

THE ECONOMIC ANALYSIS OF *TECHNOLOGY* POLICY



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Preface

I offer this book as a small contribution to a continuing debate on government involvement in the process of technological change. Its origins lie within a continued personal interest in the process of technological change, how it works, and how it may be made to work better. Much of the material in one way or another has been used on graduate and undergraduate students at the University of Warwick and I express my thanks to those students for acting as experimental guinea-pigs. Very preliminary drafts of some chapters were prepared while I was visiting Stanford in early 1984 and I would particularly like to thank both the Department of Economics at Stanford and Paul David especially for making my stay a happy and productive one. Most of the volume has been written at Warwick, and among my colleagues I owe a debt of gratitude to Keith Cowling, Shiv Nath, and Norman Ireland for comments, assistance, and encouragement. I also wish to thank Stan Metcalfe at Manchester for comments on an earlier version, Luc Soete at Maastricht for comments on the employment chapter, Derek Bosworth at Warwick for comments on the patents chapter, and Keith Hartley at York and Ron Smith at Birkbeck for their help on the defence chapter. The secretarial staff at Warwick have struggled to interpret my handwriting and deserve more, perhaps, than just thanks, especially Teresa Forsyiaak who has borne the largest part of the typing burden.

The opinions expressed in this book should not be considered as anything other than my personal views and in particular should not be considered as representative of the views of any public or private organization with which I am connected. Similarly all errors that remain are my responsibility alone.

Coventry

January 1987

PAUL STONEMAN

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PART I

Some Preliminary Issues

A Preamble

It is tempting, when writing a conclusion to a book of this length and scope, to step sideways from the material presented and to start deriving some policy implications based on the material. I have resisted this temptation, . . . because the whole question could fill a volume on its own.

Stoneman (1983), 263.

The quotation above opens the closing chapter of my previous book on technological change; it is thus appropriate that I should use it to start the first chapter of this volume. It is not only appropriate because this volume is intended to provide a comprehensive study of the economic analysis of technology policy, but also because this and the previous volume are complementary. In the previous book many of the positive issues in the area of the economics of technological change are considered in some depth. This has enabled me to take an extensive body of analysis as given when proceeding to discuss the normative issues at which this book is directed. However, I believe that this volume can stand alone, although there may be advantages in its being read in conjunction with the previous volume. As this volume proceeds the necessary positive base has been provided to support the normative analysis, but that base is treated in much more detail in the previous book. This volume is also complementary to the previous one in that in the four years since that was finished I have learnt more and increased my understanding of more of the literature. I have taken the opportunity in this volume to update, where necessary, some of the content of the previous volume.

Partly for the above reasons the amount of explicit modelling in this volume is extensive and this may surprise those who come to it looking for a general, non-technical discussion of policy issues with a clear set of answers to all the difficult policy questions. The main reason for this orientation, however, is that I do not consider that there are simple answers to many of the policy questions; the answers one derives are often model- and/or situation-specific. It seemed to me therefore that it was necessary to provide detail on the models used to derive policy conclusions so that the reader may be clear as to the assumptions being made and the arguments being presented. Also, by detailing these models, it is hoped that others in the field may use them as a suitable base from which to advance our understanding of the issues involved. This does make the volume, perhaps, less accessible to policy

makers than one would like. I consider the volume as directed more to the advisers to policy makers than to the policy makers themselves. A background involving some basic intermediate courses in macro- and micro-economics should enable the reader to comprehend most of the volume. At times, however, it extends beyond this level, for I am also talking to my fellow researchers in the field, and in their case I am assuming a much greater level of expertise. For such readers certain chapters may be considered over-simple or unnecessary (especially some of those in Part I), but these are directed more at the non-expert. For non-experts, some sections, especially in Part II, may be considered over technical, but these are aimed at my fellow researchers. Overall I hope that within these pages there will be material of interest to all readers even if it is not all both of interest and accessible to each of them.

An obvious opening salvo to the book is to provide a definition of technology policy. The working definition used throughout this volume is that a technology policy is a set of policies involving government intervention in the economy with the *intent* of affecting the process of technological innovation. This definition excludes general monetary and fiscal (i.e. demand management) and other macro-level policies, which although they may impact on the process of technological change are primarily targeted elsewhere. Such a definition does allow that there will be a considerable overlap between technology policy and industrial policy (which term I take to be defined as any policy targeted at improving industrial performance), but although there is such an overlap, the two terms are by no means synonymous. Industrial policy has some technology-related aspects, industrial performance cannot be adequately discussed without considering technology, but it necessarily covers many other issues. Technology policy must be concerned with industrial performance, but the focus of emphasis is on the dynamic aspect of this performance to the exclusion of others.

In the minds of many commentators there is a distinction between science and technology, and as such there are two fields of related study, science policy and technology policy. This is not a distinction that has any role to play in this volume. The term technology policy is taken as encompassing what others might define as science policy. To rationalize this it is perhaps necessary to define a difference between science and technology. Historians, sociologists, and others have offered many different criteria by which science may be distinguished from technology. The definition, however, that I find most useful is that provided by Dasgupta and David (1985):

an essential difference between science and technology lies in the respective goals that the two communities—scientists and technologists—have set for themselves. Roughly speaking, the scientific community appears concerned with the *stock* of knowledge and is devoted to furthering its growth. The technological community is concerned with the private returns or economic *results* that can be earned from that stock. In the social role of ‘scientist’ a researcher views the stock of knowledge as a

public consumption good; in the role of technologist he or she regards it as a *private capital* good.

Such a definition may at first sight appear to imply that science and technology policy require separate analysis. However, I am unconvinced that such an implication can be drawn. My reaction is that the difference is not a matter of substance, only a matter of degree, and as such exactly the same forms of analysis are appropriate to both science and technology policy. This is a view also expressed by Dasgupta (1987):

As a very first approximation . . . the winner in both science and technology, takes all. For this reason the economics of technology policy bears a strong resemblance to that of science policy. The benefits of a scientific discovery may be far away in the future and, more to the point, be highly conjectural. But then so are often the benefits of technological innovation. It is a matter only of degree not of substance.

Throughout this volume, therefore, the term technology policy is considered to embrace also the early or scientific part of the technological innovation process. To make the concept of the process of technological change clearer, Chapter 2 is devoted to clarifying and detailing this concept.

Any rational policy of intervention will be conditioned by a set of objectives. Such objectives may be implicit or explicit. Similarly, any study of the motives for and appropriate instruments of intervention must proceed in terms of a set of objectives for such intervention (which may differ from those conditioning actual policies). The implicit and explicit view taken in this volume is that the objective of technology policy should be to maximize (or at least increase) welfare. In Chapter 3 the welfare concept is discussed in more detail. Also in that chapter, a reasonably non-technical exposition of some aspects of welfare economics is presented. The prime objective of doing this is to isolate situations in which a free-market economy is likely to deviate from welfare optimality, for by doing so one may provide reasons for government intervention in the technological change process. These reasons are, of course, expanded upon in later chapters, but at this early stage it is clear that such simple analysis indicates that situations may often arise when intervention is desirable.

Given the welfare concepts established in Chapter 3, the following chapter is devoted to attempting to quantify the impact of technological change on economic performance. The reason for doing this should be obvious. If technology contributes only minimally to economic performance then it is inappropriate to devote much in the way of resources to its analysis. The theme running throughout the chapter is in fact that technology is a prime mover in economic development and a major contributor to improved economic performance.

With the importance of technological change established and some simple rationales for government intervention provided, Chapter 5 provides some institutional and other material on existing patterns of government inter-

vention in the technological change process. This chapter is designed to illustrate not only the patterns but also the extent of this intervention, partly in order to illustrate the expenditure currently being devoted to technology policy and thus the need for a soundly based analysis of the requirements for and best uses of such expenditures.

Chapters 2–5 are jointly designed as an introductory package. Parts II and III contain the core of the book. Part II, Chapters 6, 7, and 8, is an attempt to look at technology policy in a model that brings together the three stages of technological change—invention, innovation, and diffusion. The starting-point is diffusion. The emphasis on the use of technology is carried over from the previous volume, and was a distinguishing characteristic of that volume. It is also a distinguishing characteristic of this part. The emphasis on diffusion and the attempt at integrated modelling make these three central chapters very different from other literature on the topic with which I am familiar. Of necessity, however, although Part II considers questions of diffusion policy, research and development, patents, subsidies, and incentives, by its nature it is not possible to consider such issues in any great detail. This task is left to the third part of the book.

Part III contains a series of chapters devoted to particular topics within the area of technology policy. There is an extensive body of work to be discussed and it has to be compartmentalized in some way. The division chosen is one that in my mind reflects to a great degree the separate issues with which policy makers are concerned. However, such issues are often interconnected and moreover the analysis of each issue is not separate from the analysis of other issues. This has presented a problem of ordering chapters in Part III, in that, at times, some points are established by reference forward. This would, however, be the cost of any ordering of the chapters, and I feel that the ordering here, even if perhaps not optimal, is definitely satisfactory. The chapters themselves cover patents, finance, standards, the international dimension, defence, and employment. Of these, defence requires special mention. As is illustrated in Chapter 5, military R. & D. expenditures, at least in the UK and the US, dominate government support for R. & D. This cannot be ignored. However, by looking at defence one can investigate a number of technology policy-related issues, and thus the analysis has wider implications as well.

Much of this volume is concerned with the issue of why government should intervene. There is the related issue of how. It was never the intent of the volume to try and set out the institutional detail of policy. There is, however, one issue that runs through a number of chapters and can perhaps best be labelled as the environment vs. targeting problem. If intervention is desirable, should that intervention be to correct market failures by improving the operation of the market or should the intervention be targeted at particular industries, products, or technologies? These issues are addressed at various points in this volume, but they are considered in most detail in the

concluding chapter. That chapter also includes a number of final comments, including an attempt to bring together the whole by considering technology policy in the UK.

Two further distinguishing characteristics of this volume should be mentioned. First, it is written with developed rather than developing economics in mind, although to a large degree the material would also be relevant to the latter. Second, the book is directed more towards theory than towards empirics. This is the same stance taken in the previous volume. However, the book is about the theory of policy rather than theory *per se*, and the empirical issues where particularly relevant are not ignored. It is for this reason that I label the content as economic analysis rather than economic theory.

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The Process of Technological Change

2.1 Introduction

This chapter is used to discuss the nature of the process of technological change and to introduce some enabling concepts. First the concept of technological change *per se* is discussed and this is followed by the description of a 'Basic Type' of technological change that is used in later chapters. Next, some introductory remarks on the role of research and development and patenting activity are provided to illustrate their position in the technological change process and to illustrate the extent of the resources devoted to technological activity. Finally, a few comments are made concerning the areas on which technological change might have an impact, in order to illustrate its role in the economy. In each case the material should be considered as 'scene-setting' rather than detailed investigation.

Schumpeter (1942) defines technological change as covering five main types of technological dynamism in an economy: new processes, by which is meant new ways of using existing resources to produce existing products; new products, encompassing the use of existing processes and materials to produce completely new or changed versions of existing goods and services; new sources or types of raw materials, covering discoveries of new sources of supply or changes in the raw materials available (one may reasonably extend this category to include improved intermediate inputs into production); new markets, either in a geographic sense or in the sense of applications of existing products to new uses; and new organizational methods, that is new means of controlling and organizing productive inputs. Frequently technological change is equated with technological advance, but it should be immediately clear that the two terms are not synonymous. Not every change is an advance, even though each advance will be a change.

Schumpeter proceeds to suggest that the process of technological change can be usefully considered as involving three stages, generally classified as the Schumpeter trilogy. The first stage is invention, which I consider to be the generation of new ideas. The second stage is innovation, which covers the development of new ideas into marketable products. The third stage is diffusion, which is the adoption of these products by the actors in and across economies. Experience indicates that not all inventions will lead to innovations and not all innovations will be successfully diffused. At each stage