A Guide for Data Collection on Technological Innovation: Extracts from the OECD "Oslo Manual", 2nd Edition, 1996

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Foreword

This document has been prepared to provide a shorter version of the Organization for Economic Cooperation and Development (OECD) guide for data collection on technological innovation, otherwise known as the "Oslo Manual", for use by researchers. **This document has not been reviewed or approved by OECD authorities and use of it does not imply any acceptance of it by OECD authorities.**

The vast majority of enterprises in all economies are innovative in some way, simply in order to stay in business, yet most do not have formal innovation or knowledge acquisition policies or

programs. These firms have neither the time or the capacity to answer detailed questionnaires on their internal innovation processes. Thus it is important to have a methodology for measuring innovation in the context of small and medium-sized enterprises, in a simple and non-confrontational manner.

Every attempt has been made to make this document relevant to studies of innovation in all types of economies: industrialized and developing, resource-based and manufacturing, large and small. The concepts are based on theories of the market-driven economy, so that it may not be entirely appropriate for use in centrally-planned economies. However, although there is little research in the area, there is no obvious reason why innovation studies could not be adapted for use in the public sector. Some public sector institutions (schools, libraries, hospitals, etc.) operate in a competitive environment, and must innovate to maintain the level of their operations.

The manual consists of :

- a general introduction
- a review of the need to measure innovation for policy development
- basic definitions to establish a common base for surveys
- standard questions for inclusion in surveys

The editing process for this document assumed the following:

- that a national system of innovation exists in each and every economy
- most establishments innovate in ways that are not based on internal R&D programs
- the measurement of the effects of innovation are not based on requests for explicit sales or expenditure figures
- that any one survey of innovation is but a single image in time of the phenomenon

The numbers attached to paragraphs in this document refer to the paragraph numbers in the "Oslo Manual". Some of the paragraphs may have been shortened, but no material has been added. For the most part, examples have been removed for brevity. An appendix on statistical issues is also attached.

Chapter 1 - Introduction

1. It is now 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. 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 changes 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 the ability to improve the information available.

7. In constructing innovation indicators the information needs of policyrnakers and analysts are of paramount consideration. Chapter 2 reviews these needs, which are part of a broad information system which helps to reduce uncertainty in policymaking, and which have been influenced even since the first version of this manual, by developments in the understanding of economics of innovation.

8. Thus innovation policy has only recently emerged as an amalgam of science and technology (S&T) policy and industrial policy. Its appearance signals a growing recognition that knowledge in all its forms plays a crucial role in economic progress, that innovation is at the heart of this "knowledge-based economy", and also that innovation is a more complex and systemic phenomenon than was previously though. Systems approaches to innovation shift the focus of policy towards an emphasis on the interplays between institutions, looking at interactive processes both in the creation of knowledge and in its diffusion and application. The term "National System of Innovation" (NSI) has been coined for this set of institutions and flows of knowledge.

14. Scope of the Manual:

- this manual covers innovation in the business enterprise sector only,
- it deals with innovation at the level of the firm (or more properly at the level of the enterprise)
- it concentrates on technological product and process (TPP) innovation
- it covers diffusion up to "new to the firm";

15. Innovation can of course occur in any sector of the economy, including government services such as health or education. The guidelines in this manual are essentially designed to deal with innovations in the business enterprise sector.

17. This manual deals with changes which take place at the level of the individual firm.

19. A firm can make many types of changes in its methods of work, its use of factors of

production and its types of output which improve its productivity and/or commercial performance. An exhaustive study of such changes would be unwieldy in terms both of data collection and of subsequent analysis.

20. Different analytical approaches can be used to select a subset of these changes for further study, for example all those related to the diffusion of IT or those involving intangible investment (R&D, software, training, marketing etc.) This manual deals with changes which involve a significant degree of novelty for the firm. It excludes changes which are "more of the same".

21.The body of the manual concentrates on new and significantly improved products (goods and services)and processes. It is recognizes that purely organizational innovation is widespread and may result in significant improvements in firm performance.

22.The main text deals with "technologically" new or improved products and processes. The meaning of the label "technological", as applied to products and processes, and its precise scope in surveys and studies, can be unclear; this is particularly true in an international context. The dictionary definitions of the word (or its nearest equivalent in some languages) which may differ subtly between countries, and the overtones of the word to which respondents may react.

24. **A technological product innovation is the implementation/commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods**. It may involve changes in equipment, human resources, working methods or a combination of these.

26. Because of the lack of criteria for answering these questions, technological product innovation as defined in this manual excludes changes in products which provide largely subjective improved customer satisfaction based on personal taste and aesthetic judgement, and/or derived from following fashions and/or brought about largely by marketing. However, since such changes are extremely important in certain industries and involve the same or similar activities as TPP innovation (design, marketing, etc.), they have been separately identified under the heading "other creative product improvements".

27. Diffusion is the way in which TPP innovations spread, through market or non-market channels, from their first worldwide implementation to different countries and regions and to different industries/markets and firms. In order to include some degree of diffusion, the minimum entry to the system described in this manual has been set as "new to the firm" This means that the complete diffusion of a new technology through a firm after its first adoption/commercialization is not included.

31. TPP innovation activities are all those scientific, technological, organizational, financial and commercial steps which actually, or are intended to, lead to the implementation of new or improved products or processes. Some may be innovative in their own right, others are not novel but are necessary for implementation.

33. Furthermore, innovation is not a linear process and there may be important loops back in the system. The main activities involved are R&D, other acquisition of knowledge (patents, licences, technical services etc.), acquisition of machinery and equipment (incorporating new technology and for standard use when producing a new product), various other preparations for production/delivery, including tooling up, staff training etc. and last but not least marketing Of

these, only R&D and the acquisition of machinery incorporating new technology are automatically TPP innovation activities. The others are only included if they are required for the implementation of TPP innovations, not if they are undertaken in connection with organizational innovation, other creative improvements or straightforward capital or production extension.

36. One of the first steps in an innovation survey is to measure the proportion of firms which are "innovating" as opposed to "non-innovating". This proportion threatens to become a "magic number", comparable to the percentage of GDP devoted to R&D. It is a figure that requires some care in presentation and interpretation. It is best calculated taking into account industrial structure crossed, if possible, with a breakdown by size of firm; a global figure can be very misleading. Furthermore, it is important to ensure that only TPP innovations have been included, not organizational innovations or even other creative improvements.

37. The TPP innovating firm is one that has implemented new or significantly improved products, processes or combinations of products and processes during the period under review. It is a firm with successful innovation activities during the period. Within this category it may be interesting to divide out firms which have only "passive" TPP innovation, i.e. those which have innovated exclusively by importing technology incorporated in new machinery and equipment.

38. The impact of TPP innovation can be measured by the percentage of sales derived from new or improved products.

39. The indicator is also influenced by the length of the product's life cycle. Within product groups with shorter life cycles, there is a more frequent need for innovation compared with product groups with longer life cycles.

41.There are two main approaches to collecting data on TPP innovations by firms, the "subject approach" which starts from the innovative behavior and activities of the enterprise as a whole and the "object approach" which concentrates on the number and characteristics of individual innovations

45. In order to achieve a satisfactory response rate the questionnaire should be as short as possible and should include clearly formulated questions and instructions. This may involve expressing the formal definitions in Chapter 3 in ways which are appropriate and meaningful to respondents in the industry concerned, notably in the service industries.

48. There are two basic families of S&T indicators which are directly relevant to the measurement of TPP innovation: resources devoted to R&D, and patents statistics.

49. R&D data are collected through national surveys according to the guidelines laid down in the Frascati Manual (OECD, 1993). Then data have proved valuable in many studies: for example, the effects of R&D on productivity have been measured by econometric techniques, at the country, sector and firm levels. These data have two main limitations. First, R&D is an input. Although it is obviously related to technical change, it does not measure it. Second, R&D does not encompass all the efforts of firms and governments in this area, as there other sources of technical change, such as learning-by-doing, which escape from this narrow definition.

50. A patent is a legal property right over an invention, which is granted by national patent offices. A patent provides to its owner a monopoly (with limited duration) for exploiting the patented invention, as a counterpart for disclosure (which is intended to allow a broader social use of the discovery). Patents statistics are increasingly used in various ways by technology

students as indicators of the output of invention activities. The number of patents granted to a given firm or country may reflect its technological dynamism; examination of the technologies patented can give some hints on the directions of technological change. The drawbacks of patents as indicators are well known. Many innovations do not correspond to a patented invention; many patents correspond to invention with a near zero technological and economic value, and some patents never lead to innovation.

51.These two basic families of statistics are complemented by several others, including: statistics on scientific publications (bibliometrics), publications in trade and technical journals (so-called literature-based indicators of innovation output -LBIO), the technology balance of payments, and activity in high-tech sectors (investment, employment, external trade). Moreover, some information on innovation and innovative activities can be drawn indirectly from many other sources, such as business surveys or education statistics.

52. Wherever possible this manual draws on the concepts and classifications set out in other volumes in the set of OECD manuals for the measurement of scientific and technological activities, especially the Frascati Manual on the measurement of resources devoted to R&D.

53. Because of the need to place innovation in a wider context, both conceptually and in terms of databases, United Nations guidelines and classifications are used as far as possible, notably the System of National Accounts, and the International Standard Industrial Classification - ISIC Rev.3.

The OECD "Frascati Family" of Guidelines for the Measurement of Scientific and Technological Activities:

- Proposed Standard Practice for Surveys of Research and Experimental Development "Frascati Manual" 5th edition (OECD: 1993)
- Main Definitions and Conventions for the Measurement of Research and Experimental Development (R&D) A Summary of the Frascati Manual (OECD: GD 1993)
- Proposed Standard Method of Compiling and Interpreting Technology Balance of Payments Data - TBP manual (OECD: GD1992)
- OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data "Oslo Manual" 2nd edition (OECD / EC/Eurostat 1996)
- Using Patent Data as Science and Technology Indicators - Patent Manual- (OECD: GD 1994)
- The Measurement of Human Resources Devoted to S&T - "Canberra Manual" (OECD / EC/Eurostat: GD 1995)

Chapter 2 - The Need to Measure Innovation

59. The "knowledge-based economy" is an expression which describes trends in the most advanced economies towards greater dependence on knowledge, information and high skill levels, and an increasing or ready access to all of these.

60. Within the knowledge-based economy, innovation is seen to play a central role, but until recently the complex processes of innovation have been insufficiently understood. Better understanding, however, has emerged from many studies in recent years. At the macro-level, there is a substantial body of evidence that innovation is the dominant factor in national economic growth and international patterns of trade. At the micro-level - within firms - R&D is seen as enhancing a firm's capacity to absorb and make use of new knowledge of all kinds, not just technological knowledge.

61. Other factors which influence firms' abilities to learn are also seen to be of fundamental importance. Ease of communication, effective channels of information, skills transmission and the accumulation of knowledge, within organizations and between them, are highly important. In particular, management and an appropriate strategic outlook am key factors. They determine much of the scope for the external linkages and the positive attitudes inside firms that promote receptivity to the adoption of improved practices and improved technology. According to a recent European Commission Green Paper:

"The innovative firm thus has a number of characteristic features which can be grouped into two major categories of skills:

1. strategic skills: long-view, ability to identify and even anticipate market trends; willingness and ability to collect, process and assimilate technological and economic information;
2. organizational skills: taste for and mastery of risk; internal co-operation between the various operational departments, and external co-operation with public research, consultancies, customers and supplier; involvement of the whole of the firm in the process of change, and investment in human resources,

62. Better awareness of the significance of innovation has made it a major item on the policy agenda in most developed countries. Innovation policy grew primarily out of science and technology policy, but it absorbed significant aspects of industry policy as well. As the understanding of innovation improved, there were substantial changes in the development of innovation-related policies. Initially, technological progress was assumed to be achieved through a simple linear process starting with basic scientific research and progressing in a straightforward manner through more applied levels of research, embodying the science in technological applications, and marketing. Science was seen as the driver, and all that government needed was science policy. Fresh thinking about innovation has brought out the importance of systems and led to a more integrated approach to the delivery of innovation-related policies.

63. Innovation is at the heart of economic change. In Schumpeter's words, "radical- innovations shape big changes in the world, whereas "incremental" innovations fill in the process of change continuously. Schumpeter proposed a list of various types of innovations:

i) introduction of a new product or a qualitative change in an existing product;
ii) process innovation new to an industry;
iii) the opening of a new market;
iv) development of new sources of supply for raw materials or other inputs;
v) changes in industrial organization.

64. It is crucial to know why technological change occurs, why firms innovate. The reason put forward, based on Schumpeter's work is that firms are seeking rents. A new technological device is a source of some advantage for the innovator. In the case of productivity-enhancing process innovation, the firm gets a cost advantage over its competitors, which allows it to gain a higher mark-up at the prevailing market price or, depending on the elasticity of demand, to use a combination of lower price and higher mark-up than its competitors to gain market share and seek further rents. In the case of product innovation, the firm gets a monopoly position due either to a patent (legal monopoly) or to the delay before competitors can imitate it This monopoly position allows the firm to set a higher price than would be possible in a competitive market, thereby gaining a rent.

65. Other work has emphasized the significance of competitive positioning. Firms innovate to defend their competitive position as well as to seek competitive advantage. A firm may take a reactive approach and innovate to prevent losing market share to an innovative competitor. Or it may take a proactive approach to gain a strategic market position relative to its competitors, for example by developing and then trying to enforce higher technical standards for the products it produces.

66. Technical change is far from smooth. New technologies compete with established ones, and in many cases replace them. These processes of technological diffusion are often lengthy, and usually involve incidental improvement both to new and established technologies. In the turbulence adjusting new firms replace incumbents which are less capable of adjusting. Technical change generates a reallocation of resources, including labour, between sectors and between firms. As Schumpeter pointed out, technical change can mean creative destruction. It may also involve mutual advantage and support among competitors or among suppliers, producers and customers.

67. Technological knowledge displays the features of a public good, as the costs of making it available to many users are low compared to the cost of its development and, once disseminated, users cannot be denied further access to it. This characteristic is a source of two main problems for private innovators. The first is spillover of the benefits of innovation (positive externalities), and the fact that the social return on innovation is usually higher than the private return (customers and competitors benefit from a firm's innovations). The second problem is another aspect of the first that knowledge cannot be appropriated. In such a case the firm cannot capture all the benefits generated by its innovation, which lessens the incentive to invest in innovative activities. Thus where technological knowledge has public good characteristics, there is a failure in the market forces that would otherwise be expected to motivate firms to innovate.

68. From this theoretical stand, many studies have derived statistical data and indicators that refer mainly to the cost of innovation and to the private and social rates of return on innovation activities. In such work, the private return on technological activities has been inferred through econometric methods involving the estimation of production functions that relate the inputs and outputs of innovation activities at the firm or aggregate level. To the extent that technological knowledge displays public good characteristics, science and technology policies have been conceived as responses to lessened incentives and other market failures such as risk and transaction costs. The main policy tools have been government direct funding of research, especially basic research (government as a provider of a public good), and patents (property rights).

69. Technological knowledge is also increasingly being understood to display other characteristics such as accumulation (which results in increasing returns) and influencing the

dynamics of markets so that they remain far from equilibrium (and tend to be pushed away from, not towards, equilibrium).

71. The higher-level or systems view of innovation emphasizes the importance of the transfer and diffusion of ideas, skills, knowledge, information and signals of many kinds. The channels and networks through which this information circulates are embedded in a social, political and cultural background, they are strongly guided and constrained by the institutional framework. The 'National Systems of Innovation" (NSI) approach studies innovating firms in the context of the external institutions, government policies, competitors, suppliers, customers, value systems, and social and cultural practices that affect their operation.

72. Systems approaches to innovation shift the focus of policy towards an emphasis on the interplay between institutions, looking at interactive processes in this creation of knowledge and in the diffusion and application of knowledge. It has led to a better appreciation of the importance of the conditions, regulations and policies within which markets operate - and hence the inescapable role of governments in monitoring and seeking to fine-tune this overall framework. The OECD has recognized that issues of system failure should be considered along with issues of market failure.

74. There are three major categories of factors primarily relating to innovation. These concern business enterprises ("firms"), science and technology institutions, and issues of transfer and absorption of technology, knowledge and skills. In addition, the range of opportunities for innovation is influenced by a fourth set of factors - the external environment of institutions, legal arrangements, and macro-economic settings. These factors (or human agents) are significantly determined by the social and cultural characteristics of the society in which innovation is being measured.

77. The external arena, within which firms can manoeuvre and change, and which thus surrounds innovation activities at the firm level , comprises institutions and conditions which have mostly been established (or have developed) for reasons unconnected to innovation. This general institutional environment provides the framework conditions within which innovation can occur.

78. The general institutional environment includes:

- the *basic educational system for the general population*, which determines minimum educational standards in the workforce and the domestic consumer market;
- the *communications infrastructure*, including roads, telephones and electronic communication;
- *financial institutions* determining, for example, the case of access to venture capital;
- *legislative and macro-economic settings* such as patent law, taxation, corporate governance rules and policies relating to interest and exchange rates, tariffs, and competition;
- *market accessibility*, including possibilities for the establishment of close relations with customers as well as matters such as size and ease of access;
- *industry structure and the competitive environment*, including the existence of supplier firms in complementary industry sectors.

79. Scientific knowledge and engineering skills are a primary support for business innovation. In most countries, these reside and are further developed in public sector science and

technology institutions. The worldwide output of scientific knowledge from these institutions provides an essential understanding and theoretical base for business innovation.

80. The differences in the nature of activities within science and technology institutions and innovating firms need to be understood. There are significant motivational differences between the communities within these two domains. Achievement is generally recognized in different ways, and reward structures are also different. In science, individuals tend to have a stronger role than the institutions which employ them. On the other hand, "the firm" (and hence organizational issues such as teamwork and strategy) tends to be more important than the individual in business innovation and technology.

However networks of individuals - and thus many aspects of social behavior - are of key importance in the transfer of information both among scientists and among those involved in business innovation. The national science and technology institutions can act as effective local conduits to this base and can provide the skilled personnel to fill key positions concerned with innovation. For much of business innovation they also provide sources of specialist advice, fruitful interaction and collaboration, and significant technological advance - often having their origin in their own scientific needs for improved instrumentation.

81. The elements of the national science and engineering base include:

- the specialized *technical training* system;
- the *university* system;
- the support system for *basic research* (radical breakthroughs and long-term benefits aside, basic scientific research is sometimes perceived as providing little direct benefit to business Innovation. However, its indirect benefits can be very substantial. Scientific investigation often requires the development of highly sophisticated and ultra-sensitive equipment Thus, many areas of basic research provide fertile ground for the training of skilled technology-oriented scientists - whose experience can often be successfully directed to industrial problems.);
- *public good R&D activities* - finding programmes and institutions generally directed towards areas such as health, the environment and defense;
- *strategic R&D activities* - funding programmes and institutions directed towards "pre-competitive R&D" or generic technologies; and
- *non-appropriable innovation* support - funding programmes and institutions directed towards research in areas where it is difficult for individual enterprises to appropriate sufficient benefit from their own in-house research.

82. Research on innovation has identified a number of human, social and cultural factors which are crucial to the effective operation of innovation at the firm level. These factors are mostly based around learning. They relate to the ease of communication within organizations, informal interactions, cooperation and channels of information and skills transmission between and within organizations, and social and cultural factors which have a pervasive influence on how effectively these activities and channels can operate. A key point from research on innovation is that much essential knowledge, particularly technological knowledge, is unwritten. Thus some kinds of information can only be transferred effectively between two experienced individuals - through transmission to a receptive individual who has enough expertise to understand it fully, or by physical transfer of the people who are carriers of the knowledge. It is learning by firms as a whole (i.e., diffusion of knowledge to a broad range of key individuals within them) that is critical to firms' innovative capabilities.

83. Broadly, these transfer factors may be listed as:

- formal and informal *linkages between firms*, including networks of small firms, relationships between users and suppliers, relationships between firms, regulatory agencies and research institutions, and stimuli within "clusters" of competitors, can all produce information flows conducive to innovation or lead firms to be more receptive to it;
- the *presence of expert technological "gatekeepers" or receptors* - individuals who, through many means, keep abreast of new developments (including new technology and codified knowledge in patents, the specialized press and scientific journals), and maintain personal networks which facilitate flows of information - can be crucial to innovation within a firm;
- *international links* are a key component of the networks through which information is channeled networks ("invisible colleges") of international experts are a key means of transmitting up-to-date scientific understanding and leading-edge technological developments;
- the degree of *mobility* of expert technologists or scientists will affect the speed at which new developments can spread;
- the *ease of industry access to public R&D capabilities*;
- *spin-off company formation* - usually involving the transfer of particular skilled individuals is often a valuable means of achieving commercialization of new developments arising out of public sector research,
- *ethics, community value-system, trust and openness* that influence the extent to which networks, linkages and
- other channels of communication can be effective, by affecting the informal dealings between individuals which underpin many business arrangements, and setting the parameters and accepted rules of behavior within which communication and exchanges of information occur, and
- *codified knowledge* in patents, the specialized press and scientific journals.

85. The technological capability of a firm is partly embedded in its labour force. Skilled employees are a key asset for an innovative firm. Without skilled workers a firm cannot master new technologies, let alone innovate. Apart from researchers, it needs engineers who can manage manufacturing operations, salespeople able to understand the technology they are selling (both to sell it and to bring back customers, suggestions). and general managers aware of technological issues.

87. The options open to a firm which wants to innovate, i.e. to change its technological assets, capabilities and production performance, are of three kinds: strategic, R&D and non-R&D.

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

1. *R&D*: Some of the options relate to R&D (in the Frescoed Manual sense, including experimental development that goes well beyond basic and applied research):

    - the firm can undertake basic research to extend its knowledge of fundamental processes related to what it produces;
    - 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 am open to it, and applied research to produce specific inventions or modifications of existing techniques;

- 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.

2. *Non-R&D*: The firm may engage in many other activities that 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:

   - it can identify new product concepts and production technologies

     - via its marketing side and relations with users,
     - via the identification of opportunities for commercialization resulting from its own or others' basic or strategic research,
     - via its design and engineering capabilities.
     - by monitoring competitors and
     - by using consultants;

   - it can develop pilot and then full-scale production facilities;

   - it can buy technical information, paying fm 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;

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

   - it can reorganize management systems and the overall production system and its methods, including new types of inventory management and quality control, and continuous quality improvement

Six areas for investigation in innovation studies

a) Corporate strategies

97. Corporate strategies are not easily classified by means of a survey. Firms can be asked how they perceive the development of their markets and the importance of various strategic choices in connection with the development of products and markets. The mix of strategic choices is likely to vary from industry to industry. Because the particular pattern is of policy significance, every effort should be made to obtain data classified by type of strategy.

b) The role of diffusion

98. The importance of the diffusion of new developments throughout an economy should not be

overlooked. An innovation may have little effect unless it is widely applied beyond its place of origin (first in the world) in other countries industries and even firms in the same industry.

99. 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 activity". How do firms incorporate innovations that have been developed elsewhere? Also, what is the weight of diffusion in relation to innovation?

c) Sources of information for innovation and obstacles to innovation

103. The general objective here should be to relate the technological assets and strategies of firms to the scope of their sources of information for innovation and to the obstacles which they perceive. Most firms have a wide range of potential sources of technical information. Their importance will vary with the firm's technological capabilities and strategy.

104. 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 and on innovation activities. Externally, the focus will be on public research institutions as sources of technical information, and on inter-firm or inter-industry technology flows. 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 unresolved problems with the technology balance of payments.

d) Inputs to innovation

108. 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. For example, it is often argued that firms need to perform R&D in order to recognize and use, and hence adopt, technologies that have been developed elsewhere.

109. Although 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.

e) The role of public policy in industrial innovation

110. Given that publicly funded R&D often accounts for a substantial proportion of total R&D 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.

111. Other areas can also promote innovation performance, or restrict it (education and the supply of skills; taxation policy and accounting regulations; industrial regulation, including environmental regulation, health standards, quality controls, standardization and so on; the legal system of intellectual~ property rights and hence problems of appropriability and the operation of the patent and copyright' systems; the operation of the capital market). These aspects of public policy can be examined via questions on firms' perceptions of obstacles to innovation.

f) Innovation outputs

113. 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 geographically. However, the definition of what constitutes an innovation poses a number of definitional difficulties. Most products, and certainly the processes by which they are made, am complex systems. Change thus has to be defined in terms of:

- the attributes and performance characteristics of the product as a whole, and

- changes in components of the product which improve its efficiency, including 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.

"*What do we want to measure*?": Technological Product and Process - TPP innovations

117. This manual deals with innovation at the level of the firm. When firms innovate, they are engaging in a complex set of activities with multiple outcomes, some of which, moreover, can reshape the boundaries and nature of the firm itself The problem is to decide which of these activities and outcomes should and can be measured.

113.This manual concentrates on two of Schumpeter's categories, new and improved products and processes, with the minimum entry set as "new to the firm" in order to take in the recommendations on diffusion. However, practical experience has shown that not all the changes in products (and to a much lesser extent processes) which firms see as being new or improved match the model of technical change described above. This is not merely a matter of excluding changes which are insignificant, minor or do not involve a significant degree of novelty, but also of deciding how to treat aesthetic changes in products which may have an important effect on their appeal to customers and thus on the performance of the firm concerned. This manual deals only with "technological" innovation which requires an objective improvement in the performance of a product.

119. In undertaking innovation firms must in some way change the stock of tangible and intangible assets which they possess. The intangible assets can be seen in part as capabilities and competencies, which are built up via learning processes. Given that innovation is multifaceted, one key element of innovation is organization, and this is an area which has received considerable attention in recent years. Organization is essentially a process for the gathering, management and use of information, and for the implementation of decisions based on such information. Such processes have a strongly intangible dimension, but taken together they make up the learning capacity of the firm and as such am a central element in innovation capability. These are specific institutional "rules of the game" which regulate possible modes of organization on a broad level, but within such institutional parameters firms can and do exhibit considerable diversity. If we look at firms from an information-theory and learning point of view, it seems clear that "organization" may have very little to do with formal structures.

120. From this standpoint, organization is a critical dimension of innovation, but its measurement is be very difficult both conceptually and in practice. Moreover organizational change is highly firm-specific, making it still more difficult to summarize in aggregate, sector or economy-wide statistics. In consequence, organizational innovation has not been included in the measures recommended in the body of the manual.

"*How should It he measured?*"- choice of the survey approach

122. There are two main approaches to collecting data on innovations:

i) the "subject" approach survey starts from the innovative behavior and activities of the firm as a whole. The idea is to explore the factors influencing the innovative behavior of the firm (strategies, incentives and barriers to innovation) and the scope of various innovation activities, and above all to get some idea of the outputs and effects of innovation. These surveys are designed to be representative of all industry, so the results can be grossed up and comparisons made between industries;

ii) the other survey approach involves the collection of data about specific innovations (usually a 'significant innovation' of some kind, or the main innovation of a firm), the "object" approach. One starts by identifying a list of successful or unsuccessful innovations, often on the basis of experts' evaluations, or of new product announcements in trade journals. The suggested approach is to collect some descriptive, quantitative and qualitative data about the particular innovation at the same time as data is sought about the firm.

123. From the point of view of current economic development, it is the differential success of firms which shapes economic outcomes and which is of policy significance. It is the subject, the firms, which count, and the first approach has been chosen as the basis for these guidelines.

"*Where should it be measured?*": Sectoral coverage

125. Innovation can of course occur in any sector of the economy, including government services such as health or education. Given the focus on the firm, the concepts and definitions that will be presented in this manual are mainly designed to deal with innovations in the business enterprise sector.

128. Nevertheless, the definitions and concepts used in this manual have been adapted, on the basis of experience gained so far, to apply to TPP innovations in manufacturing, construction, utilities and marketed services.

Chapter 3 - Basic Definitions

Technological Product and Process (TPP) Innovation

130. Technological Product and Process (TPP) innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation). TPP innovations involve a series of scientific, technological, organizational, financial and commercial activities. The TPP innovating firm is one that has implemented technologically new or significantly technologically improved products or processes during the period under review.

131. The minimum entry is that the product or process should be new (or significantly improved) to the firm (it does not have to be new to the world). TPP innovations relating to primary and secondary products are included as are process innovations in ancillary activities.

132. TPP innovations can be broken down between product and process, and by the degree of novelty of the change introduced in each case.

Technological product innovation

133. The term "product" is used to cover both goods and services.

134. Technological product innovation can take two broad forms:

- technologically new products;
- technologically improved products.

135. A technologically new product is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such innovations can involve radically new technologies, can be based on combining existing technologies in new uses, or can be derived from the use of new knowledge.

137. A technologically improved product is an existing product whose performance has been significantly enhanced or upgraded. A simple product may be improved (in terms of better 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.

Technological process innovation

140. Technological process innovation is the adoption of technologically new or significantly improved production methods, including methods of product delivery. These methods may involve changes in equipment, or production organization, or a combination of these changes, and may be derived from the use of new knowledge. The methods may be intended to produce or deliver technologically new or improved products, which cannot be produced or delivered using conventional production methods, or essentially to increase the production or delivery efficiency of existing products.

Diffusion of TPP Innovations: Institutional Novelty

142. Worldwide TPP innovation occurs the very first time a new or improved product or process is implemented. Firm-only TPP innovation occurs when a firm implements a new or improved product or process which is technologically novel for the unit concerned but is already implemented in other firms and industries.

150. Innovations may be implemented for both the principal and secondary production activities of a firm.

152. Technological innovation can occur both in the production process and/or products of the firm and in ancillary supporting activities supplied by its purchasing, sales, accounting, computing or maintenance departments. In practice it will be very difficult to identify product innovation in ancillary services.

154. TPP innovation must be distinguished from:

- organizational innovation,
- other changes in products and processes.

Organizational innovation

155.Organizational innovation in the firm includes:

- the introduction of significantly changed organizational structures
- the implementation of advanced management techniques,
- the implementation of new or substantially changed corporate strategic orientations.

157. Whereas the complete reorganization of a firm is "organizational innovation-, the re-organization of its production facility can be considered as TPP innovation. The introduction of just-in-time systems, for example, should be treated as process innovation as it has a direct effect on the production of products for the market.

158.In service industries, technological process innovation includes improved capabilities embodied in organizations and routines as long as these have resulted in a measurable change in output.

Other changes in products and processes

159. These are changes which:

- are insignificant, minor, or which do not involve a sufficient degree of novelty;
- make "other creative improvements" where the novelty does not concern the use or objective performance characteristics of the products or in the way they are produced or delivered but rather their aesthetic or other subjective qualities.

160. Many borderline cases will clearly occur in both these areas, and the final judgement about the nature of the change rests with respondents and/or persons selecting TPP innovations to include in databases.

Excluded changes

(a) Ceasing to use a process or to market a product

161.Stopping doing something is not a TPP innovation, although it may improve a firm's performance.

(b) Simple capital replacement or extension

162. The purchase of more machines of a model already installed, even if extremely sophisticated, is not a technological process innovation. A new model is defined as one with

clearly improved specifications, not merely one with a new number or title in the manufacturer's catalogue

(c) Changes resulting purely from changes in factor prices

164. TPP innovation requires a change in the nature (or use) of the product or process. A change in price of a product or of the productivity of a process resulting exclusively from changes in the price of factors of production is not an innovation.

(d) Custom production

166. Firms engaged in custom production, making single and often complex items to a customer's order, have to analyze every product to see whether it fits the definitions of TPP set out above. Unless the one-off item displays significantly different attributes to products that the firm has previously made, it is not to be regarded as a technological product innovation.

(e) Seasonal and other cyclical changes

168. In certain industries such as clothing and footwear there are seasonal changes in the type of goods or services provided which may be accompanied by fashion changes in the products concerned. Typically a given type of product will reappear after a period of absence. This should not be treated as innovation unless the returning product has been technologically improved.

(f) Product differentiation

169. Product differentiation is the introduction of minor technical (or aesthetic) modifications in order to reach a new segment of the market, to increase apparent product range or to reposition a product in relation to a competing one. It can only be considered technologically improved product innovation if changes significantly affect the performance or properties of the product concerned or the use of materials or components therein.

(g) Other creative product improvements

172. Technological innovation requires an objective improvement in the performance of a product or in the way in which it is delivered. In the case of many goods and services sold directly to consumers or households, the firm may make improvements in its products which make them more attractive to the purchasers without changing their "technological" characteristics. These improvements may have a considerable effect on the firm's sales, and it may well view them as innovations. They are not, however, TPP innovations.

TPP Innovation Activities

176. TPP innovation activities are all those scientific, technological, organizational, financial and commercial steps, including investment in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products or processes. Some may be innovative in their own right, others are not novel but are necessary for implementation.

179. Innovation activities may be carried out within the firm or may involve the acquisition of goods, services or knowledge from outside sources, including consulting services. Thus a firm may acquire external technology in disembodied or embodied form.

180. The list of activities below is not exhaustive. Its aim is to explain when certain activities should be included in TPP innovation.

Acquisition and generation of relevant knowledge to the firm

(a) Research and experimental development

181. Research and experimental development (R&D) comprises 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 Frescoed Manual).

182. Construction and testing of a prototype is often the most important phase of experimental development. A prototype is an original model (or test situation) which includes all the technical characteristics and performances of the new product or process. 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 Frescoed Manual).

183. Software development is classified as R&D as long as it involves making a scientific or technological advance and /or resolving scientific and technological uncertainty on a systematic basis.

(b) Acquisition of disembodied technology and know-how

194. Acquisition of external technology in the form of patents, non-patented inventions, licences, disclosures of know-how trademarks, designs, patterns and computer and other scientific and technical services related to the implementation of TPP innovations, plus the acquisition of packaged software that is not classified elsewhere.

(c) Acquisition of embodied technology

135. Acquisition of machinery and equipment with improved technological performance (including integrated software) connected to technological product or process innovations implemented by the firm.

Preparation for production

(a) Tooling up and industrial engineering

186. Changes in production and quality control procedures, methods and standards and associated software required to produce the technologically new or improved product or to use the technologically new or improved process.

(b) Industrial design

187. Plans and drawings aimed at defining procedures, technical specifications and operational features necessary to the production of technologically new products and the implementation of new processes.

Capital acquisition

188. Acquisition of buildings, or of machinery, tools and equipment - with no improvement in technological performance - which are required for the implementation of technologically new or improved products or processes.

Production start-up

189. This may include product or process modifications, retraining personnel in the new techniques or in the use of the new machinery, and any trial production not already included in R&D.

Marketing for new or improved products

190. Activities in connection with the launching of a technologically new or improved product. These may include preliminary market research, market tests and launch advertising, but will exclude the building of distribution networks to market innovations.

Borderline cases
191. Of all the above types of work, only R&D and the acquisition of machinery incorporating new technology are by definition TPP innovation activities. The others may or may not be depending on the reasons for which they are carried out.

Design

192. Industrial design is an essential part of the TPP innovation process. Though it is listed above in the same subsection as tooling up, industrial engineering and production start-up, it may also be a part of the initial conception of the product or process, i.e. included in research and experimental development, or be required for marketing technologically new or improved products.

193. Artistic design activities are TPP innovation activities if undertaken on a technologically new or improved product or process. They are not if undertaken for other creative product improvement, for example purely to improve the appearance of the product without any objective change in its performance.

Training

194. Training is a TPP innovation activity when it is required for the implementation of a technologically new or improved product or process, for example in order for production workers to be able to identify the desired consistency of a new type of yoghurt in a food factory, for a marketing manager to understand the characteristics of the improved braking system on a new model of car in order o prepare the market launch.

195. Training in a firm is not a TPP innovation activity when it is undertaken solely in connection with "organizational innovation" or " other creative product improvement", or when it is not oriented towards a specific improvement in productivity at the level of the firm. For example, the following are not TPP innovation activities: training in existing production methods for new employees, general upgrading training for individuals (supervisors, managers etc.), ongoing computer training, language classes.

Marketing

196. Marketing is a TPP innovation activity when it is required for the implementation of a technologically new or improved product (or, more infrequently, a new process). It is not a TPP innovation activity when it is undertaken for purely organizational innovation, for example a campaign to promote a firm's new structure and corporate image, or as part of other creative product improvement, for example publicity for the spring range of clothing, or to maintain market share for products which are essentially unchanged, for example soap powder.

Software

197. The development, acquisition, adaptation and use of software pervade TPP innovation activities. On the one hand, developing new or substantially improved software, either as a commercial product or for use as an in-house process (TPP innovation in its own right), involves research and experimental development and a range of post-R&D innovation activities. On the other, many of the innovation activities for other TPP innovations involve the use of software as a process and hence its acquisition and adaptation.

The TPP Innovating Firm

199.The TPP innovating firm is one that has implemented technologically new or significantly improved products or processes or combinations of products and processes during the period under review. It is a firm with successful TPP innovation activities during the period.

199. A firm, which has had aborted TPP innovation activities is not included, nor is one which, at the end of the period under review has ongoing TPP innovation work in progress which has not yet resulted in implementation.

(For Chapter 4 - Survey Methods - See Annex 1)

Chapter 5 - Measuring Aspects of the Innovation Process

217. The innovation process has its starting point in the objectives of the firm, and is assisted or hampered by a range of factors. The types of innovations that emerge from the process can be described in different ways. Perhaps the most important indicators (and the most difficult and controversial ones) describe the influence of innovation on the performance of the firm. Further indicators describe diffusion of innovation and other related themes such as R&D, patenting, and the acquisition/diffusion of technology.

218.The indicators may be binary yes/no data. the factor is important/not important. Alternatively, they may rank factors on an ordinal scale (Liekert scale) : first ascertaining whether a factor is relevant or not (0 = not relevant), then running from 1 (not important) to 5 (very important), or from I (not important) to 3 (important).

Objectives of Innovation

220. It is recommended that a firm's reasons for engaging in innovation activity should be identified via its economic objectives in terms of products and markets, and how it rates a number of goals that process innovation can bring within reach. The question should relate to all

of its innovation activities. Several objectives will usually be relevant.

Economic objectives of innovation

- replace products being phased out;
- extend product range:
    - within main product field,
    - outside main product field;
- develop environment-friendly products;
- maintain market share;
- increase market share
- open up new markets:
    - abroad;
    - new domestic target groups;
- improve production flexibility;
- lower production costs by:
    - reducing unit labour costs;
        - cutting the consumption of materials;
        - cutting energy consumption;
        - reducing the reject rate;
        - reducing product design costs;
        - reducing production lead times;
- improve product quality;
- improve working conditions;
- reduce environmental damage.

Factors Assisting Innovation

223. The list shows sources which have been found relevant in a number of surveys.

Internal sources within the firm or business group:

- in-house R&D;
- marketing;
- production;
- other internal sources;

External market/commercial sources:

- competitors;
- acquisition of embodied technology;
- acquisition of disembodied technology;
- clients or customers;
- consultancy firms;
- suppliers of equipment, materials, components and software;

Educational/research institutions:

- higher education institutions;
- government research institutes;
- private research institutes;

Generally available information:

- patent disclosures;
- professional conferences, meetings and journals;
- fairs and exhibitions.

Factors Hampering Innovation

225. The list below shows obstacles or barriers to innovation that have been found relevant in a number of surveys. They may be reasons for not starting innovation activities at all, or reasons for innovation activities not leading to the expected results.

Economic factors:

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

Enterprise factors:

- innovation potential (R&D, design etc.) insufficient;
- 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;
- lack of opportunities for co-operation;

Other reasons:

- lack of technological opportunity;
- lack of infrastructure;
- no need to innovate due to earlier innovations;
- weakness of property rights;
- legislation, norms, regulations, standards, taxation;
- lack of customer responsiveness to new products and processes.

Identification of the TPP Innovating Firm

227. The simplest indicator relates to the population of innovating firms. It is obtained by counting the number of firms with successful TPP innovation activities during the last three years; they comprise firms which were in existence at the beginning of the period and which have implemented TPP innovations during the period which are new (or improved) for the said

firm, and firms which have come into existence during the period and which at their foundation implemented TPP innovations which are new (or improved) for the operating market of the said firm, or which, after their foundation, implemented TPP innovations which are new (or improved) for the firm.

230. A filter question on the results of innovation activities should be asked to discriminate between innovators and non-innovators, and information on structural changes in the enterprise within the reference period (notably the date of such changes) should also be collected.

The Impact of Innovations of the Performance of the Firm

231. Various indicators can be used to measure the impact of innovations on the performance of the firm. These indicators are:

- the proportion of sales due to technologically new products;
- the results of innovation effort;
- the impact of innovation on the use of factors of production.

Proportion of sales due to technologically new products

232. A question about the share of sales and exports due to technologically innovative products put on the market within the last three years has been included in most of the innovation surveys carried out to date. Experience with this question has been encouraging, in spite of some problems of interpretation.

233.When constructing this indicator, firms established during the reference period must be treated separately, as new products will by definition account for all their sales. For these firms, only products new to their operating market should be included. Firms which have come into existence as the result of mergers, demergers and other kinds of reorganization should not be treated as newly established firms if similar activities were carried on previously.

234. It is recommended that this question should be put as:

Percentage share of sales due to:

- technologically new products commercialized during the last three years;
- technologically-improved products commercialized during the last three years;
- products that are technologically unchanged, or subject only to product differentiation, produced with changed production methods during the last three years;
- products that are technologically unchanged, or subject only to product differentiation, produced with unchanged production methods during the last three years.

235. The sales due to technologically new products and technologically improved products may be further broken down by:

- sales due to products that are new or technologically improved for the operating market of the firm;
- sales due to products that are new or technologically improved only for the firm.

236. For preference, respondents should supply their best estimates of the actual percentages.

When presenting the results by industry, size of firm and so on, the percentages should be weighted by sales.

Impact of TPP innovation on the use of factors of production

243. 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.

244. It is suggested that a question could be included on how TPP Innovations have influenced the use of factors of production, i.e. manpower use, material consumption, energy consumption and utilization of fixed capital.

Special questions on R&D

258.It is recommended that information should be requested on R&D expenditure and R&D personnel, if applicable, except if the information is available from another related R&D surveys or sources. The question on R&D expenditure overlaps with the question on innovation expenditure, which might cause a problem. In addition, it is suggested that the question should ask whether the R&D activity is performed on a continuous or an occasional basis. Distribution of R&D expenditure into product and process oriented R&D could also be requested.

259.An important question deals with R&D co-operation with other firms, institutes and universities, both inside the country concerned and with other countries.

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

Questions on patents and the appropriability of innovations

261. Patent data, whether applications or grants, are not indicators of innovation outputs; they are indicators of inventions, not necessarily leading to innovations.

262. It is suggested that firms should be asked to evaluate the effectiveness of various methods for maintaining and increasing competitiveness of innovations introduced during the last three years. The methods could be:

- patents;
- registration of design;
- secrecy
- complexity of product design
- having a lead time advantage over competitors.

Questions on the acquisition/diffusion of technology

267. In order to obtain some picture 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 inventions, licences, know-how, trade marks, services with a

technological content, use of consultancy services, acquisition/transfer of technology through the purchase/sale of an enterprise, through the purchase/sale of equipment, mobility of skilled personnel, etc.).

Chapter 6 - Breakdown by source of funds

318. It is important to know how TPP innovation expenditure is financed, for instance in order to evaluate the role of public policy and internationalization in the innovation process. The following classification by source of firms is suggested:

Sources of funds:

- own funds,
- funds from related companies (subsidiary or associated companies),
- funds from other business enterprises,
- funds from government (loans, grants, etc.),
- funding from supranational and international organizations;
- other sources (specify).

319. It is enough, for a variety of policy and research issues, to collect information on whether or not each source is used, instead of seeking an estimate, probably imprecise, of the amount (either in monetary or percentage terms) contributed by each source. This will considerably reduce the response burden on firms, and hence increase the total response rate to the survey as well as cutting the non-response to this question.

Annex 1

Chapters 4 & 7 - Survey Procedures

Institutional Classifications

202. The institutional approach focuses on the characteristic properties of the innovative firm, and all characteristics of innovation activities, and their inputs and outputs, arc classified to one class or subclass according to the unit's principal activity.

203. A clear distinction has to be made between the reporting and the statistical units. The reporting unit is the entity from which the recommended items of data are collected. They may vary from sector to sector and from. country to country, depending on institutional structures, the legal status of data collection, tradition, national priorities and survey resources. It is therefore almost impossible to make international recommendations about the reporting unit for innovation surveys. However, whenever countries provide statistics for international comparisons, the reporting units should be specified.

204.The statistical unit is the entity for which the required data is compiled. It may be observable units on which information is received and statistics are compiled, or analytical units which statisticians create by splitting or combining observable units with the help of estimations or imputations in order to supply more detailed and/or homogeneous data than would otherwise be possible.

Classification by Main Economic Activity

209. Statistical units of innovation surveys can be broken down by quite different variables. Perhaps the most important variable is the principal economic activity of the statistical unit ("industry"). The International Standard Industrial Classification (1SIC Rev.3) is an appropriate international classification for this purpose

Classification by Size

212. The other essential classification of statistical units for innovation surveys is by size. Though different variables can be used to define the size of a statistical unit in innovation surveys, it is recommended that size should be measured on the basis of the number of employees

324.In reality, for various theoretical and practical reasons, a survey will not cover all possible units. The concept of innovation is still unclear in some parts of an economy, especially with respect to non-market oriented activities. It is therefore recommended that innovation surveys should primarily refer to innovation activities in market-oriented industries. These should include manufacturing industries as well as market-oriented service industries. As long as knowledge about innovation activities in service industries remains fairly limited, at this early stage of the methodology's development a concentration on technology-intensive service industries is preferable.

325. Innovative activities take place in small and medium-sized units as well as large ones. In theory, innovation surveys should therefore include units of all sizes. [For practical reasons, however, only units with at least one employee working in an S&T capacity should be surveyed.]

326. [All units with at least one employee working in an S&T capacity form the target population

of innovation surveys.] The target population includes innovators and non-innovators, R&D performers and non-R&D performers.

327.In practice it is almost impossible to identify and approach all units in the target population, regardless of the type of survey. For example, the frame underlying the survey, (such as a business register) may include units which no longer exist or units which no longer belong to the target population. At the same time, it may not contain units which in fact belong to the target population.

Survey Methods

Census or sample survey

329.Innovation data may be collected through census or sample surveys. Resource limitations and response burden will in most cases rule out a survey of the entire population (census). If sample surveys are designed, the units should be selected on the basis of a random procedure (random sample surveys). Sample surveys should be representative of the basic characteristics of the target population, such as industry or size.

Mandatory or voluntary survey

331.Innovation surveys may be mandatory, or voluntary. If they are voluntary, higher non-response rates have to be expected. Low response rates may lead to very low numbers of replies which cannot be used for further analysis. This effect could be compensated to some extent, in the case of sample surveys, by higher sampling fractions. But, increasing the sampling fractions does not solve the basic problem of bias due to high non-response rate.

332. To follow the development of the innovation process over time, panel (sample) surveys offer special opportunities. Notably they will allow analysts to look at links between different variables over time. Panel surveys require special care in selecting the units and in the treatment of refusing, dying and newly created units.

Survey methods and suitable respondents

335.Various methods techniques can be used for the collection of information, including postal surveys and personal interviews. Once innovation surveys are well established, automated data exchange between reporting units and the surveying institute may be possible as well.

336. These methods each have different strengths and weaknesses. Postal surveys are well established and comparatively less expensive, but present problems as well. Experience has shown that questionnaires for postal surveys have to be extremely well designed in order to get sufficient response rates and the surveying agency should encourage phoning from respondents for clarification and assistance. Several reminders are usually necessary to increase response rates to an acceptable level. Another difficulty is that reminders may generate different answers from different respondents in the same firm. Additional action can be taken to increase response rates further sending a cover letter from the minister, sending basic results of previous innovation surveys (if any), or a promise to send respondents the main findings from the current survey.

337. Most of the problems with postal surveys can be avoided when data is collected by personal interview. The quality of the results should be far higher. Item and unit non-response rates should be much lower, so that a far smaller number of units need to be approached to achieve the same quality. Despite these obvious advantages, this method is not recommended for general use as the cost is still fairly high and in most cases too high.

338. Combining the advantages of postal and interview methods and avoiding their weaknesses could be the best solution. Computer Assisted Telephone Interview (CATI) techniques take this course, where individual questionnaires are designed for each unit, based on information gained through personal contact (e.g. on the telephone) with the most suitable respondent there. The unit-specific questionnaires are then sent by mail.

339. Choosing the most suitable respondent in the units is particularly important in innovation surveys, as the questions are highly specialized and can be answered by only a few people in the unit, usually not the ones who complete other statistical questionnaires. In small units, managing directors will often be good respondents. Directors responsible for technology may well be the best people to answer the questions in larger units. Several people will often be involved, but one must be responsible for coordinating the replies. A special effort to identify respondents, before data collection starts, is highly recommended. It will contribute greatly to a survey's success, but may prove difficult in practice. It is important that the partner in the unit has the power to decide on participation in the survey (if voluntary) and to collect the necessary data for the unit.

The questionnaire

340.All data collection techniques are based at least to some extent on a questionnaire. Some basic rules should be followed when designing the questionnaire for an innovation survey. Special attention is necessary in the case of postal surveys. Each questionnaire should be tested before it is used in the field (pre-test).

341. The questionnaire should be as simple and short as possible, logically structured, and have clear definitions and instructions. Generally, the longer the questionnaire, the lower the unit and item response rates. This effect can be minimized by devoting special attention to the design and layout and by giving clear and sufficient explanatory notes and examples. It is particularly important to design the questionnaire in such a way that units with no formal innovation activities will nonetheless reply.

342. Respondents' understanding of the questionnaire may well increase as they move from question to question. This means that their answers may depend on the order of the questions. Adding or deleting a category may influence answers.

343.All questions in a questionnaire should be checked to see whether a "not applicable" category is needed to distinguish this answer from item non-response.

Innovation and R&D surveys

346. As R&D and innovation are related phenomena, countries may think of combining R&D and innovation surveys. There are a number of points for and against:

- first, with a combined survey, the overall response burden of the reporting units would go down (a single questionnaire, instead of two separate surveys asking partly the same questions). But the individual burden may not necessarily be reduced. With two surveys the burden may be better distributed across the units. In addition, combination may reduce the response rate, as the questionnaire will be longer than in either of the surveys separately;
- second, a combined survey offers scope for analyzing the relations between R&D and innovation activities at unit level. There is less scope for this with separate surveys, especially when they are carried out by different institutions;

- third, units which are not very familiar with the concepts of R&D and innovation may mix them up in a combined survey. Confusion is less likely with separate surveys;
- fourth, at least in larger units, R&D and innovation questions may be answered by different people, so a combined survey may not be an advantage;
- finally, the frames for the two surveys are different. Combining them would involve sending questions about R&D to a large number of non-R&D performers", who are included in the frame population for the innovation survey, and this would increase the cost of the joint survey.

Sample Surveys

348. In almost all cases, innovation surveys are random sample surveys. The relevant literature offers quite different sampling techniques, such as the simple random sample technique, stratification techniques or cluster sample techniques. In the past, stratified sample surveys have proved to lead to reliable results.

349. If stratification techniques are used, some general rules with regard to the selection of the stratification variables should be respected. In principle, stratification of the population should lead to strata which are as homogeneous as possible in terms of the phenomenon under consideration, i.e. strata of units for innovation surveys should consist of units which are as similar as possible as far as their innovation or non-innovation activities are concerned. It is common knowledge nowadays that innovation activities of units in different industries and in different size classes generally differ significantly. It is therefore recommended that the stratification of random sample innovation surveys should be based on the size and principal activity of the units.

350. The size of the units should be measured by the number of employees. Given the different types of units and different national conventions, general recommendations on appropriate size classes are fairly difficult.

352. If regional aspects are of importance, the stratification should also include the regional dimension. An appropriate regional classification should be used.

353. In order to guarantee high accuracy, the sampling fractions for the individual strata should not be the same for all strata. It is generally recommended that the sampling fraction of a stratum should be higher as the number of its units in the survey population is smaller, and as the population in the stratum is more heterogeneous. The sampling fractions should be up to 100 per cent, for example in strata with only few units, as may be the case in strata consisting of large units in certain industries (or certain regions). Another factor which should be taken into account when fixing the individual sampling fractions is the propensity to respond in the strata. Examples of strata in which the propensity to respond may be relatively low are those consisting of smaller units, as they may not be very familiar with the concept of innovation.

354. The results of sample surveys need to be expanded to obtain information on the survey population. There arc various methods for expanding sampling results. The easiest one is the free expansion technique, where the individual results are weighted by the inverse of the sampling fractions of thee sampling units (raising factors). If a stratified sampling technique is used the free expansion technique should be performed individually for all strata, especially where sampling fractions differ between strata. The raising factors may be modified in the event of unit non-response above a certain threshold.

355. Expansion techniques have to be applied to both quantitative and qualitative variables, but in different ways. In the case of quantitative variables the observed values can be directly; in the case of qualitative variables the frequencies must be raised.

Estimation of Results - The Non-Response Problem

356. In practice the responses to innovation surveys are always incomplete, irrespective of the survey method used. Two types of missing values can be distinguished: item and unit non-responses. Unit non-response means that a reporting unit does not reply at all. Possible reasons are, for example, that the surveying institute cannot reach the reporting unit or that the reporting unit refuses to answer. In contrast, item non-response is the case when a unit does answer but at least one question is left blank. Even the extreme case where all but one of the questions are left blank may be considered item non-response.

357. Item and unit non-responses would be less a problem if the missing values were randomly distributed over all sampling units and all questions. In reality, however, both types of missing values are biased with respect to certain characteristics of the population and the questionnaire. Experience with the Community Innovation Survey showed that unit non-responses were concentrated, for instance, in some situations ("we are faced with serious economic problems and have no time to fill in your questionnaire") or in some industries ("innovation is an unknown concept in our branch"). Item non-response is more likely when the question is (or seems to be) more difficult. A prominent example of item non-response in the Community Innovation Survey was the question on the innovation costs.

358. Item and unit non-responses clearly affect the comparability of the results of national and international innovation surveys. Appropriate methods have to be developed and used to overcome this problem. As different methods may lead to different results, some general recommendations should be followed. Otherwise, differences in innovation results over time and/or between countries may be caused by using different concepts to reduce the bias of item and unit non-responses.

359. For practical as well as theoretical reasons, one recommended way to overcome the problem of item non-response is a group of methods called "imputation methods". Basically, imputation methods seek to estimate missing values on the basis of additional information. This information may come from the same survey, previous surveys or some other related source. A special group of imputation techniques, the hotdecking methods, were used to clean the national results from the Community Innovation Survey. The idea here is to estimate the missing values on the basis of available information in the same survey. Hotdecking methods themselves contain a large variety of methods, like replacing the missing values for each variable by the mean of the strata, and using regression techniques or nearest neighbour techniques where the missing values are replaced by the values of the unit which is most similar with respect to other (relevant) variables. The decision upon the most appropriate hotdecking method should also be based on the type of variable (quantitative versus qualitative variables).

360. Which method to use to overcome the problem of unit non-response will depend on the level of non-response. If the non-response rate is fairly low, the raising factors should be directly adjusted. In the case of free expansion, the raising factors should not be calculated on the basis of the units selected for the survey but on the basis of the units which replied. This procedure is based on the assumption that the innovative behavior of responding and non-responding units is identical. This assumption could be tested through non-response analysis. Even if the assumption is wrong, the bias introduced can be disregarded as long as the fraction of

non-responding units is fairly small.

361.In contrast, if the unit non-response rate is very high, no method can be recommended to solve the problem. In such a case the results of the innovation survey can only be used for descriptive purposes. No further conclusions should be drawn, even about the target population in general, as the bias will be too high.

362. In all other cases, i.e. when the unit non-response rate is beyond a lower threshold but less than an upper threshold, some more complicated and partly more expensive techniques are recommended. One solution would be to select reporting units which have answered randomly until the response rate is 100 per cent, i.e. to use the results of randomly selected units twice or even more often. Other methods are based on the results of non-response analysis. the objective of non-response analysis is to obtain information on why reporting units did not answer. In this non-response survey, non-reporting units should be contacted by phone or by mail (using very a simple questionnaire not exceeding one page) and should be asked for some general information like ISIC/NACE code or size if not already available from other sources such as business registers, for the reason they did not answer, and for answers to a few key points in the original survey to see whether the results are biased. This information can then be used to adjust the expansion factors. The results of non-response analysis should only be used if the response rate in the non-response survey exceeds 80 per cent.