Introduction: scope and outline

1 Production process and economic analysis of technical change

The purpose of this book is to present a consistent scheme capable of unifying the economic analysis of the production process in order to understand the effects of technical change. The investigation can be seen from two different points of view: either as a *scheme* of relations between the economic variables of production, open to changes in 'environment' factors (influenced by expectations, industrial relations, institutional aspects), or as a *methodology* useful for studying the economic effects of changes in techniques, and hence for empirical research.

The economic problem of production is far more complex than choosing the combination of inputs: inputs combinations are for the most part technically determined, by their indivisibility characteristics and by their complementarity relations. Consequently economic choice in production mainly concerns combining processes or single phases. This choice involves a host of organizational, temporal and qualitative aspects: harmonizing the productive capacities of the different production phases so as to minimize waste in the use of machinery; trying to exploit possible economies of scale at different operational levels; deciding the volume of production batches and the degree of production flexibility; evaluating transaction costs and on that basis choosing whether to produce components in house or have them produced outside; working out policies for collaboration with other firms; deciding on forms of organization, product differentiation, innovative policies and investments in equipment and human resources. These are just a few of the most important problems related to the economic decisions which lead to the harmonizing and balancing of different processes. Clearly, solving them appropriately determines the competitiveness of firms and of whole industrial sectors.

In determining the size of the firm, a static and purely quantitative representation of the production process does not give due importance to the relationship between the time profile and the organization of

production. The production process takes place in historical time; hence the concepts derived from static analysis, based on the hypothesis of reversibility of cost curves, cannot be used. These concepts refer to a logical time (partial or total adaptation) rather than to irreversible historical time. Recently, a few studies, based on John Hicks's work in the 1970s and the analyses of Adolph Lowe and Nicholas Georgescu-Roegen, brought out the importance of an accurate analysis of the production process which takes account of the *temporal* aspects of production (Hicks 1973b, 1976; Lowe 1955, 1976; Georgescu-Roegen 1966, 1971, 1976).[1] This book belongs to this broad line of research. In particular, it develops an analytical representation of the production process useful for evaluating the economic effects obtained or obtainable through changes in techniques. As we shall see, the scheme, presented in the following pages, permits organizational and technical aspects to be considered at the same time. This proves very useful in studying the evolution of production methods, and in interpreting the reasons behind the adoption of certain 'organizational systems'.

Every given combination of inputs (for example, a certain quantity of workers and tools), represented traditionally by a point on an isoquant, may correspond to numerous different ways of organizing production. Clearly, each particular technique represents a specific way of solving the economic and technical problems posed by the organization of a production unit. The organization and division of labour – in a word, the technique adopted – are the result of a complex of elements; among these we can mention the specific characteristics of entrepreneurship and the available labour forces, technological opportunities, social security systems, industrial relations, financial and market structures, and social conditions (in short, the institutional environment).

It is impossible to deal adequately with the phenomenon of technical change unless the functioning modes of the production process as a whole are taken into account. In the *absence* of an analytical representation that takes account of the different economic dimensions of the production process, the detailed analysis of the nature of technical change becomes in fact a mere taxonomy. It is important to underline the close reciprocal relationship between the analysis of the *production process* and the analysis of the *nature of technical change*. If only quantitative aspects of production are taken into account, technical change figures simply as a

[1] Among more recent contributions which discuss and develop these different approaches see, for instance: Zamagni (1984b, 1989), Tani (1988), Baldone (1984, 1989), Landesmann (1986), Leijonhufvud (1986), Faber (1986), Amendola and Gaffard (1988), Faber and Proops (1990). As far as the 'time-shape' of production is concerned, see also Frisch (1962) and Winston (1982).

factor that reduces inputs in relation to outputs. On the other hand, if we consider not only quantitative aspects but also the elements of time, organization and size, we can analyse the effects of technical change on the production process, taking account of technical change characteristics such as irreversibility, cumulativity, learning by doing, specificity, uncertainty, etc. That is what I propose to do in this study.

The need to include temporal and organizational as well as quantitative aspects obviously depends on the aims of the analysis.

In some cases it may be useful, for analytical or expository reasons, to concentrate on studying quantities alone. But it is one thing to isolate the quantitative aspects temporarily for analytical purposes – within a model which takes account of the interrelationships between quantities and temporal and organizational aspects – and quite another thing to exclude *a priori* any link between quantities and the time profile and organization of production processes, as occurs in traditional microeconomic analyses.

In many circumstances the simple analysis of quantities is not sufficient. For example, if the aim is to provide a methodology with which to evaluate the effects of technical change, a purely quantitative study can deal with one part only (though a very important one) of the economic effects of the phenomenon. In this case the analysis must extend beyond the quantitative elements to embrace the temporal, organizational and qualitative aspects of the production processes.

The inclusion of these temporal and organizational aspects may enable us to bring into a consistent context certain important analytical elements provided by recent studies on *transaction costs*, on the *nature* of *firms* and *markets*, and on the characteristics of *technical change*. On the other hand, the vast interest aroused in recent years by literature on transaction costs, on the nature of firms and markets, and on determinants and effects of technical change, has helped to fill in part the traditional gap between industrial economics and management disciplines. This book is addressed to readers interested in these fields. Its intention is to contribute to bringing these two areas of research closer, by providing a general taxonomy and methodology for production processes.

What I call the *matrix of production elements* is a useful analytical tool for representing the various dimensions of the production process and understanding the economic effects of changes in techniques. This matrix not only highlights the links between intermediate stages within a given production process, but also makes it possible to consider both the *quantitative aspects*, dealt with in traditional microeconomic analysis (based on the production function or on activities analysis) and the *temporal* and *organizational aspects* which find no place in traditional analysis. The matrix of production elements allows, among other things,

changes in production techniques to be classified according to three main forms: 'time-saving', 'inventory-saving', and 'input-saving technical change'. The matrix of production elements is transformed for empirical research, and its applicability is then verified in some case studies. This is the first time an attempt has been made to adopt such a representation of production process in applied analyses, because, as far as I know, no empirical work has hitherto been based on a fund–flow model.

The main purpose of this part of the book is to discuss the theoretical assumptions and implications of the proposed scheme, and to assess its possible empirical applications, leaving to further studies the actual implementation of the model to time series analyses or simulation techniques. In fact, as will emerge in the following pages, the scheme could be applied to historical series or to cross-section data (comparing different processes). If the sample is statistically representative, the economic effects of technical change in the various sectors of economic activity can be studied. Furthermore, the scheme could be used to ascertain the economic effects of possible changes by applying simulation techniques to the current data of a single production process at a given moment in time, adopting specific hypotheses on agents' behaviour and market structure.

In conclusion, this book has a two-fold nature. On the one hand, it is an analytical representation of the production process, on the other, it is a fact finding model for studying the economic effects of technical change. These two aspects are closely linked because clearly the capacity of empirical observations to answer the questions posed by transformations of the production process depends on the adequacy of the framework within which these empirical observations are expressed. It may serve as a useful decision-making tool for changes in techniques within a firm's production unit. These business decisions may involve, for instance, the evaluation of the relationship between (external) transaction costs and internal costs in organizing production in different intermediate stages (in other words, 'buy or make' choice), or generally the problem of investment choice. Moreover, this representation also proves fruitful in analysing problems related to changes in techniques such as variations in dimension of scale or in degree of production flexibility. Computer-based technology tends to link economies of scope with economies of scale by cutting flexibility costs in large plants. This allows the trade-off between economies of scale and production flexibility to be overcome. These last two aspects will be considered at some length in the final part of the book.

2 Plan of the book

The book consists of three parts: Part 1, basic hypotheses and concepts; Part 2, the model and its application; Part 3, economies of scale, economies of scope, and production flexibility. Part 1 is devoted to:

(a) analysing the relationship between the different economic dimensions of production process and the nature of technical change;
(b) introducing some preliminary definitions, such as microeconomic unit, flow and fund, indivisibility and complementarity of production elements and processes, historical and logical time, *ex-post* and *ex-ante* analysis;
(c) discussing the link between efficiency and organization.

The importance of this last point was quite clear to classical economists, who examined the relationship between the time profile of the production process and the organization of labour in determining the size of the production unit. Later, at least until quite recent times, the study of this relationship was largely neglected. As is well known, a reductive approach prevails in which size is simply linked to the configuration of the static (and independent) curves of unit costs of single intermediate stages. This link, between *efficiency* and *organization*, is an essential point in understanding the economic effects of change in techniques. However, readers who are less interested in the theoretical implications of this relationship, and the related debate, and more interested in *applied aspects* and *management studies*, may wish to start from Part 2, perhaps examining the discussion about the assumptions and hypotheses, presented in Part 1, at a later moment.

In Part 2 a fund–flow model is developed which permits temporal and organizational elements to be included in an analysis of the production process. The main analytical tool presented in this part is the *matrix of production elements*, mentioned above. In chapter 9 of Part 2, the applicability of this methodology is verified in some case studies. The cases examined serve mainly as numerical examples of how this methodology can provide a concise description of the production process's principal elements, in terms of its main economic dimensions (quantitative, temporal, organizational, and qualitative) which are influenced by technical change.

Part 3 deals with some of the basic problems in the theory of production for which the proposed scheme may serve as a fruitful analytical tool. Two particular cases of technical change will be examined: varying the dimension of scale and the degree of production flexibility.

The Introduction to Part 3 (chapter 10) discusses the usefulness of the

proposed scheme in measuring efficiency changes, as the scale varies, and in ascertaining the economic effects of introducing new information technology or/and new organization systems, which increase flexibility. The concepts of complementarity and indivisibility, introduced in Part 1 are essential to a precise and consistent definition, understanding, and description of *economies of scale*; while it is impossible to deal with *production flexibility* without taking into account the time profile of production processes.

Chapter 11 considers the definition of returns of scale and economies of scale, different methods of collecting data on costs, the problem of the choice of the unit of analysis (such as plant, production unit or firm), the relationship between economies of scale and technical change, the relationship between indivisibility (of processes and production elements) and economies of scale, and, more generally, the underlying causes of economies of scale.

In chapter 12 of Part 3 the following points are discussed: the different meanings of the term flexibility in economic literature, the relationship between flexibility and economies of scope, the link between uncertainty and flexibility, differences between the various industrial organization models (such as traditional artisan production, industrial mass production, small-scale flexible industrial production, large-scale flexible industrial production), the role of organizational and technical aspects in determining production flexibility, the relationship between the elementary process time profile and production flexibility (reducing set-up times is a key factor in determining production flexibility), and the economic effects of computer-based technology.

Part 1

Basic concepts and hypotheses

1 Introduction

The effects of introducing new techniques – especially those involving the application of microelectronics to production processes in market economies – are of increasing interest. During the last twenty years the development of different lines of research has considerably broadened our knowledge of the determinants and effects of technical change, considered as a variation in the method of production and/or in the quality of goods produced. In particular, recent research in innovation has been along the following lines: (a) the nature, sources and procedures of innovative activity;[1] (b) the relationship between technical change and economic growth;[2] (c) the relationship between technical change and market structure;[3] (d) the relationship between innovation, industrial structure, economic development, and international trade;[4] (e) the evolutionary theories of the firm and the theory of transaction costs;[5] (f) the diffusion of new techniques.[6]

There is an increasing need for a representation of the production process, which may be consistent with some of the recent advances, mentioned above, and in particular with studies on the nature of technical change, firms and markets. In the preceding pages the close links between analysing the production process and the nature of technical change have

[1] See notes to chapter 2, section 2.2, which analyse the nature of technical change.
[2] See Pasinetti (1981).
[3] Among others: Dasgupta and Stiglitz (1980), Kamien and Schwartz (1982), Stoneman (1983, Part 1), Baldwin and Scott (1987); for more recent literature on game-theoretical analysis of innovative activity and market structure, see the excellent survey by Beath, Katsoulacos, Ulph (1989).
[4] For instance: Freeman (1974), Nelson and Winter (1982), Dosi (1984 and 1988), Dosi and Soete (1988).
[5] On the evolutionary theory of firm see Nelson and Winter (1982), Dosi (1984), Metcalfe (1989); on transaction costs see Williamson (1985), Teece (1980, 1988), Demsetz (1988b), Alchian and Woodward (1988). Finally, see Hodgson (1988) and Langlois (ed.) (1986) for the relationship between these themes and the neo-institutional approach.
[6] For example: Nabseth and Ray (1974), Brown (1981), Metcalfe (1981, and 1988), Sahal (1981, Chapter 5), Rosenberg (1982), Soete and Turner (1984), Stoneman and Ireland (1983), Stoneman (1983 Part 2, 1986, and 1987a Part 2), Santarelli (1987), Antonelli (1989 and 1990), Hagedoorn (1989, Chapter 4), Antonelli, Petit and Tahar (1989).

been stressed. In fact, without a model capable of considering all the main economic production dimensions, a detailed analysis of the nature of technical change appears to be a simple taxonomy. This lack of an appropriate representation of production processes may lead to a dichotomy between the analysis of the nature of technical change and the characteristics of these processes.

The representation of the production process, presented in the following pages, takes account of three *self-evident* and fundamental characteristics of production. First, in order to produce a commodity a technique must be created. Secondly, creating a technique and the consequent production of a commodity takes time. Thirdly, production is characterized by pronounced asymmetries in its component elements. These asymmetries arise from the unequal distribution of the 'individuals' power' and the productive capacity of instruments, and imply that individual agents' ability to influence the market is different.[7]

It is clear that the first two characteristics are closely linked to the temporal, organizational, and qualitative dimensions of the production process. These dimensions characterize the production process together with the quantitative dimension (given by the relationship between inputs and outputs).

As far as asymmetries in production processes are concerned, it can be argued that they are attributable in the last analysis to the factors of indivisibility, economies of scale, specialization, externalities and others such as 'information' and knowledge distribution, specificity of resources, diversity of interests and aims, capacity and ability in labour and negotiations, endowment of resources, and the definition of property rights.

Chapter 2 is devoted to analysing the different economic dimensions of the production process and the nature of technical change. The inclusion of the different production dimensions, i.e. the relationships between quantities of inputs and outputs, between time and organization, and between different qualities of production elements, allows the above-mentioned dichotomy between the analysis of the nature of technical change and the study of the characteristics of production units to be overcome. The importance of this point is evident, since it is closely linked to

[7] On this matter Frank Hahn writes 'those who regard power as central to economic understanding must look beyond classical General Equilibrium Theory. I rather count myself among those, and my earlier strictures were directed at the unfortunate fact that no serious work in new directions is available' (1981, p. 132). On the agents' power, considered in a broad sense, Jacob Viner notes that 'the important freedom ... is freedom of choice, but absence of power in the sense of economic resources, or of acquired knowledge and skills ... makes subjective exercise of that freedom of choice little more than indulgence in wishful daydreaming' (1961, p. 47).

the main aim of the book which is to provide a representation of production process which encompasses the economic effects of technical change.

The following chapter gives the main definitions of microeconomic unit, operational level and production element. A single microeconomic unit corresponds to each operational level. The distinction between *fund* and *flow* elements is considered here. Moreover, I introduce the concepts of *economic indivisibility* and *technical indivisibility*, and discuss the implications of *complementary* relationship between production elements in production unit organization and size. Lastly, the time dimension, in the creation of techniques and in the production process itself, is analysed. Production is seen as a sequential process which means taking historical irreversible time into account, instead of logical time.

Chapter 4 shows that economic efficiency cannot be considered *independent* of the production process organization. We shall consider the mutual interdependence of organization, size, division of labour, resources specificity and learning processes. It is clear that the level of demand and the specific characteristics of inputs/outputs (indivisibility and specialization) play an essential part in determining the kind of organization and size of the production units; and that the last two factors (organization and size of the production unit) are closely connected to the production process time profile.

In Part 2 a model of the production process is developed, whereby all main dimensions of the production process can be embraced. As we shall see, this model will allow the links between organization and efficiency to be considered, in addition to those between division of labour and the time profile of equipment utilization.