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OECD PROPOSED GUIDELINES FOR COLLECTING AND INTERPRETING TECHNOLOGICAL INNOVATION DATA -- OSLO MANUAL --

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Paris 1992

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This Manual has been prepared in collaboration with the Nordic Fund for Industrial Development, according to the recommendations made at the meeting of National Experts on Science and Technology Indicators held at OECD headquarters on 28 to 30 November 1989. Its first version was examined by a group of experts at an informal meeting organised by the Nordic Fund for Industrial Development on 25 and 26 September 1990 in Oslo. After revisions, it was subsequently discussed and adopted at the special joint meeting of the Group of National Experts on Science and Technology Indicators and of Working Party No. 9 on Industrial Statistics held at the OECD on 10 December 1990. After amendments, the manual was approved by the committee for scientific and technological policy which also recommended that it should be released for general distribution, at its 56th session on 22-24 October 1991. This Manual is derestricted on the responsibility of the Secretary-General.

The present manual is intended to serve as a guide for data collection on technological innovation. After a first round of surveys in member countries during the coming three years, it will be reviewed, revised and further developed in the light of the experience gained.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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PREFACE

For many years research and experimental development -- R&D -- was generally considered to be the key factor in technological development. In consequence R&D statistics were often used as indicators of the technological levels of industries or countries.

However, as stressed in the OECD TEP Programme publication {Technology } {and the Economy: The Key Relationships}, "The understanding of technological innovation has recently changed dramatically. Interactive models, differing significantly from the earlier linear approach, now emphasise the central role of industrial design, the feedback effects between downstream (market-related) and upstream (technology-related) phases of innovation and the numerous interactions between science, technology and [other] innovation-related activities within and among firms."

The needs for a better understanding of the innovation process and a wider range of information have become increasingly urgent over the last decade. During this period, decisions on innovation policy had to be taken in the light of sparse data with only R&D and patent statistics as regular sources of information.

OECD interest in direct measures of technological innovation dates back to the late 1970s, when its work on direct or proxy output indicators, encouraged by the recommendations of the second Ad Hoc Review Group on R&D Statistics, led to two seminars being held in 1978 and 1979.

These were followed by a major conference on Science and Technology Indicators at OECD Headquarters in Paris in September 1980, the aim of which was to reach a consensus on R&D output indicators amongst users in OECD Member countries and to examine those output indicators which seemed most promising for international purposes. One of the conference workshops dealt with "innovative activity, including the measurement of innovation proper and patent statistics". Several papers were presented on this theme, describing relevant work in the United Kingdom by J. Townsend, in Canada by C. DeBresson and in Germany by L. Scholz. These topics were reviewed and developed at an OECD workshop in June 1982, seeking to shed light on the advantages and disadvantages of the various national survey methods in use and on a number of conceptual and practical problems.

A further OECD workshop on the development of innovation indicators, in 1986, examined J. Hansen's paper "International Comparisons of Innovation Indicator Development", written for the United States National Science Foundation. The paper contained a detailed description and analysis of innovation surveys in seven countries (Canada, France, Germany, Italy, the Netherlands, the United Kingdom and the United States). The objective of the workshop was for Member countries to share their experience so as to provide guidance for those starting out with innovation surveys and to encourage the development of internationally comparable statistics, and hence to work towards establishing common ground and definitions for a range of substantive questions.

Building on this workshop, the first co-ordinated project on innovation surveys was launched two years later in the Nordic S&T indicators group, under the aegis of the Nordic Fund for Industrial Development. The project (in which Denmark, Finland, Norway and Sweden participated) was aimed at developing a common Nordic methodology for innovation surveys, to allow cross-country comparisons.

More and more countries were launching innovation surveys, and the Nordic group made an important contribution to co-ordination with the conceptual framework presented in "New Innovation Indicators: Conceptual Basis and Practical Problems" to the OECD Group of National Experts on Science and Technology Indicators (NESTI) in November 1989. This paper had been prepared by Keith Smith of the Research Policy Group (GRS) in Oslo and the Department of Economics and Management of the University of Keele, and revised by the author after it had been discussed in Oslo in September 1989 at a conference organised by the Nordic Fund for Industrial Development. The NESTI meeting also examined the outline of a standard practice for the collection and interpretation of innovation data proposed by Giorgio Sirilli of the National Research Council (CNR), Italy.

These guidelines were drafted by Mikael Akerblom of the Central Statistical Office of Finland, consultant to the OECD, and Keith Smith of the Innovation Studies and Technology Policy Group (Norwegian Computing Centre) in Oslo, consultant to the Nordic Fund for Industrial Development, in collaboration with the OECD Secretariat.

Acknowledgements

The Oslo Manual could not have been completed without the active co-operation of national experts on innovation surveys and the assistance of the Nordic Fund for Industrial Development, which gave considerable support to its preparation.

- •••••Robert Chabbal
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- ••••• and Industry

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{Chapter I}

OBJECTIVES AND SCOPE OF THE MANUAL

1. INTRODUCTION

1. It is now commonly accepted that the development and diffusion of new technologies are central to the growth of output and productivity. But our understanding of the innovation process, and its economic impact, is still deficient in many areas. For example, we are clearly in the throes of a major technological revolution, with the world economy being reshaped by new information technologies and by fundamental change in fields such as biotechnology and materials science. Yet these radical technological shifts are not being reflected in improvements in total factor productivity and in output growth rates.

2. Attempts to understand such puzzles have come to focus, in recent years, on the critical importance of parts of the innovation process other than R&D, in particular as they affect diffusion rates. These are areas in which we face serious difficulties, however, in particular the absence of reliable and systematic data. Success in refining the analysis of innovation, and in tackling the policy problems it poses, will both depend in part on our ability to improve the information at our disposal.

3. Is it possible to develop and collect data on the whole complex and differentiated process of innovation? The answer is definitely yes. Recent research has shown that the amounts and types of usable data which surveys provide can be extended significantly.

4. An OECD overviewF
References are given at the end of the Manual.
F in 1990 covered 12 survey-based projects on innovation, and some countries had run their innovation surveys more than once. The work described differs widely in terms of objectives, methods, definitions and so on. But it does conclusively show that a wide range of data can be produced on the innovation process. What is more, it has generated results which could not be obtained with existing data; these either add significantly to our knowledge or raise major questions for future research. In different ways, all the various surveys have produced significant outcomes. There is hence no overriding obstacle, practical or technical, to the collection of data on innovation.

5. This Manual sums up the experience of past surveys, and sets it in a consistent framework of concepts, definitions and methodology. It provides guidelines by which comparable innovation indicators can be developed in OECD countries, and discusses the analytical and policy problems to which the indicators are relevant. The Manual has two objectives, to provide a framework within which existing surveys can evolve towards comparability, and to assist newcomers to this important field.

2. WHAT IS AN INNOVATION?

6. That question is a broad one, and the precise answer will depend on the particular objectives of measurement or analysis. This Manual is concerned with technological innovation. For innovation surveys, Chapter IV proposes definitions and suggests how they should be applied in practice, with examples. At this stage, for the purposes of the introductory discussion in Chapters II and III, some working definitions will be sufficient.

7. A product innovation is the commercialisation of a technologically changed product. Technological change occurs when the design characteristics of a product change in ways which deliver new or improved services to consumers of the product.

8. A process innovation occurs when there is significant change in the technology of the production of an item. This may involve new equipment, new management and organisation methods, or both.

9. Diffusion is the way in which innovations spread, through market or non-market channels. Without diffusion, an innovation will have no economic impact. It is difficult to measure, though methods are now being developed. Some guidance, in the context of operational survey techniques, is offered in Chapter V.

3. OUTLINE OF THE MANUAL

10. How can we decide on the appropriate structure, scope, terminology and so on for internationally comparable data collection? The variety of subjects that earlier innovation surveys have taken in is evidence that an extensive range of data is potentially available. Obviously, a survey covering all the ground of these previous investigations would be so cumbersome as to be quite impracticable. That means identifying priorities, and selecting the topics on which to concentrate. There is also a need to distinguish between data which are best collected on a regular basis, and matters which can be tackled more effectively by one-off projects.

11. The Manual starts with a general discussion of points that are likely to have some effect on the choice of indicators:

(i) an adequate conceptual understanding of the structure and characteristics of the innovation process (Chapter II);

(ii) the key unresolved problems which further data could clarify (Chapter III).

12. After that, we put forward suggestions and recommendations for national innovation surveys:

(i) basic definitions of innovation and innovative activities (Chapter IV);

(ii) measuring aspects of the innovation process (Chapter V);

(iii) measuring the cost of innovation (Chapter VI);

(iv) classifications and areas of difficulty for innovation surveys (Chapter VII).

13. The major policy questions to which improved data and analysis are relevant, including data needs related to existing policy instruments, are discussed in Chapter VIII.

{Chapter II}

BACKGROUND AND CONCEPTUAL FRAMEWORK

14. In this chapter we shall attempt to set out a conceptual framework for the collection of data on innovation. Collecting quantitative data requires a framework of this kind, explicit or not, which enables us to organise and understand them. It presupposes ideas about the nature of the subject, its essential features, and what is important in it and what is not.

15. Accordingly, we shall in turn consider the economic significance of technological change and innovation, the nature of the innovation process and the importance of non-R&D inputs.

1. THE ECONOMIC SIGNIFICANCE OF TECHNOLOGICAL CHANGE

16. Technological change and innovation have become regular topics in economic analysis and policy discussion, in the OECD and in individual Member countries, over the past twenty years. The growing interest is a reflection of two related trends:

(i) the general slowdown and instability in economic growth since the mid-1970s, and the prolonged slowdown in productivity growth which has been a persistent feature of most OECD economies; and

(ii) significant change in the distribution of world trade in manufactures. Some economies' shares of world manufacturing exports have increased sharply, while others have declined.

17. Any full explanation of these trends would of course be highly complex. But among the factors that stand out, there does appear to be a strong link between macro-economic performance and innovative behaviour. The pace and flexibility of technological change in products and processes seem to be key elements in economic performance.

18. In recent years the relationships between competitive performance and technological strategy have been widely explored to see whether they can account for success and failure, both micro- and macroeconomic.

19. Despite the considerable efforts of researchers, however, we are still a long way from understanding all of the factors which shape the rate, direction and effects of technological change, at enterprise, industry, regional or country level.

20. There are many reasons for this. Some are theoretical, to do with the difficulties of building technological change into economic theory and analysis. Others are practical. For instance, the statistical methods used in compiling national accounts and production statistics do not reflect the presence or impact of technological advance. That raises numerous problems, particularly in policy analysis, where it is often desirable to use quantitative techniques.

21. Against this background, an important strand of recent OECD work has been to develop and improve quantitative indicators which can be used to tie technology into economic policy analysis. This work has taken two main forms.

22. A major effort has been devoted to improving the R&D statistics, both conceptually (in terms of coverage, collection methods and so on) and practically (in terms of consistency and completeness). The important work here has been in the revision of the Frascati ManualF
F.

23. The second thrust, of direct relevance to this Manual, has been the construction of new indicators of technological change and innovation activity. A number of countries have been devising and analysing indicators in various forms for some years, with little co-ordination or even contact. OECD has endeavoured to establish links between the investigators in different countries, with the objective of moving towards internationally comparable innovation indicators.

24. The data available for innovation and technology analysis at present are broadly of three kinds: data on R&D inputs, collected in the OECD economies in line with the Frascati Manual; patent data, the most important body being the records of the US Patent Office, WIPO and the European Patent Office; and bibliometric data, on patterns of scientific publication and citation.

25. The fundamental limitations of these sources are well known. R&D numbers measure only inputs, which have no necessary relation to outcomes. There are many examples of successful innovating firms which perform relatively little R&D. The value of patent data is affected by variations in firms’ and industries’ propensity to patent; moreover, they relate to the first stage of the innovation process, not the subsequent use of an invention and its economic value or impact. It may also be, as K. Pavitt has argued, that R&D data underestimate the amount of innovative activity in small firms, while patent data underestimate innovation in large firmsF
F. Bibliometric data, in turn, tell us much about the changing shape of fundamental research, but little about the innovation process.

26. What is surprising and impressive, given these limitations, is how much researchers have in fact been able to achieve in empirical analysis. Over the last thirty years or so, advances in applied economics have demonstrated that:

(i) "technical change" is the most important contributory factor in economic growthF
F;

(ii) innovative activity, as measured by research and development and by patenting, is closely associated with the level of output and income at country levelF
F;

(iii) R&D is strongly associated with productivity growth in firmsF
F;

(iv) the fastest growing industries in the world economy, and the fastest growing categories of world trade, are technology-intensiveF
F;

(v) shares of world trade are correlated with innovative activityF
F.

2. THE CASE FOR NEW INNOVATION INDICATORS

27. Given this success, the need to extend the range of data being collected on technology and innovation may be questioned. The case for further sources of data is twofold.

28. First, reliance on R&D data can lead to overemphasis on the research part of the innovation process. This is arguably a problem already: in many countries, technology policy is seen mainly in terms of research policy.

29. Second, although R&D and patent data allow analysis of correlations between technology measures and economic outcomes (in the form of trade shares and growth in output and productivity), they give us little insight into the causal processes at work. For example, strong positive correlations have been demonstrated between R&D and productivity growth. But does this mean, as some have concluded, that R&D induces productivity growth, i.e. causes itF
F? Or is
R&D simply one part of a complex process?

30. Existing data give little insight into the internal characteristics or structure of innovation, how firms acquire innovative capabilities, the primary obstacles they face, or even the impact of innovation on corporate performance. It is relevant here that the Frascati Manual clearly considers R&D to be only a small part of the innovation process, and the authors were concerned that it should not be seen as a substitute for wider knowledge of innovation and technological change.

31. At the same time, a fuller grasp of how innovation works is vital for policy-making. What, for example, are the main non-R&D inputs, and how important are they? Questions like this are central to our understanding of the innovation process, and answers would greatly assist the shaping and implementing of policy. But the analysis here relies largely on case studies or data and evidence that have been specially collected. The data from the present sources cannot supply the answers. We would therefore agree with Professor Zvi Griliches that "Far too little fresh economics data is collected"F
F.

32. Those are the main arguments for collecting further innovation-related data. What is the case for improvements in international comparability?

33. As economies become more interdependent, policy is bound to look beyond the domestic arena. Accelerating interdependence is due in part to economic factors: rising levels of trade, in particular specialised intra-industry trade, and the growing integration of financial markets. It is doubtful that purely national policies can now be pursued in any economic sphere. Monetary and fiscal policies have to take account of developments elsewhere, and the

same is becoming true with science and technology as well (where policy replication -- a common practice -- holds clear dangers of generalised failure).

34. Politically-led integration is also under way. The move towards the single European market is leading to more Community-wide science and technology programmes: for example, the budgets for the major programmesF
F are expected to
double over the five years 1990-94F
F. Though still modest in relation to EC
Member States' own R&D budgets, the programmes are increasingly integrated with national technology policy initiatives, or actually taking their place.

35. Internationally comparable data on innovation are needed in connection with other Community interests: analysis of the competitiveness of European industry and of investment policies, and the management of structural and regional funds. All this suggests that greater comparability should be an important objective of further indicator collection.

3. MODELS OF THE INNOVATION PROCESS

36. As Hansen et al.F
F have pointed out, much of the data we now have, in
particular on R&D, is shaped by the "linear" model, in which innovation is deemed to occur in roughly linear fashion: research, invention, innovation, diffusion of new techniques. A progression of this kind is found in research, from basic scientific knowledge to technological knowledge to practical engineering (which is seen as a form of applied science). This supposed linearity, of course, has been the justification for taking R&D as a major indicator of innovation activity as a whole.

37. The linear model has been widely criticised, for showing innovation as a series of watertight stages (rather than a to-and-fro process of interaction and feedback) and for placing too much emphasis on R&D, so that other inputs to innovation are left in the background. However, as Kline and Rosenberg observe, "improved models have not yet come into widespread use. Consequently the linear model is still often invoked in current discussions, particularly in political discussions"F
F.

38. A second approach sees the innovation process in terms of interaction between opportunities (held out by technology or the market), capabilities and strategies. Opportunities or incentives may arise, for example, from changing patterns of demand, changes in the size of markets, the product cycle or developments in science and technology. The key questions are how firms recognise these opportunities, and respond through product-mix strategies and then innovative efforts. The technological opportunities that present themselves differ, of course, and so do the ways in which firms (and industries) perceive them.

39. The capabilities of the firm lie in its engineering, design, research and marketing resources and assets. Opportunities and capabilities must be combined in an innovative or technological strategy, which is where the management and organisation of the firm enter the picture.

40. Strategy involves assessments of the market and an innovation's place there. Success in technological competition is usually based on difference or

diversity: it implies a conscious attempt by firms to differentiate their products or processes. For all these reasons, technological strategies, assets and behaviour vary considerably among firms in the same sector, and across industryF
F.

41. The options open to a firm which wants to innovate, i.e. to change its technological assets, capabilities and performance in the area of productionF
F,
are of three kinds: strategic, R&D and non-R&D.

Strategic: As a necessary background to innovative activity, firms have -- explicitly or not -- to make decisions about the types of markets they serve and the types of innovations they will attempt there.

R&D: • Some of the options relate to R&D (in the Frascati Manual sense, going well beyond basic and applied research):

- (i)• the firm can undertake basic research to extend its knowledge of fundamental processes related to what it manufactures;

- (ii)• it can engage in strategic research (in the sense of research with industrial relevance but no specific applications) to broaden the range of applied projects that are open to it, and applied research to produce specific inventions or modifications of existing techniques;

- (iii)• it can develop product concepts to judge whether they are feasible and viable, a stage which involves (a) prototype design, (b) development and testing, and (c) further research to modify designs or technical functions.

Non-R&D:• Many other activities do not have any straightforward relation to R&D, and are not defined as R&D, yet play a major role in corporate innovation and performance:

- (iv)• the firm can identify new product concepts and production technologies (a) via its marketing side and relations with users, (b) via its design and engineering capabilities, (c) by monitoring competitors and (d) by using consultants;

- (v)• the firm can develop pilot and then full-scale production facilities;

- (vi)• it can buy technical information, paying fees or royalties for patented inventions (which usually require research and engineering work to adapt and modify), or buy know-how and skills through engineering and design consultancy of various types;

- (vii)• human skills relevant to manufacturing can be developed (through internal training) or purchased (by hiring); tacit and informal learning -- "learning by doing" -- may also be involved;

•(viii)• it can invest in process equipment or intermediate inputs which embody the innovative work of others; this may cover components, machines or an entire plant;

• (ix)• it can reorganise management systems and the overall production system and its methods; recent advances here include new types of inventory management and quality control.

42. A firm can carry out all these activities on its own, but some may opt for joint ventures or inter-firm agreements of various kinds, or collaboration with the public sector. The outcome may be small-scale incremental change, or radical disruption of existing methods. Innovation processes can also extend into the firm’s marketing and distribution. There is no simple linear relation between all these activities; we are dealing with a system of complex interdependence.

44. The clearest available model that takes account of these innovation activities is the "chain-link" model proposed by Kline and RosenbergF
F. It is
illustrated in Figure 1.

Figure 1. The Chain-Link Model of InnovationF
F

```
       •
       •      |•   ••••••  |
       •      |•   ••   RESEARCH•••  |
       •      |•                                                  |
       •      •    |•••••      |
       •      •    |••   KNOWLEDGE••     |
       •            |                                         |
    |  •     • |          |            |             |             |
    |  POTENTIAL |   INVENT   |• DETAILED  |   REDESIGN  |  DISTRIBUTE |
    |   MARKET• |  AND/OR    |•DESIGN AND |     AND      |     AND      |
    |  •     • |  PRODUCE   |•   TEST    |   PRODUCE   |   MARKET   |
    |            | ANALYTICAL |            |             |             |
    |            |   DESIGN   |            |             |             |
    |  •         |            |            |             |             |
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44. The chain-link model conceptualises innovation in terms of interaction between market opportunities and the firm’s knowledge base and capabilities. Four broad functions are involved:

(i) product strategies and the identification of market opportunity;

(ii) analytical and engineering design;

(iii) production engineering;

(iv) marketing and distribution.

45. Each involves a number of sub-processes, and their outcomes are highly uncertain. Accordingly, there is no simple progression; it is often necessary to go back to earlier stages in order to overcome difficulties in development. This means feedback between all parts of the process. A key element in determining the success (or failure) of innovation is the extent to which firms manage to maintain effective links between phases of the innovation process: the model emphasises, for instance, the central importance of continuous interaction between marketing and the invention/design stagesF
F.

46. An important point, and one often overlooked, is that innovation is rarely a one-off matter, especially for the larger enterprises. A firm may gain an advantage by introducing an innovation, but its competitors will soon react, and in the longer term consumer demand too will evolve. Firms cannot stand still; their products need to be updated or replaced. This entails more or less continuous qualitative change in the products and in the processes used to make them. It is of value to map the extent, nature and impact of such ch ange.

47. What is the role of research in innovation? Here there is a sharp difference between the models. In the chain-link model research is viewed not as a source of inventive ideas but as a form of problem-solving, to be called upon at any point. When problems arise in the innovation process, as they are bound to do, a firm draws on its knowledge base at that particular time, which is made up of earlier research findings and technical and practical experience. The research system takes up the difficulties which cannot be settled with the existing knowledge base, and so extends it if successful.

48. This approach has implications for how we understand "research". Given that it can relate to any stage of innovation, research is a complex and internally differentiated activity with, potentially, a wide variety of functions. It is an adjunct to innovation, not a precondition for it. Many research activities will be shaped by the innovation process, in fact, and many of the problems to be tackled will derive from innovative ideas that were generated elsewhere. Accordingly, for the chain-link approach, research cannot be seen simply as the work of discovery which precedes innovation.

49. It is not the purpose of this discussion to present any particular model of innovation as definitive. Some serious question marks hang over all the available models. The point to be noted, however, is that innovation is a complex, diversified activity with many interacting components, and sources of data need to reflect this.

50. A slightly different approach is outlined in the 1980 Frascati Manual dealing with R&D data. The Manual notes, at the very beginning, that "(Innovation) consists of all those scientific, technical, commercial and financial steps necessary for the successful development and marketing of new or improved manufactured products, the commercial use of new or improved processes or equipment or the introduction of a new approach to a social service. R&D is only one of these steps"F
F (Emphasis in original).

51. The Frascati Manual goes on to emphasise the importance of six non-R&D activities in innovation: new product marketing, patent-related work, financial and organisational change, design engineering, industrial engineering and manufacturing start-upF
F. Chapter III considers the ways in which both the R&D and non-R&D aspects of innovation are core issues for survey research.

{Chapter III}

CORE ISSUES FOR SURVEYS TO INVESTIGATE

52. The next step is to identify those key policy and analytical issues whose resolution is held back by lack of data about innovation. There is much scope for discussion hereF
F. Working within the conceptual framework outlined above it is necessary to find a "robust design"F
F for surveys which is capable of extension in various directions, taking into consideration both what is desirable and what is practicable.

53. Core areas for investigation have already been suggested, on the structure and characteristics of the innovation process in industry and the importance of non-R&D inputs. It will also be of value to examine the connections with corporate technological strategy, the role of diffusion, factors that shape a firm’s capabilities and performance (including public policy), and innovation outputs.

1. SIX AREAS FOR INVESTIGATION

1.1 Corporate strategies

54. Technological strategies are not something that can be easily classified by means of a survey. But firms can be asked how they perceive the development of their markets (in product-cycle terms, for example). Then questions can be put about simple forms of product development strategy in relation to those markets. The technological strategy of a firm can be seen as a set of market objectives, to be achieved through various combinations of the activities described in Chapter II.

55. Among the options open to a firm are to:

i) attempt to develop radically new products which will create new markets;

ii) attempt to imitate innovative leaders (what has been termed the "fast second" strategy);

iii) attempt to adapt technologies developed elsewhere to the needs of the enterprise;

iv) focus on the incremental development of existing techniques;

v) change the methods used to make existing products.

56.   The occurrence of these types of technology strategy is likely to vary from industry to industry. The particular pattern is of policy significance, so every effort should be made to obtain data classified by type of strategy.

1.2 The role of diffusion

57.   Some distinction is required between internal and external sources of innovative activity, and the importance of diffusion should not be overlooked. An innovation will have no effect unless it is applied, i.e. diffused, so it is clear that to concentrate on innovation would give a misleading picture of the economic impact of technological change.

58.   A difficulty in much analysis of technological change and productivity growth is that it is extremely hard to track flows of innovation and technological change from one industry to another, and hence to trace the spillover of productivity-raising activityF
F. How do firms incorporate
innovations that have been developed elsewhere? From a slightly different perspective, what is the weight of diffusion in relation to innovation?

59.   One objective of further survey work should be to clarify these inter-industry flows. This is especially important when surveys are confined to manufacturing, for it is essential to recognise the extent to which the service sector generates innovations or provides inputs.

60.   A separate but related issue concerns the role of inter-firm co-operation via shared R&D, licensing, joint ventures and so on. In many industries, co-operative arrangements have become so widespread that it is difficult to distinguish the individual processes of innovation, and sometimes even to see where the firms’ boundaries areF
F. Consideration of external
sources of innovation or technological change ought logically to extend to international sources of technology, and be structured in such a way as to throw light on some of the many unresolved problems connected with the technology balance of payments.

61.   All this has obvious implications for policy, much of which is aimed, explicitly or implicitly, at promoting R&D, and pays far less attention to the other parts of the innovation process. In particular innovation capability is given precedence over diffusion capability, yet the latter is a key component in a firm’s performance.

1.3 Sources of innovative ideas and obstacles to innovation

62.   The general objective here should be to relate the technological assets and strategies of firms to the scope of their innovative ideas and to the obstacles which they perceive.

63.   Most firms have a wide range of potential sources of technical information and innovative ideas. Their importance will vary with the firm’s technological capabilities and strategy.

64.   It is important to distinguish between internal and external (or endogenous and exogenous) sources of change. Internally, interest is likely to focus on the role -- or roles -- of the R&D department, and the involvement of

all parts of the firm, particularly the marketing side, in decisions to innovate. Externally, the focus will be on public research institutions as sources of technical information, and on inter-firm or inter-industry technology flows.

65. A problem to be resolved here is the classification of firms and industries that is used to analyse technology flows. Pavitt speaks of "supplier-dominated firms", "production-intensive firms" and "science-based firms", and uses the SPREE database to analyse connections between them. Archibugi et al use a similar classification in analysis of the Italian dataF
F.

66. The underlying issue here, which has considerable significance for policy, is that we know relatively little about "who innovates?". In complex networks of enterprises, innovation can obviously occur at a variety of places. But what factors of environment, opportunity or regulation actually determine the locus of innovation?F
F.

67. Obstacles to innovation are significant for policy as well, since a good proportion of government measures are in one way or another aimed at overcoming them. Many obstacles -- skill shortages, problems of competence, finance, appropriation -- are relatively straightforward to assess with survey methods.

1.4 Inputs to innovation

68. One starting point for analysis of innovation activity could be R&D, which takes on a wide variety of functional forms related to problem-solving. Even though most of the data we have at present relate to R&D, we in fact know little about what R&D departments actually do. This could be a key component of further survey work.

69. For example, it is often argued that firms need to perform R&D in order to recognise and use, and hence diffuse, technologies that have been developed elsewhere. Is this true? More broadly, can we move to a better understanding of the activities of R&D departments, and hence to the economic functions of R&D?F
F.

70. A related issue is the composition of R&D performed by the firm: there is evidence that innovation outputs are strongly shaped by, for example, the proportion of basic research which firms do. In general we need to understand more about how variation in the composition of a firm’s R&D relates to its innovation performance.

71. Although for all these reasons it is desirable to include a measure of R&D within the survey, the core task is to integrate an understanding of the R&D contribution with an account of the non-R&D inputs to the innovation process. These inputs were described in Chapter II. It would be most useful to have an overview of the balance which firms strike between R&D and non-R&D activities, and the pattern of these balances in particular industries and across all industry.

72. Evidence on the cost distributions of innovation suggests that we need more information on R&D costs as a proportion of the overall cost of introducing an innovation. When Mansfield et al examined these cost distributions for the chemicals, machinery and electronics industries, they

found that research costs averaged respectively 16.9, 3.0 and 3.9 per cent of innovation costs, while prototype development and establishment of manufacturing capability involved 54.0, 78.0 and 74.4 per centF
F. R&D costs
depend on how R&D is defined, but when design and prototype development are included they appear to make up approximately 50 per cent of innovation costs.

73.   A wider understanding of these distributions, and their variation across industry, is of obvious importance for innovation policy. Such data would be of direct use for general analysis and more specifically would supplement R&D data in the productivity growth studiesF
F. Collecting the information may pose
serious practical difficulties, especially when firms have many divisions, but it is one of the most important possibilities of this type of survey workF
F.

1.5 The role of public policy in industrial innovation

74.   Given that publicly funded R&D often accounts for a substantial proportion of total R&D in OECD economies, there is a clear need to understand its industrial effects more clearly. But R&D is only one element of public policy with effects on innovation performance. Other areas can also promote innovation performance, or restrict it:

a) education and the supply of skills;

b) taxation policy and accounting regulations;

c) industrial regulation (including environmental regulation, health standards, quality controls, standardisation and so on);

d) the legal system of intellectual property rights (and hence problems of appropriability and the operation of the patent and copyright systems);

e) the operation of the capital market.

75.   These aspects of public policy can be examined via questions on firms' perceptions of obstacles to innovation, by asking for example whether access to risk capital is a significant hindrance to innovative activity.

76.   With the data on R&D, it is important to look for industrial applications of basic research results from universities and publicly funded laboratories. Edwin Mansfield recently surveyed some 70 major US firms, asking for information on industrial innovations which had used the findings of university research performed within the previous fifteen years. He estimated that products based on recent academic research accounted for approximately 5 per cent of US industrial outputF
F.

77.   Public R&D also has indirect effects in stimulating private research. Despite considerable work this area has still to be clarified, and an innovation survey should attempt to throw more light here.

1.6 Innovation outputs

78. Perhaps the most interesting aspect of these surveys is their potential capacity to measure directly the output of innovation activities. Past surveys have revealed that a very high proportion of firms had introduced innovations within the previous year, which shows that innovation activity is far more widespread than R&D data would suggest, for R&D is quite highly concentrated, both industrially and geographicallyF
F.

79. Serious difficulties arise with definition and interpretation, however. What is actually being measured in surveys of innovation output? What in fact is an innovation? It needs to be isolated, for descriptive purposes.

80. Most products, and certainly the processes by which they are made, are complex systems. Change thus has to be defined in terms of:

i) the attributes and performance characteristics of the product as a whole, and

ii) changes in components of the product which improve its efficiency, but not in the nature of the services which it delivers. Sub-system changes of this kind may be very small in scale but their cumulative impact can be considerable, and important from an analytical perspective.

Chapter IV will propose a distinction between major innovation (a completely new product), incremental innovation and product differentiation (minor aesthetic or technical improvements).

81. Innovation implies novelty, but how is "new" to be defined -- new for the firm, the country or the world? These distinctions have implications for enterprise performance, for regional or national capabilities and for the global rate of technical advance.

82. It would make little sense to compare firms on the basis of the numbers of innovations produced. But we can well use definitions of the type proposed in Chapter IV to count numbers and types of innovation within a firm in relation to its total product base. The classification will further assist questions about the introduction of new products to the market, and about the proportion of sales or exports they account for.

{Chapter IV}

BASIC DEFINITIONS

1. INITIAL CONSTRAINTS

83. A general framework for the construction of indicators on innovation has now been outlined. Before proposing basic definitions of innovation and innovative activities, a number of limitations to the scope of the Manual must be briefly discussed. There are three main constraints at this stage:

-- the Manual covers industrial innovation in the business enterprise sector only;

-- it covers technological innovation, not other forms such as organisational change;

-- it describes enterprise-level innovation surveys.

1.1 Sectorial coverage

84. Innovation can of course occur in any sector of the economy, including government services such as health or education. The concepts and definitions that will be presented in this chapter are mainly designed to deal with innovations in the business enterprise sector. At present they relate to innovation in goods and processes rather than services. They will be adjusted to take in service industries as well once more empirical results and experience become available.

1.2 Technological innovation

85. Innovation is a broad concept, as noted in Chapter I, and the precise meaning it is given will depend on particular objectives of measurement or analysis. SchumpeterF
F distinguishes five types of innovation:

-- the introduction of a new good;

-- the introduction of a new method of production;

-- the opening of a new market;

-- the conquest of a new source of supply of raw materials or semi-manufactured goods;

-- re-organisation of an industry.

86. These guidelines will deal only with the first two, new products and new processes, which are technological innovations proper.

1.3 Collection approach

87. There are two main approachesF
F to collecting data on innovations:

(i) One starts by identifying a list of successful or unsuccessful innovations, often on the basis of experts' evaluations. Once the list has been established, various factors which have influenced the innovations are explored by surveying the enterprises which introduced them. This approach has been used by SPRU to establish a database on significant innovations in the United Kingdom, which has been extensively used for different research projects.

(ii) The other survey approach starts from the innovative behaviour and activities of the enterprise as a whole. The idea is to explore the factors influencing the innovative behaviour of the enterprise (strategies, incentives and barriers to innovation) and the scope of various innovative activities, and above all to get some idea of the outputs and effects of innovation. These surveys are designed to be representative of all manufacturing industry so the results can be grossed up and comparisons made between industries. The pioneer with enterprise-based innovation surveys is IFO in Germany, which has been undertaking them since 1979.

88. The second approach is more amenable to international standardisation, and has been chosen as the basis for these guidelines. The proposed definitions and classifications are therefore framed for use when designing enterprise-based innovation surveys, though they may also be of interest for other types.

2. BASIC DEFINITIONS OF INNOVATION

89. The word "innovation" is given different meanings in different contexts; considerable precision is needed in designing a statistical system. The proposed definitions of product and process innovations are based on those used for survey purposes in various countries.

90. {Technological innovations comprise new products and processes and }
{significant technological changes of products and processes. An innovation has }
{been implemented if it has been introduced on the market (product innovation) }
{or used within a production process (process innovation). Innovations }
{therefore involve a series of scientific, technological, organisational, }
{financial and commercial activities. }

2.1 Product and process innovation

91. In line with the definition above we identify two classes of innovation: product innovation and process innovation.

92. Product innovation can take two broad forms:

-- substantially new products: we call this {major product innovation};

-- performance improvements to existing products: we call this
• {incremental product innovation.}

93. {Major product innovation is a product whose intended use, performance } {characteristics, attributes, design properties or use of materials and } {components differs significantly compared with previously manufactured } {products. Such innovations can involve radically new technologies, or } {can be based on combining existing technologies in new uses.}

94. The first microprocessors and video cassette recorders were product innovations of the radical type. The first portable cassette player, which combined existing tape and mini-headphone techniques, was an innovation of the second type. In each case the overall product had not existed before.

95. {Incremental product innovation is an existing product whose performance } {has been significantly enhanced or upgraded. This again can take two } {forms. A simple product may be improved (in terms of improved } {performance or lower cost) through use of higher performance components } {or materials, or a complex product which consists of a number of } {integrated technical subsystems may be improved by partial changes to } {one of the subsystems.}

96. Incremental product innovations may have both major and minor effects on the firm. The substitution of plastics for metals in kitchen equipment or furniture is an example of the first kind. The introduction of ABS braking or other subsystem improvements in cars is an example of the second kind.

97. {Process innovation is the adoption of new or significantly improved } {production methods. These methods may involve changes in equipment or } {production organisation or both. The methods may be intended to produce } {new or improved products, which cannot be produced using conventional } {plants or production methods, or essentially to increase the production } {efficiency of existing products.}

2.2 Borderline cases

(i) Determining what is new and significant

98. The main criteria for distinguishing between innovation and differentiation (minor modifications of products and processes) are the elements of novelty and significance. The difference between "new" and "old" and "significant" and "insignificant" is of course very difficult to specify, and has to be determined by survey respondents. One criterion for qualifying as an innovation could be that the product has been introduced on the market as

a new product or a significant improvement of an old product. The classifications by type of novelty suggested in Chapter V, using both technological and market variables, may also be helpful.

(ii) Product differentiation

99. Minor technical or aesthetic modifications of products (product differentiation) are not incremental product innovations. The changes do not significantly affect the performance, properties, cost or use of materials and components in a product.

100. For example, a changed mix of synthetic or natural fibres in a textile might be considered an incremental innovation because it changes the performance and properties of the product. But a new colour or print design for a textile would not change these characteristics, and would therefore be regarded as product differentiation.

101. Food products with a new or significantly changed composition of raw materials, or new methods of preservation, might be considered incremental product innovations. Introduction of a new flavour to an existing range -- such as a new fruit flavour within a range of yoghurts -- is product differentiation.

102. New models of complex products, such as cars or television sets, are product differentiation if the changes are minor compared with the previous models. If the changes are significant, based on new designs or technical modifications to subsystems for example, the improved products could be considered incremental product innovations.

103. Many borderline cases will clearly occur in this area, and the final judgement about the nature of the change rests with respondents.

(iii) Custom production

104. Enterprises engaged in custom production, making single and often complex items to a customer’s order, have to analyse every product to see whether it fits the definitions set out above. A criterion for qualifying as an innovation could be that the planning phase includes construction and testing of a prototype or other research and development activities in order to change one or more of the product’s attributes. Unless the one-off item displays different attributes to products that the enterprise has previously made, it is not to be regarded as a product innovation.

(iv) Organisational change

105. Although technological innovation can occur both in the production process and/or products of the enterprise and in ancillary and supporting activities, only the former are counted as they alone result in new products or processes. Hence the computerisation of the sales or finance department should not be considered an innovation. Similarly, the complete reorganisation of an enterprise is not per se an innovation, though reorganisation of its shop-floor can be so considered. The introduction of "just-in-time" systems, for example, should be treated as innovations.

(v) Machinery and equipment

106. Innovation, especially process innovation, often entails the installation of new machinery and equipment. Three cases may be identified:

- -- The installation of machinery and equipment which improves the firm's production methods is a process innovation. The cost of the equipment is to be shown as capital expenditure for innovation. From a different perspective, this is a component of gross fixed investment by the firm; the classification approach taken here is, however, directed at gaining an understanding of expenditure on the diffusion of innovations (see Chapter VI, section 2.2).

- -- The installation of machinery and equipment which is needed to produce a new product but does not improve production methods (e.g. an additional moulding or packaging machine) is not a process innovation. The cost of equipment is, however, shown as capital expenditure for innovation.

- -- Other purchases of machinery and equipment are not considered process innovations and are not to be included in innovation expenditure. For example the extension of production capacity by adding more machines of a model already in use, or even replacing machines with more recent versions of the same model, are not innovations.

3. INNOVATIVE ACTIVITIES

107. Technological innovation may be linked to various factors. It may stem from innovative activities carried out within the enterprise or directly on its behalf. In other cases the enterprise acquires technology from outside in the form of equipment and disembodied technology, i.e. licences, know-how, etc. The monitoring of technological development, a factor in formulating corporate innovation strategy, is also significant. The list of innovative activities below is not exhaustive.

{Research and experimental development}

108. {Research and experimental development (R&D) comprise creative work } {undertaken on a systematic basis in order to increase the stock of knowledge, } {including knowledge of man, culture and society and the use of this stock of } {knowledge to devise new applications (as defined in the Frascati Manual). }

109. Construction and testing of a prototype is often the most important phase of experimental development.

110. A prototype is an original model which includes all the technical characteristics and performances of the new product or process.

111. The acceptance of a prototype often means that the experimental development phase ends and the other phases of the innovation process begin. Further guidance on this will be found in the Frascati Manual.

{Tooling up and industrial engineering}

112. {Acquisition of and changes in production machinery and tools and in } {production and quality control procedures, methods and standards required to } {manufacture the new product or to use the new process. }

Manufacturing start-up

{113. This may include product or process modifications, retraining personnel } {in the new techniques or in the use of the new machinery, and trial production } {if it implies further design and engineering. }

{Marketing for new products}

114. {Activities in connection with the launching of a new product. These may } {include market tests, adaptation of the product for different markets and } {launch advertising, but will exclude the building of distribution networks to } {market innovations.}

115. An enterprise may acquire external technology in disembodied or embodied form.

{Acquisition of disembodied technology}

116. {Acquisition of external technology in the form of patents, non-patented } {inventions, licences, disclosures of know-how, trademarks, designs, patterns } {and services with a technological content. }

{Acquisition of embodied technology}

{117. Acquisition of machinery and equipment with a technological content } {connected to either product or process innovations introduced by the firm. }

{Design}

118. {Design is an essential part of the innovation process. It covers plans } {and drawings aimed at defining procedures, technical specifications and } {operational features necessary to the conception, development, manufacturing } {and marketing of new products and processes}.

119. It may be a part of the initial conception of the product or process, i.e. research and experimental development, but may also be connected to tooling up, industrial engineering, manufacturing start-up and marketing of new products.

4. THE RELATION BETWEEN INNOVATIVE ACTIVITIES AND INNOVATION

120. Not all innovative activities result in actual innovations. Examples are:

- -- basic research and general technological research which cannot be related to any particular innovation project;

-- innovative activities undertaken for a project which is aborted before it becomes an actual innovation (i.e. before it reaches the market introduction phase).

121. In both cases the activities are necessary for actual innovations to take place, and it is natural to regard actual innovations as the outcome of all the innovative activities of the enterprise, not only those activities directly linked to actual innovations.

122. Most of the indicators presented in Chapter V (especially sections 1 to 5) are focused on actual innovations, while Chapter VI on innovation expenditure relates to the innovative activities of the enterprise as a whole.

{Chapter V}

MEASURING ASPECTS OF THE INNOVATION PROCESS

123. A number of indicators, based on experience with surveys to date, will now be described. The innovation process has its starting point in the objectives of the enterprise, and is assisted or hampered by various factors. The types of innovations that emerge from the process can be described in different ways. Perhaps the most important (and most difficult and controversial) indicators describe the influence of innovation on the performance of the enterprise. Finally there are indicators describing related themes such as R&D, patenting, the technology balance of payments and so on.

124. The indicators may be binary yes/no data: the factor is important/not important. Alternatively, they may rank factors on an ordinal scale: first ascertaining whether a factor is relevant or not (0 = not relevant), then running from 1 (not important) to 5 (very important). It may be useful to break some of the indicators down by the firm's main product groups. The product group classification is explained in more detail in Chapter VII, section 4.4.

1. OBJECTIVES OF INNOVATION

125. Determining an enterprise's reasons for engaging in innovative activity can be done in two ways. One is to ask about the technological objectives which the firm has set itself.

Technological objectives

Develop radically new products which will create new markets

Imitate innovative leaders

Adapt technologies developed elsewhere to the needs of the enterprise

Make incremental developments to existing techniques

Change the production methods of existing products.

126. The other way is to ask about the firm's more general economic objectives, relating to products and markets, and how it rates a number of goals that process innovation can bring within reach.

Economic objectives of innovation

Product innovations:

-- Replace products being phased out;

-- Extend product range:
- -- within main product field;
- -- outside main product field;

-- Maintain market share;

-- Open up new markets:
- -- abroad;
- -- new domestic target groups;

Process innovations:

-- Improve production flexibility;

-- Lower production costs by:
- -- reducing the share of wage costs;
- -- cutting the consumption of materials;
- -- cutting energy consumption;
- -- reducing the reject rate;
- -- reducing product design costs;

-- Improve working conditions;

-- Reduce environmental damage.

127. The classification by economic objective is likely to be preferable if only one of these approaches is to be used. The objectives may vary across the firm's product groups, so these questions should be asked at product group level if possible. Several objectives will usually be relevant. The data may be binary (aim is important/not important) or ordinal (scale assessment of the importance of each objective), and should relate to innovations introduced the last three years. Questions on expected changes in the firm's objectives are also possible.

2. FACTORS ASSISTING OR HAMPERING INNOVATION

128. Three sets of factors that influence the innovation process will be considered here:

(i) the starting point of an innovation project is usually an innovative idea. This may come from a variety of sources, both inside the enterprise and outside;

(ii) after the project has started a variety of factors contribute to its success. These too may be internal or external;

(iii) innovation may be hampered by economic factors, ones relating to innovation potential, and a miscellany of others.

129. The sets overlap to some degree, so that a factor can assist in one case and be an obstacle in another. Information on these factors may be presented in binary form (important/not important) or using a scale, as in the previous section. It should relate to the innovative activities of the firm in the previous three years. Questions on expected changes in the importance of different factors are also possible.

2.1 Sources of innovative ideas

130. The list shows sources which have been considered relevant in various countries. It can be modified to meet national requirements.

Sources of innovative ideas

-- Internal sources:

- -- top management;
- -- in-house R&D;
- -- marketing;
- -- production;
- -- in-house incentive schemes;
- -- monitoring of technological development;
- -- personnel with specific qualifications;

-- External sources:

- -- public support programmes for innovation;
- -- government contracts;
- -- fairs, exhibitions, meetings;
- -- competitive situation;
- -- acquisition of embodied technology;
- -- acquisition of disembodied technology;
- -- training courses;
- -- co-operation with customers;
- -- co-operation with consultants;
- -- co-operation with sub-contractors;
- -- co-operation with other firms;
- -- co-operation with universities;
- -- co-operation with research institutes;
- -- scientific or technical literature, patents;
- -- commercial literature (from competitors);
- -- legislation, norms, regulations, standards, taxation.

131. Some of these items can, if desired, be further divided into domestic and foreign sources.

2.2 Factors contributing to the success of innovative projects

132. The range of factors listed can be modified to meet specific national requirements.

Factors contributing to the success of innovative projects

-- Internal f actors:

- -- contribution of top management;
- -- co-operation of R&D with marketing and production;
- -- personnel with specific qualifications;

-- External factors:

- -- public support programmes for innovation;
- -- use of advisory services;
- -- co-operation with customers/suppliers;
- -- co-operation with other firms;
- -- co-operation with research institutes;
- -- co-operation with universities.

2.3 Factors hampering innovative activities

133. The list shows obstacles or barriers to innovation that have been considered relevant in various countries. It can be modified to meet national requirements.

Factors hampering innovative activities

-- Economic factors:

- -- excessive perceived risks;
- -- lack of appropriate sources of finance;
- -- innovation expenditure too high;
- -- pay-off period of innovation too long.

-- Innovation potential:

- -- R&D expenditure too small;
- -- qualitative shortcomings of own R&D;
- -- lack of skilled personnel ;
- -- lack of information on technology;
- -- lack of information on markets;
- -- innovation costs hard to control;
- -- resistance to change in the firm;
- -- deficiencies in the availability of external services and;
- -- opportunities for co-operation.

-- Other reasons:

- -- innovation has no place in the firm’s strategy ;
- -- lack of technological opportunity;
- -- no need to innovate due to earlier innovations;
- -- innovation too easy to copy;
- -- legislation, norms, regulations, standards, taxation;
- -- lack of customer responsiveness to new products and processes;
- -- uncertainty in timing of innovation.

134. To throw some light on innovation failure, it may be possible to combine information on these obstacles with information on innovation projects never started or aborted as a direct consequence of severe barriers.

3. IDENTIFYING INNOVATING ENTERPRISES AND NUMBERS OF INNOVATIONS

135. From the policy viewpoint, indicators of the outcomes of the innovation process are perhaps the most important results of innovation surveys. They are the most problematic ones as well.

136. The simplest indicator relates to the population of innovating firms. It is obtained by counting the number of firms which have introduced product innovations, process innovations or combined product and process innovations and expressing that number as a proportion of the total number of firms in the same industry, across the economy.

137. Counting the number of innovations is tricky. Products may be anything from single items such as an electronic component to complex systems with many parts. The innovation may relate to the entire product or process, if it is completely new, or to a few components that change the features and uses of an existing product or process. Counting innovations related to different functions or components of an existing product or process does not seem meaningful. It is therefore suggested that new or significantly improved products or processes alone should be identified as innovations.

138. In Chapter IV, substantially new products were termed major product innovations. Performance improvements to existing products were called incremental product innovations. The adoption of new or significantly improved production methods was termed process innovation.

139. Even by this approach, interpreting numbers of innovations is extremely hard. Their significance can differ widely both within a given industry and from one sector to another. An innovation can be the sole result of one firm’s R&D activities over a couple of years. Another enterprise may produce 30 new products for the market every year. The number of innovations becomes a meaningful indicator only when compared with the total number of products or processes in the enterprise.

140. The survey should therefore ask, for products and processes separately:

-- Total number of products at the end of the year:

- of which:
- -- major product innovations (as defined in paragraph 93)
- commercialised during the last three years;
- -- products subjected to incremental innovation (as defined in
- paragraph 95) during the last three years;
- -- products unchanged, or subject only to product differentiation,
- during the last three years.

-- Total number of processes at the end of the year:

- of which:

- -- process innovations (as defined in paragraph 97)
- introduced during the last three years.

141. It may also be useful to have information on innovations under development, whose use or market launch is scheduled for the next three years, and on planned innovations, those whose development has not yet begun.

142. Similarly, it would be of interest to know how many innovation projects have been temporarily shelved or permanently abandoned over the last three years.

143. These indicators are directly influenced by the length of products' lives. They are likely to be higher in product groups where life-cycles are short and innovation can be expected to occur more frequently. But innovation of that kind is not necessarily the most significant or most technologically advanced. High shares of new or significantly changed products do not therefore necessarily indicate a high innovation rate, something that also has to be taken into account when interpreting indicators based on the share of sales accounted for by innovative products or by products in the introduction phase (see sections 5.1 and 5.2 below).

144. Other factors also have to be considered when interpreting the data obtained with these indicators:

(i) firms engaged in custom production will often have higher shares of new or significantly improved products than firms engaged in batch or mass production, or firms in the process industries;

(ii) younger firms will have higher shares of new products than older firms.

4. QUALITATIVE ASPECTS OF INNOVATION

145. Given the difficulties of interpretation that arise with the purely quantitative indicators suggested in section 3, supplementary indicators which can throw some light on qualitative aspects are needed to help evaluate the significance of innovations. The following classifications serve that purpose.

4.1 Type of novelty

146. The novelty of an innovation can be defined using a number of technical variables or in terms of the market.

Classification by type of novelty using technical variables

- Product innovations:

  - -- use of new materials;
  - -- use of new intermediate products;
  - -- new functional parts;
  - -- fundamental new functions (fundamental new products).

- Process innovations:

  - -- new production techniques;
  - -- higher degree of automation;
  - -- new organisation (with regard to new technologies).

147. The information here can be obtained by ticking relevant categories. It may be useful to break the information down by product group.

148. Classification by type of novelty for the market

-- new for the industry world-wide or for the industry in the particular country;

-- new only for the firm.

149. This classification is designed for data on numbers of innovations. These are difficult to use on their own, but some impression of the originality of innovations can be obtained by comparing the number of new-for-the-industry innovations with the total number. It may again be useful to have information by product group for this classification.

4.2 Nature of innovation

150. This classification may provide valuable supplementary information as it gives some indication of the source of innovation.

Classification by nature of innovation:

-- application of a scientific breakthrough;
-- substantial technical innovation;
-- technical improvement or change;
-- transfer of a technique to another sector;
-- adjustment of an existing product to a new market.

151. The information can be obtained, preferably for each product group, by ticking relevant categories.

5. THE IMPACT OF INNOVATIONS ON THE PERFORMANCE OF THE ENTERPRISE

152. The indicators described in sections 3 and 4 all relate to innovations introduced in the previous three years. The ones discussed here focus on the impact of these innovations on the performance of the enterprise:

(i) the proportion of sales due to new products (PNP);

(ii) the proportion of sales due to products in the introduction phase (SPI);

(iii) the results of innovative effort;

(iv) the impact of innovation on the use of factors of production.

5.1 Proportion of sales due to new products (PNP)

153. A question about the share of sales and exports due to innovative products introduced on the market within the last five years has been included in most of the innovation surveys carried out to date. Experience with this PNP indicator has been encouraging, though some difficulties of interpretation have been pointed out by Lothar ScholzF
F.

154. Differences in PNP from industry to industry depend on the rate of technological progress in supply and demand markets and the homogeneity or heterogeneity of the product mix in the industry. The two effects are interrelated and it is not possible to separate them.

155. Innovation and diffusion both affect the PNP indicator because products which have already reached the growth phase on the market within the five-year period influence PNP more than new ones. The PNP indicator may also change over time due to changes in sales of old products.

156. When constructing this indicator, enterprises established during the reference period must be excluded or treated separately: new products will account for all their sales. Firms engaged in custom production will again, by definition, show higher values for this indicator than other enterprises.

157. There seems some agreement that the five-year period used in this question to date is too long. A shorter period may remove some of the indicator’s shortcomings, and prove easier for enterprises to apply, especially when their products have short life-cycles. With a five-year span, two generations of the same product may in fact be reported.

158. It is therefore recommended that the proportion of sales and exports due to new products introduced on the market within the last three years should be included in innovation surveys as one of the innovation output indicators. When presenting results, for example for an industry, these percentages should be weighted by the sales of the firms concerned.

159. This question may be put more thoroughly, using much the same method as for the number of innovations (see section 3 above):

Percentage share of sales due to:

-- major product innovations (as defined in paragraph 93) commercialised during the last three years;

-- products subjected to incremental innovation (as defined in paragraph 95) during the last three years;

-- products unchanged, or subject only to product differentiation, during the last three years.

A similar question on the impact of process innovations on the firm's sales does not seem feasible for the moment.

160. For preference, respondents should supply their best estimates of the actual percentages. Another possibility is to report in terms of set intervals, i.e. estimates of the interval in which the percentage falls (0-10 per cent, etc.). These are easier for the respondents, but are more difficult to use in analysis, especially if the shares are small. When presenting the results by industry, size of firm and so on, the percentages should be weighted by sales.

5.2 Proportion of sales due to products in the introduction phase (SPI)

•

161. The SPI indicatorF
F is based on the portfol io theory developed by the Boston Consulting Group. The share of sales due to products in the introduction phase of their life-cycle is taken as an indicator of innovation output; it is not influenced by diffusion as the PNP indicator is. The medium-term growth prospects of a given industry are good when the SPI indicator bears a greater value than the corresponding SPD indicator, sales due to products in the decline phase.

162. Not all firms may find it easy to distinguish the stages in the life-cycle, especially the borderline between the introduction and growth phases. The theoretical definitions available are hard to apply in practice, and do not take market-specific conditions into account. No particular definition is recommended. Respondents will be assumed to be able to make a reasonably good estimate, taking their market-specific conditions into account.

163. When interpreting the SPI indicator, some attention may be given to the growth phase as well, as it also reflects innovative output to a certain extent.

164. The life-cycle theory on which this indicator rests is not universally accepted. Some products have no clear life-cycle. In such cases (which may be exceptions) the SPI indicator is not very meaningful.

165. In addition, it may prove more difficult for enterprises engaged in custom production to apply.

166. It is suggested that the proportion of sales due to new products in the market introduction phase be included as an additional innovation output indicator. The information should be given by product field if possible. When presenting results, the percentages should be weighted by sales.

5.3 Results of innovative effort

167. The indicators described in sections 5.1 and 5.2 relate to the results of the innovation process. Attention now turns to indicators describing how the results influence the performance of the enterprise.

168. The effect of successful innovation on the performance of firms is difficult to measure with general performance indicators. In a competitive environment, firms have to innovate just to maintain their sales and profits. Firms may be asked to evaluate the success of innovative effort against a number of performance variables:

- -- sales (domestic and foreign markets);
- -- profits;
- -- access to new markets;
- -- share of traditional markets.

169. Scale assessment may be used, as with the questions on factors assisting or hampering innovation.

170. This indicator may refer to innovations introduced over the last three years, or to a broader evaluation of how innovation has influenced performance.

5.4 Impact of innovation on the use of factors of production

171. One of the results of innovation, especially process innovation, is usually a change in the production function, i.e. a change in the use of factors of production.

172. It is suggested that a question should be included on how innovations have influenced the use of factors of production, i.e. manpower use, material consumption, energy consumption and utilisation of fixed capital.

173. This information can be obtained more simply by asking firms if there has been a major, minor or nil change in the use of factors of production as a result of innovation.

174. This indicator too may refer to innovations introduced over the last three years or to a broader evaluation of how innovation has influenced performance indicators.

5.5 Descriptive information on innovation output

175. Alongside the quantitative indicators, some information on the content of the innovations introduced may be of value.

176. Although case studies are better means of collecting descriptive information, it is suggested that a short technical description should be requested for one or more of the most important innovations.

177. The information can be used to evaluate the quantitative data, and to see how well the enterprise has understood the definition of innovation. It can also be used to build up a database on significant innovations for more

qualitative analysis of the technical content of innovation, and subsequently for follow-up studies of successful and unsuccessful innovations. A problem may arise with confidentiality.

6. DIFFUSION OF INNOVATION

178. In Chapter I we defined diffusion as the way in which innovations spread, through market or non-market channels; without diffusion, an innovation will have no economic impact. Some indicators of diffusion are presented below.

6.1 User sectors

179. In theory, innovations can be classified by three criteria:

- the technological group (product group) to which the innovation belongs;
- the sector of activity of the producer;
- the sector of utilisation.

180. The first two criteria will be discussed more fully in Chapter VII when we deal with classifications. To date, only the Italian survey has included a question about the user sector. For the most important innovation, enterprises were asked to indicate the typical area of use. As diffusion is an important aspect of the innovation process, it would be of value to develop indicators which give a more detailed picture of user sectors. Diffusion questions are most appropriate for innovations in intermediate and investment goods, less appropriate for consumer goods.

6.2 New technologies as part of the innovation process

181. Several countries have carried out surveys of the use of selected new technologies in manufacturing, and in one case in the service sector as well. They cover an important aspect of diffusion, i.e. the extent to which innovations in the form of new technology are used in production. Specialised manufacturing surveys, focusing mainly on micro-electronics applications, have also been conducted at some point by many OECD countries.

182. The surveys of manufacturing technology requested information about use, planned use and non-use of certain specified technologies. They showed that technology use surveys are easily run and analysed and are readily compared internationally. They can also be designed for specific industries.

183. The cost of technology use surveys lies in the effort required to produce a list of advanced technologies which are recognised by the industry concerned and are not so advanced as not to be used at all. The technologies must be sufficiently used so that statistics about their use and planned use across an industry provide useful information to the policy maker.

184. Another cost of technology use surveys is negotiating international comparability. This has three components: the list of technologies; either an agreed concordance between the industrial classifications used, or the use of an agreed international industrial classification; and the use of common coverage criterion.

185. Use and planned use of technologies can be linked to other questions related to innovation. Questions on whether the technology used was modified to improve productivity or ease of use give insight into the propensity to innovate on the factory floor.

186. Innovation in management practice can be linked to technology use. In manufacturing, for example, a firm supplying to a client which wants "just-in-time" delivery (JIT) may wish to improve its quality control and assurance to reduce the reject rate of parts produced. As part of improving quality, the firm may adopt statistical process control (SPC) and, as a consequence use automated sensors in its production process. The client firm may use automated supervisory control and data acquisition (SCADA) and both supplier and client may be linked by a computer network.

187. Barriers to innovation can also be probed in surveys of technology use as questions can be asked about the availability of highly qualified and skilled people to work with the new technology, and the availability of funds to purchase technology and to train workers.

188. Technology use surveys are considered a relatively straightforward way of obtaining information on innovation diffusion that is relevant to policy. While they can be integrated with innovation surveys, they are also of use as an independent source of reproducible and internationally comparable statistical information relevant to industry and trade policy.

189 Surveys of technology use should be encouraged and, when appropriate, integrated into the broader context of the innovation surveys.

6.3 Use of new technologies in innovative activities

190. A similar question has been asked as a part of the general innovation survey. The coverage was, however, different as information was requested about use of new technologies in the innovative activities of the firm.

7. SPECIAL QUESTIONS

191. A number of other topics relevant to the innovation process will now be considered: questions on R&D which are not presented in the Frascati Manual (and hence not usually included in R&D surveys), and questions on patenting and the technology balance of payments.

7.1 Special questions on R&D

192. All the innovation surveys which have been carried out to date overlap to some extent with R&D surveys; R&D expenditures, for instance, are included

in both. In some cases there are other common topics as well. The overlap may well be unavoidable, as the institutions responsible for the innovation survey do not usually have access to data at enterprise level from the R&D survey. It sheds additional light on R&D: almost all the innovation surveys so far have recorded many more enterprises carrying out R&D than are covered by R&D surveys. One reason may be that occasional or informal R&D is excluded from R&D statistics in some countries, another that the complexity of the R&D questionnaire discourages smaller firms from responding. The firms that innovation surveys reach, but R&D surveys do not, are usually small or medium-sized ones.

193. Innovation surveys supplement the picture of R&D given by R&D surveys. Though it is conceivable that they might ultimately be combined, there are two good arguments against this:

(i) a combined survey would be long and rather complicated, which might well reduce the response rate;

(ii) different people in the company may well be responsible for answering questions on R&D and questions on innovation.

194. The two surveys must of course be consistent and apply the same basic definitions. It is worth considering whether some of the special questions on R&D proposed below for innovation surveys would not in fact be more appropriate in the ordinary R&D surveys. At all events, the same questions should not appear in both.

195. The first special question on R&D is to ask firms whether the R&D activity is performed on a continuous or an occasional basis; or for the non-R&D performers if the firm has no plans for R&D in the future or if some R&D is planned for the next few years.

196. Another very popular question on R&D in innovation surveys asks whether there is a formal R&D unit (R&D department, R&D centre, etc.) in the company and how big is its share of total R&D expenditure. Some countries have attempted to find out more about the location of R&D activities by also asking for the proportion carried out in other parts of the company, such as production or design departments.

197. It is suggested that innovation surveys should include a question on the existence of a central R&D unit and the distribution of intramural R&D between it and other departments of the company.

198. Some surveys have also asked questions about how R&D decision-making and management are organised in the firm.

199. An important question deals with R&D co-operation with other firms, institutes and universities, both inside the country concerned and in other countries or country groups (transnational co-operation).

200. It is recommended that a question on R&D co-operation by partner and country group should be included in innovation surveys.

201. Participation in (and awareness of) government, European and other international programmes to encourage R&D and innovation is of considerable relevance to policymaking, and speci al questions have been included in several surveys. This is also discussed in Chapter V, section 2, factors assisting or hampering innovation, and Chapter VI, section 2.3, source of funds.

202. Last, questions have been asked on the number of R&D projects of various lengths.

7.2 Questions on patents

203. Patent data, whether applications or grants, are not indicators of innovation outputs; they are indicators of inventions, not necessarily leading to innovations. But questions about patenting are essential for a deeper understanding of the innovation process. The basic general series, of course, are the numbers of patents applied for and granted, available from various national and international data banks. Questions on patenting have been included in a number of countries' R&D or innovation surveys.

204. In the US innovation survey, firms were asked which of four approaches most closely described their general patenting practice in a given year:

"(i) We rarely filed patent applications.

(ii) We patented only major discoveries or discoveries in only a small proportion of our lines of business.

(iii) We relied on patent protection in many lines of business, but in others we relied on trade secrets.

(iv) We patented virtually all of our discoveries we believed to have commercial potential. In addition we patented many for which the commercial potential could not be assessed, or for which it was desirable to prevent competitors from obtaining patent rights."

205. The question provides information on patenting policies which is of value in evaluating trends in the numbers of applications and patents.

206. The innovation survey may also include a question on the use of the firm's own patents.

7.3 Questions on the technology balance of payments (TBP)

207. TBP questions have been included in innovation surveys at two levels of detail.

208. The more ambitious approach asks questions about expenditure on and revenue from patents, licences, know-how, technical assistance and other kinds of acquired or sold technology.

209. In the other approach, no monetary data at all are collected, only information on whether the firm has acquired domestic or foreign technology and sold technology on the domestic or foreign market.

210. The methodology here is described in the OECD TBP Manual. But the feasibility of asking for detailed TBP information in innovation surveys is uncertain; it is probably best left to a separate survey. The less ambitious approach is therefore recommended for innovation surveys.

211. In order to obtain some impression of the connections between acquisition of technology, innovation and sale of technology it is recommended that the innovation survey should at least ask if the firm has acquired technology from the domestic or foreign market (if possible subdivided by region) or sold technology to the domestic or foreign market (similarly subdivided). The information should, if possible, be further subdivided by type of transaction (patents, non-patented innovations, licences, know-how, trade marks, services with a technological content, etc.).

8. SUGGESTED LIST OF QUESTIONS FOR INCLUSION IN INNOVATION SURVEYS

212. Many possible questions have been mentioned. The aim has been to present a menu of indicators from which to compose a national innovation survey, based on those used to date. It may not in fact be possible or practicable to include all the recommended indicators in a single survey. The cost could well be too high, and the large number of questions would probably cut the response rate.

213. Hence, if the national survey results are to be used for international comparisons it is important to decide on a set of core questions based on common definitions.

214. The following indicators seem the most suitable for inclusion in a national or international survey of innovation.

Proposed indicators:

-- economic objectives of innovation (section 1);

-- sources of innovative ideas (section 2.1);

-- factors hampering innovative activities (section 2.3);

-- proportion of sales and exports due to new products introduced on the market within the last three years (section 5.1);

-- R&D co-operation (section 7.1);

-- acquisition/sale of technology (section 7.3);

-- innovation costs (Chapter VI, section 2);

-- general information about the firm (sales, exports, employment) (except if the innovation survey is linked to a more general survey requesting such information).

{Chapter VI}

MEASURING THE COST OF INNOVATION

215. Measuring the total cost of innovation activities in enterprises and industries is one of the major aims of innovation surveys. Until recently the only item which had been measured regularly was R&D expenditure, and that is only part of the financial input. Examining the cost of all aspects of innovation may facilitate more meaningful calculations of the return on innovative investment.

1. THE METHOD OF MEASUREMENT

216. To date, survey questions on innovation expenditure have been put in two ways:

i) total expenditure on innovation for the whole enterprise in a given year;

ii) total expenditure for innovations introduced in a given year or during a given period.

217. there is a fundamental difference between the two approaches, and the results that they yield are not comparable.

1.1 Innovation expenditure in a given year

218. tHe first approach emphasises the input side of the innovation process as a whole, including activities that do not in the end lead to innovations. It is, in a way, a wider form of measurement of R&D expenditure. The actual R&D portion corresponds to the expenditure covered by Frascati Manual R&D surveys. Not many enterprises keep separate records of other innovation expenditure, but experience has shown that it is quite possible for them to give acceptable estimates of the non-R&D portion.

1.2 Expenditure for innovations introduced in a given period

219. The second approach looks at the total cost of innovations that have been brought to market during a given period. It excludes expenditure on projects that are aborted, and on general R&D not connected to any specific

product or process application. The stress is more on the output side of the innovation process. This approach seems particularly suitable for innovation surveys starting from a set of successful innovations. But it could also be used in surveys of the innovative activities of enterprises.

220. With the second approach it seems to be more difficult for enterprises to report accurate figures, as they have to go back into their financial records for earlier years. It also assumes that companies have information about innovation expenditure at project level; that is rarely the case.

221. For international comparability, only one of these approaches can be used. The first, emphasising total expenditure on innovation in a given year, is more realistic in enterprise-based surveys and is therefore recommended.

222. Many firms find innovation expenditure difficult to report; the non-R&D items in particular are not usually available from their accounting systems. To evaluate the reliability of answers, it may be useful to ask firms to indicate the degree of uncertainty by saying whether their figures are based on accounts or are fairly accurate or rough estimates.

2. SUGGESTED BREAKDOWNS

2.1 Breakdown by type of innovative activity

223. The descriptions of expenditure items which should be included under various categories of innovative activities are based on the definitions of innovative activities in Chapter IV, section 3.

Current and capital expenditure on innovation by type of innovative activity

{Intramural R&D expenditure}

224. {This item comprises total intramural expenditure on R&D as defined in } {the Frascati Manual and as reported in R&D surveys. In most cases all this R&D } {is intended to contribute to the introduction of new products and processes in } {the firm concerned. However where a firm carries out R&D purely as a service } {for another enterprise (or government agency) to contribute exclusively to } {innovation by the latter, an attempt should be made to identify the funds } {concerned so that they can be excluded in order to avoid double-counting when } {total (intramural and extramural) expenditure is summed over industries. }

{Extramural R&D expenditure}

225. {This comprises the acquisition of R&D services}.

{Expenditure for the acquisition of disembodied technology}

226.{ This item comprises the cost of transfers of patents and non-patented } {inventions, licensing and disclosure of know-how, transactions involving } {trademarks, designs, patterns and services with a technological content. }

{Expenditure for tooling up, industrial engineering and manufacturing start-up}

227. {This item comprises mainly:}

{ -- design expenditure not included in R&D expenditure;}

{ -- expenditure for software adapted to the requirements of new products } {and processes;}

{ -- training expenditure in connection with the introduction of new } {products and processes (training for other activities should be } {excluded);}

{ -- expenditure for trial production not attributable to R&D;}

{ -- expenditure for tooling up and organisational development in } {connection with manufacturing start-up;}

{ -- expenditure for acquisition of machinery and equipment linked to the } {introduction of new products and processes (see Chapter IV, } {section 2.2, v) machinery and equipment).}

{Marketing of new products}

228. {This item comprises expenditure for the launch of a new product, } {including preliminary market research, market tests, adapting the product for } {different markets and launch advertising, but excludes expenditure for the } {building of distribution networks to market innovations}.

2.2 Classification by source of funds

229. It is important to know how innovation expenditure is financed from different sources, for instance in order to evaluate the role of public policy and internationalisation in the innovation process. The following classification by source of funds is suggested.

Classification of innovation expenditure by source of funds:••

-- own funds;

-- funds from related firms;

-- funds from other enterprises;

-- government procurement;

-- government grants;

-- government loans;

-- funding from abroad:
• -- from related firms;
• -- from other firms;
• -- from EC;

- -- from other international agencies;
- -- other funding from abroad;

-- Other sources.

It would be useful to ask for the R&D component of the above classes, at least for the following categories:

-- R&D commissioned by government
-- R&D commissioned by private sources
- and if appropriate
-- R&D commissioned by EC.

2.3 Cross-classification by type of cost

230. Expenditure by type of innovative activity should, if possible, be broken down into current and capital expenditure. This is most important if the data are to be compared with those on {intangible investment}, with which {innovation expenditure} is sometimes confused (see section 2.4 below, the relation between intangible investment and innovation expenditure).

231. All depreciation provisions for building, plant and equipment, whether real or imputed, should be excluded from the measurement of intramural expenditure.

232. Current expenditure is composed of {labour costs} and {other current costs}.

-- Labour costs comprise annual wages and salaries and all associated costs or fringe benefits such as bonus payments, holiday pay, contributions to pension funds and other social security payments, payroll ta xes, and so on. The labour costs of persons not involved in innovative activities (such as security personnel and maintenance staff) should be excluded and considered with other current costs.

-- Other current costs comprise non-capital purchases of materials, supplies and equipment to support innovative activities performed by the firm in a given year.

233. Capital expenditure is the annual gross expenditure on fixed assets used for the innovative activities of the firm. It is composed of expenditure on {land and buildings} and on {instruments and equipment}.

-- Land and buildings includes the acquisition of land and buildings for innovative activities including major improvements, modifications and repairs.

-- Instruments and equipment includes major instruments and equipment acquired for use in the innovative activities of the firm.

All capital expenditure should be reported in full for the period when it took place and not be registered as an element of depreciation.

2.4 The relation between intangible investment and innovative expenditure

234. {Intangible investment} covers all current expenditure for the firm's development which is expected to give a return over a longer period than the year in which it is incurred. There is no standard definition, but it is generally taken to cover non-routine marketing expenditure, training expenditure, expenditure on software and some other similar items, in addition to current expenditure on R&D.

235. Current expenditure on innovation is clearly a part of intangible investment. If innovation is limited to technological innovation, as is proposed, then intangible investment is broader. For example, only training in connection with the introduction of new products and processes is classed as innovation expenditure; intangible investment takes in all of the firm's training expenditure. Marketing in connection with the introduction of new products and processes is classed as innovation expenditure. Intangible investment, on the other hand, includes marketing expenditure in general (e.g. improving the image of the firm, or capturing new markets with no direct connection to new products and processes).

236. At the same time, innovation expenditure includes tangible investment such as capital expenditure on R&D and acquisition of new machinery and equipment related to innovations.

3. TYPE OF REPLY

237. If possible, all replies concerning innovation costs should be expressed in monetary terms. If this is thought too difficult, the total should be requested together with estimated percentage breakdowns for the components.

{Chapter VII}

CLASSIFICATIONS AND SURVEY PROCEDURES

238. Some matters to do with the design and conduct of an innovation survey will now be discussed:

- -- population and sample design;
- -- statistical units;
- -- general information about the enterprise;
- -- classifications relevant for innovation surveys;
- -- data collection.

1. POPULATION AND SAMPLE DESIGN

239. The population of innovation surveys usually consists of enterprises in manufacturing industry. It may also be useful to include parts of the service sector, particularly those working directly with manufacturers. It is important to obtain information on non-innovators as well as innovators, and on non-R&D performing innovators as well as R&D performing innovators.

240. Resource limitations will in most cases rule out a survey of the entire population, so a sample has to be designed. It must be representative of the industries covered and of the various types of innovators and non-innovators. Once that has been done, weighting the data to obtain the innovation variables for all manufacturing industry is not particularly complicated. Sampling principles should be kept fairly stable so that meaningful time series can be built up at all-manufacturing level.

241. Construction of the sample can usefully start with a fairly simple questionnaire to establish a general inventory of innovating firms in different categories. After that, designing the final sample for the more detailed innovation survey is relatively straightforward.

2. STATISTICAL UNITS

242. It is recommended that statistical units (units classified) for innovation surveys should be the same as for R&D surveys. In most cases the enterprise-type unit is the most appropriate one for innovation surveys as well.

243. By "enterprise-type unit" is meant the smallest possible separate legal entity with a degree of economic independence. In some cases, especially when the enterprise is engaged in many branches of activity, a smaller unit (for example, a division of the enterprise such as an establishment or a kind-of-activity or local unit) could be recommended. The enterprise group should not, in general, be taken as the statistical unit unless its productive activities are homogeneous, i.e. largely confined to one industry.

244. In innovation surveys, multinational companies with different parts of the innovation process located in different countries may merit special treatment.

3. GENERAL INFORMATION ABOUT THE ENTERPRISE

245. Information of this kind is of value in putting data on innovation into context.

246. Is the enterprise independent, or part of a conglomerate? Is the entity concerned an enterprise, a division of an enterprise, or another unit? Which precise units does the survey return cover?

247. Economic variables such as sales, exports, employment and investment are relevant as well. This information, which is needed for the analysis, is usually available in industrial databases or other statistical systems. There may be difficulties in matching data from different sources, because of differences in sample construction for example, so these variables should be requested in the innovation survey.

248. A question on the average life span of the firm’s product groups will assist evaluation of the data on its innovation output.

4. RECOMMENDED CLASSIFICATIONS

4.1 Classification by main economic activity

249. The most important classification of the statistical units is by main economic activity. The International Standard Industrial Classification (ISIC) has traditionally been used for this purpose. The most recent revision (ISIC Rev. 3) was adopted in 1989. The industrial classification to be used in the European Community (NACE Rev. 1) will also be applied by EFTA countries. ISIC Rev. 3 and NACE Rev. 1 are closely harmonised.

250. It is not clear, as yet, which classification will be recommended for innovation surveys. It will depend on general OECD practice for other statistics, and on decisions taken in revising the Frascati Manual.

4.2 Classification by size

251. The other essential classification of enterprises is by size. This can be based on turn-over or other financial items, or on employment. The Frascati Manual chooses employment as the basis for classification. It can be recommended for innovation surveys as well. The classification below combines the classes suitable for large and small economies, as the utility of this distinction is not clear. Obviously, large economies have a proportionally higher share of their companies in the higher employment classes than small economies.

Classification of enterprises by size

- Number of employees:

- <20
- 20 - 49
  50 - 99
- 100 - 499
  500 - 999
  1 000 - 1 999
- 2 000 - 4 999
  5 000 - 9 999
- 10 000 - 24 999
- 25 000 and above.

252. These categories can be merged according to countries' own requirements.

4.3 Other classifications of enterprises

253. A number of other characteristics can be used as explanatory variables for aspects of the innovation process. Enterprises can, for example, be classified by main activity: mass production, custom production, process industry.

254. They can also be classified by main type of goods produced (consumer goods, intermediate goods, investment goods) or by low, medium or high R&D intensity (R&D expenditure/turnover under 1 per cent, 1-4 per cent, over 4 per cent).

255. Export intensity can serve as an explanatory variable (the classification used in some surveys is export/turnover 0 per cent, 0-20 per cent, 20-50 per cent, 50-100 per cent). Medium-term market expectations have also been used for the same purpose.

4.4 Classification of innovative activities by product group

256. In most cases, classification by main economic activity gives only a broad picture of the firm's activities. Though a firm is classified in the "machinery" group, for example, its innovative activity may concern a range of machines, and other product groups as well. The innovation indicators for the separate groups may be quite different. It is therefore recommended that data on at least some of the innovation variables should be requested at product group level.

257. Various breakdowns of product groups are possible. The standard international version is the Combined Trade/Production Goods Classification (CPC). The Frascati Manual chooses another approach, basing its product group classification on ISIC, which it also uses for economic activity purposes. This facilitates comparisons of data. The principle that the same standard international classification should be used for economic activity and product group breakdowns should be followed for innovation surveys. The classification by product group should, however, be more detailed than that by economic activity.

258. The choice for the product group classification will thus depend on which classification is to be used for economic activity (ISIC or NACE).

259. In the questionnaire, product group information can be obtained for some variables by requesting separate figures for the three most important groups, to be chosen by the enterprises themselves. The total for these three will not necessarily be the total for the enterprise, so that must be requested as well. Another possibility is to ask for a separate return for each product group in which the enterprise operates.

5. SURVEY METHODS

260. This section will deal briefly with three problems connected with data collection:

- -- mail survey or interview survey;
- -- choosing the most suitable respondent in the enterprise;
- -- motivating enterprises to respond.

261. Most of the innovation surveys carried out so far have been mail surveys, though interviews have been used in some countries. Innovation concepts are quite complex, and experience to data has shown that the interview method is preferable, as it gives more reliable and consistent results. But it is extremely expensive, and resources may not allow it to be used. The best solution may be a combination of both methods.

262. Choosing the most suitable respondent in the firm is particularly important in innovation surveys, as the questions are highly specialised and can be answered by only a few people in the enterprise, usually not the ones who complete other statistical questionnaires. In small firms, managing directors will often be good respondents. In larger companies directors responsible for technology, or sometimes marketing directors, may well be the best people to answer the questions. Several people will often be involved, but one must be responsible for co-ordinating the replies. A special effort to identify respondents in firms, before the questionnaire is sent out, is likely to assist the success of the survey.

263. It is extremely important to motivate firms to complete the questionnaire. Few countries are in the fortunate position of Italy, where returns are mandatory. The non-response rate has been a significant problem with all enterprise-based innovation surveys, except in Italy. Enterprises nowadays receive large number s of questionnaires from various sources; many overlap, are poorly designed, and do not match firms' internal reporting systems.

264. The innovation questionnaire should therefore be as simple as possible, and logically structured, and have clear definitions and instructions so that firms can see that the outcome of the survey will prove of interest and value to them. It is particularly important to design the questionnaire so that enterprises without formal R&D or other innovative activities will none the less reply. Feedback to responding enterprises -- a short summary of the findings, from which they can compare their own figures with data for their industry and for manufacturing as a whole -- will certainly improve the response rate.

6. FREQUENCY OF DATA COLLECTION

265. Firms' innovation activities seem to be on the increase. Dynamic analysis calls for time series. Annual data collection, as in the IFO survey, would be ideal. But for most countries it is not possible to run a full innovation survey every year. A limited annual survey, covering a few key variables, may be feasible in some cases. Full innovation surveys at wide intervals make it difficult to carry out a satisfactory analysis of developments over time.

266. It is therefore suggested that full surveys are repeated at least every three years, that being the reference period in the questions on innovations introduced. In addition to general innovation surveys, more detailed studies on certain sub-populations or certain specific subjects are recommended.

{Chapter VIII}

ANALYSIS AND POLICY

267. This chapter moves on from survey structure to outline some of the questions which can be analysed using the data which we can expect to produce with that structure. We should note that there is no definitive set of analytical questions, because there are so many unknowns in innovation analysis. George Eads has emphasised the "relatively primitive state of our knowledge": we are, he points out, "not putting the finishing touches on a well understood edifice called 'The Economics of Technical Change'. Instead (we) are labouring at a much earlier stage; one in which the surprises produced by even simple correlations might be enough to cause us to go back to our plans to see if we are even constructing the right structure"F
F.

268. The data which come from this type of survey have two important characteristics. First, we are dealing with an almost completely new range of data, on forms of innovative activity, on sources and obstacles to innovation, and on innovation outputs and some of their effects. Second, both the new and the more familiar data (such as R&D inputs) are available in highly desegregated form. This will enable us to look at some classic questions in innovation theory -- such as the relation between market structure and innovation, or the relationships between R&D intensity and productivity growth -- in a new way. We shall also be able to examine issues which have never been thoroughly researched. This chapter looks at some of these.

269. The list of questions below is not, it should be emphasised, exhaustive; one of the merits of the survey questionnaires which have been developed so far is that they are robust enough to support a wide range of questions and approaches.

270. (i) How is enterprise performance affected by innovative activity? We usually assume that technological change is the fundamental factor in economic growth, and that competitiveness depends on innovation performance. In fact we do not know as much about that as we should, and new survey approaches can generate a range of both innovation and outcome indicators.

271. (ii) How is innovative activity affected by enterprise characteristics? Survey methods give us the ability to define firms according to a wide range of external characteristics (size, exports, industry, sector of products, degree of competition, location of competition and so on) and internal characteristics (main competitive strategies, R&D effort and so on).

272. (iii) Why and how do firms innovate? There are two issues here, which are of course linked but should perhaps be examined separately:

- a) what are the factors which generate innovation activity (the impetus to innovation)? and

- b) what are the main sources of innovative ideas?

273. The first issue is who is making the decisions about whether to attempt to innovate, and (much more interesting) what factors are leading them (or forcing them) to choose particular areas of innovationF
F? The second issue is
who is generating the technical ideas or results on which innovation is based? Then, from a policy viewpoint, the vital question is, how does innovation relate to the public research base? There are a number of ways this question can be put: the Italian survey asked about "Scientific and Technical Literature" as a source of innovation, and got the surprising result that this was more important than internal R&D, and second only to acquisition of capital goodsF
F.

274. (iv) Users as sources of innovative ideas. It has been shown in a number of studies that this is an important factor in some industriesF
F, and it would be very useful to have a cross-industry perspective.

275. (v) How is innovative activity distributed within industries? A leading problem in the analysis of innovation concerns intra-industry distributions of R&D and innovative activity. Measures of research intensity for industries as a whole tend to obscure the fact that there is a wide dispersion of R&D input, and this makes it difficult to interpret industry-level relationships between R&D inputs and productivity growthF
F.

- Surveys give us the opportunity:

- (a) to ask questions about the relationships between intra-industry R&D distributions, and intra-industry differences in the levels and types of innovation activity; and

- (b) to get a picture of the way in which these distributions relate to outcomes.

276. (vi) How do corporate strategies for both competition and technological innovation relate to differences in innovation performance and economic results? To our knowledge this important question has never been analysed in a quantitative way, and surveys clearly open up important possibilities here.

277. (vii) How good are R&D and patenting as proxies for innovation activity? Given data limitations, most analysts use some combination of R&D inputs and patenting outputs as indicators of innovation activity. But as Kline and Rosenberg point out, "The process of R&D has often been equated with innovation. If this were true, understanding innovation would be far simpler than it truly is, and the real problems would be far simpler and less

interesting than they truly are"F
F. Surveys give us the
opportunity of checking whether this supposed R&D-innovation relationship is reliable, and can also show the links between types of R&D and types of innovation output.

278. (viii) Is the relationship between R&D inputs and innovation outputs changing over time? A major unresolved theme, both in science studies and in the economics of innovation, has concerned the productivity of research: do the costs of research rise over time in relation to output? Does a particular rate of technological advance require an increasing volume of resources?F
F

This is not a question which can be examined on the basis of one survey; but it will be possible with the results of repeated surveys.

279. (ix) How significant is the diffusion of technology, and inter-firm and inter-industry technology flows, in general technological performance? This has both domestic and international aspects. On the domestic side, there is considerable evidence that the ability to acquire and adapt technologies developed elsewhere is a central factor in economic performance; in some cases it seems to be more important than direct innovation itself. An obvious first place for firms to search is within the scientific and technological resource base of their domestic economy, especially in the public sector.

280. (x) On the international side, how significant are international technology flows in the innovation programmes of firms? For small economies such flows are probably very important indeed, and the answer to this question has considerable policy implications. But it is also highly relevant for the large R&D performing economies of the OECD. It should be noted that this information is also relevant to OECD countries' work at the present time on the technology balance of payments (TBP). But it is very important to distinguish between flows of technological information (which is what the TBP covers), and flows of equipment or inputs embodying foreign R&D and technological knowledge: we have very little real information on the latter at the present time.

281. (xi) How important is R&D in the acquisition of foreign technologies and in technology transfer? This is a component of a much wider question: what are the economic functions of an R&D department? Starting with the first of these questions, it is often argued that R&D is necessary not just to develop innovations but also as a kind of "technical intelligence function" which monitors scientific and technological developments, and searches for applications among outside (especially foreign) developments. In other words, a firm needs to do R&D just to be able to make sensible choices among technologies that are available elsewhere.

In assessing whether this is true, there are at least three questions:

(a) is this actually what R&D departments do?

(b) how important is it among their functions? and

(c) can we see any performance differences between firms which do and do not use their R&D department in this way?

282. Beyond this there is a range of questions concerning what R&D departments actually do, how they are organised, how they are linked with other departments or divisions of the firm (especially marketing, design and production engineering), and about R&D decision-making. Rejecting the linear model of innovation does not imply that R&D activities are not essential and important; it simply means that we need to be more precise about what the role of R&D in innovation actually is.

283. (xii) How important is the ability to appropriate benefits as an obstacle to innovation? This is one of the classic questions in innovation analysis and policy (it underlies major issues in patent law and property rights, for example). Some of the most important early work on the economics of R&D saw it as a central policy issueF
F, and recent work has emphasised its importance in determining who innovates and who does notF
F.

284. The questions listed here are representative only, but they indicate some of the core issues, many of them unresolved at the present time, wher e we can hope for better and more rigorous information from survey data.

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6. A comprehensive discussion and analysis of this relationship can be found in various contributions to Z. GRILICHES (ed) (1987), R&D, Patents and Productivity, Chicago.

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9. See for example, N.E. TELECKYJ, "What Do R&D Numbers Tell Us About Technological Change?", American Economic Review, Papers and Proceedings, Vol. 70, No. 2, 1980, p. 56.

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11. The major programmes currently have total budgets for 1988-92 in the region of US$4 billion. DRIVE, DELTA, BRITE/EURAM II, FLAIR, ESPRIT I, EURAM, RACE and ESPRIT II.

12. "Brussels Proposes Big Rise in High-Tech Research", Financial Times, July 26, 1989, p. 1. For a discussion of some of these integration issues in the context of the US-Canada Agreement see Guy Steed, "The Canada-US Free Trade Agreement: A Canadian Science and Technology Viewpoint", Technology in Society, Vol. 11, No. 2, 1989, pp. 235-246.

13. HANSEN et al (1984), pp. 13-15. For a discussion of the linear model, see S.J. KLINE and N. ROSENBERG (eds) The Positive Sum Strategy. Harnessing Technology for Economic Growth, (1986), National Academy Press, Washington, pp. 285-287; and S.J. KLINE, "Research is not a linear process", Research Management, Vol. 28, 1985.

14. KLINE and ROSENBERG, op. cit., p. 286.

15. Which is one reason why economic analyses based on convergence to optimal equilibria tend to be misleading. A key problem in industrial organisation is not adjustment towards similar production forms, but the coexistence of diversity.

16. EVENSON offers a somewhat similar list of the "options open to a firm to alter the technology it uses": see R. EVENSON, "International invention: implications for technology market analysis", in Z. GRILICHES (ed) 1987 R&D, Patents and Productivity, Chicago, p. 90. The list which follows draws on K. SMITH (1989), "The Nordic Innovation Indicators Project: Issues for Innovation Analysis and Technology Policy", Report to Nordic Industry Fund, Oslo, pp. 6-7.

17. KLINE and ROSENBERG, 1986, op. cit., pp. 289-291. See also Stephen J. KLINE (1987), Research, Invention, Innovation and Production: Models and Reality, Report INN-1C, Thermosciences Division, Department of Mechanical Engineering, Stanford University, July. For a closely related approach, see K.J. SCHMIDT-TIEDEMANN, "A New Model of the Innovation Process", Research Management, Vol. 25, No. 2, 1982, pp. 18-21. For a discussion of compatible examples, see HANSEN et al, op. cit., (1984), p. 34.

18. S.J. KLINE and N. ROSENBERG, "An Overview of Innovation", in R. Landau and N. Rosenberg (eds). The Positive Sum Strategy. Harnessing Technology for Economic Growth (Washington DC: National Academy Press), 1986, p. 289.

19. This accords with a very solidly established result in innovation analysis, which is that innovative success depends heavily on the degree to which marketing is integrated with the technical aspects of the innovation process. For a general discussion, see C. FREEMAN (1982), The Economics of Industrial Innovation, 2nd Edition, PINTER (London), Ch. 5: "Success and Failure in Industrial Innovation." HANSEN et al (1984) emphasise the point in relation to data collection, and this is one of the strong points of their survey work.

20. OECD (1981), op. cit., pp. 15-16.

21. OECD (1981), op. cit.

22. For a brief overview of recent research and future directions, see J.M. UTTERBACK, "Innovation and Corporate Strategy", International Journal of Technology Management, Vol. 1, Nos. 1/2, 1986, pp. 119-132.

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26. PAVITT, op. cit., 1984, pp. 353-364; ARCHIBUGI et al, op. cit., 1989, Section 5.

27. von HIPPEL E. (1988), The Sources of Innovation, (Oxford University Press, New York and Oxford), Chs. 3-5, is one of the few systematic discussions of this problem.

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30. See N.E. TERLECKYJ, op. cit., 1980, pp. 55-61, for a discussion of some of the issues here.

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END-OF-TEXT