be reached by simulation (cf. Nelson *et al.*, 1976).

Within a neoclassical framework for the determinants of invention, the pivotal element is supply. But it will be seen in Part I that there is little that can be established about the supply of inventions from an *a priori* standpoint. In comparison, economic analysis offers much greater scope on the derived demand for inventions. The basic idea that the derived demand for an invention is proportional to its extent of application is the basis for the attempt in Part II to form an empirical assessment of the responsiveness of invention supply to economic factors.

1.2 SYNOPSIS OF PART I

Part I, comprising Chapters 2–5, is theoretical. Chapter 2 examines the nature of inventive activity and its output, initially taking a taxonomic approach. The conventional classification of research into basic, applied and development has only limited usefulness for an economic analysis of invention. A more important and fundamental distinction is between agenda-reducing and agenda-increasing research, where research output is new knowledge. Building on this distinction, which is due to Fritz Machlup, it is argued that agenda-reducing research can in principle be measured by the reduction in entropy of a probability distribution over possible states of nature, where the probabilities have a subjective degree of belief interpretation. But there is no equivalent way of measuring the output of agenda-increasing research activity. As a consequence, despite the fact that the insights of information theory provide a useful vehicle for characterising research activity, it cannot provide an adequate measure of research output. When invention and innovation are treated together, a satisfactory measure of such output is the rate of cost reduction or, where new products are concerned, the increase in efficiency of satisfying consumer wants.

The basic feature of research, being an exploration of the unknown, provides scope for several related paradigms of the research process. Thus search and sampling models are presented in an attempt to make qualitative statements about the invention supply function. On this basis it is suggested that the research production function can be expected to exhibit sharply diminishing returns for a given state of scientific knowledge.

Research output is not wholly characterised by a mere description of the inventions produced: when they are produced is also important. Thus research output is an example of joint production – what and when. This points to an inherent feature being the time–cost trade-off. The final section of Chapter 2 presents a derivation of the trade-off from the sampling paradigm of research activity. In summary, Chapter 2 represents an attempt to present a coherent view of the research process from an *a priori* standpoint. It goes some way to underpinning the ideas of diminishing returns to the 'research production function' and the convexity of the time-cost trade-off that are often assumed as the starting-point of analysis in this area.

In Chapter 3, the focus is switched from the supply to the demand for invention. The basic determinants of demand are the size of the invention-using industry, the structure of costs and the prices of factors of production, together with the market organisation of that industry, and the appropriability of the returns to invention. These determinants of the derived demand for invention, excluding the influence of factor prices which is deferred to Chapter 4, are discussed in some detail. Previous analysts, beginning with Kenneth Arrow and Harold Demsetz, had focused on the apparently normative question, whether competition or monopoly in the final product market give the greater incentive to invent. Demsetz's conclusion – that the difference between them is due to the output-restricting effect of monopoly – confirms the leading role of industry size. From a positive point of view, however, the question is not whether there are many or few firms in the industry but whether there are barriers to entry. As the theory of contestable markets has shown, freedom and costlessness of entry and exit, together with fungibility of fixed cost, imply that the competitive solution can be an equilibrium even for 'natural monopolies'.

The basic analysis with limit-pricing of the invention, which is familiar in the literature, is presented in section 3.2. As elsewhere, it is assumed throughout Chapter 3 that the inventor has patent protection. When the invention-using industry is a monopoly with entry barriers this gives rise to a bilateral monopoly between the demander and the supplier of the invention. It is shown in 3.3 that it is in the production monopolist's interest to internalise the research, or else to treat the payments to the external inventor as a fixed cost of production.

In 3.4 a full neoclassical treatment of the derived demand for invention, using the fundamental propositions of duality theory, is presented. In 3.5 the degree of appropriability of the returns to invention is made a variable via the duration of patent protection. The question whether, for a given demand curve for the final product, competition or entry-protected monopoly provides the greater incentive to invent is shown to hinge on the relative permanence of the product monopoly and the monopoly implicit in the patent.

The implications for incentives to produce capital-embodied inventions when marginal costs reflect the past history of capital-embodied technologies, as postulated by W. E. G. Salter, are examined in section 3.7. Finally in this chapter, the implications for

the demand price of invention when the invention user is a protected monopoly whose goal is sales revenue-maximisation is explored.

None of the variations on the basic analysis overturns the conclusion that the demand for invention is a function of the scale of the industry. This is the most important conclusion to emerge from Chapter 3, and extensive use of it is made in the empirical sections in Part II.

It was seen above that the set of prices of factors of production in the invention-using industry is a determinant of the demand price of the invention. The responsiveness of invention characteristics to factor prices, which is referred to as the induced bias of invention, has been a distinct strand in the history of thought in this area. When factor prices change, there is a tendency to bring in new known techniques of production that imply less intensive use of the factors whose relative prices have increased. If there are also substitution possibilities in the production of inventions which imply different factor intensities in production, then invention displays an induced bias. Empirical evidence on factor-saving bias is presented in section 4.3. This presents a summary of the existing literature on this topic, and belongs naturally in Chapter 4 rather than in Part II as no new empirical results are presented.

The analysis in Chapter 4 assumes that inventions represent a particular variety of changing technology, known as factor augmentation. A model of induced invention is then naturally characterised in terms of a trade-off between attainable rates of factor augmentation. This is known as the 'invention possibility frontier'. some doubts have been expressed in the literature about the shape of this frontier, but it is argued in 4.4 that, by its analogy with a conventional isoquant, it is natural to assume that it has the postulated concave shape. The invention possibility frontier has played an important role in some macroeconomic growth theories as it implies an asymptotically Harrod-neutral equilibrium growth path. It is argued in 4.5 however that in a microeconomic context it tends to induce Hicks-neutral technological change in the long run. The difference between the micro and macro implications of the frontier is due to the fact that factor prices are treated parametrically at the micro level, whereas at the macro level it is factor supplies that are given.

Chapter 4 concludes by observing that in a world in which

technological change is occurring and is anticipated, output price must be falling. And this in turn implies a decline in the quasi-rent of capital equipment. This provides a connection between the bias of technical change, in terms of factor augmentation, and the rate of obsolescence of capital. Again Salter's 'vintage' model is used to analyse this relationship, from which it is concluded that an increased rate of technical change will tend to encourage capital augmentation.

Up to this point it has been assumed that the inventor is alone in the creation or possession of his invention. The issues that arise when there is competition between inventors are discussed in Chapter 5. In contrast to the normal case of competition in production, where it has the socially useful function of allocating resources efficiently, with technological competition there is a strong presumption that such competition would be undesirable. This is obvious where there is duplication of research activities. But even in the absence of duplication, which is the assumption in Chapter 5, there is a waste of resources in technological competition. These wastes had been pointed out by Sir Arnold Plant over half a century ago, and more recently by Yoram Barzel.

The framework of Plant's thinking is an important precursor of the modern theory of rent-seeking. And Barzel's analysis was the first to account for the dissipation of rent that occurs in the race to be first. The connection between rent-seeking and rent-dissipation is the fact that the set of problems thrown up by science and technology represents an open access pool of potential rent, which can be realised by patenting inventions that are truly the outcomes of combining research inputs with the state of science and technology. Open access competition draws socially excessive resources into research activity because science and technology are available at zero price. In the limit, the pool of rent is eroded away as research inputs are employed to the point where their average product equals their unit cost.

A necessary element of the rent-dissipation process is the ability of research resources to move from one field of rent extraction to another. Evidence that such movement takes place can be found in the empirical work reported in Chapter 7, where it is shown that the number of inventions produced in a field is inversely correlated with the level of activity (representing the demand price of inventions) elsewhere in the economy.