

Chapter 6

Measuring R&D: Methodologies and procedures

This chapter discusses how to measure research and experimental development (R&D) activity, noting that is highly concentrated, specially in the Business enterprise sector, but it is also widely spread across the economy. These characteristics give rise to measurement challenges as do the disparate uses of R&D statistics. These include the use of aggregate statistics for policy analysis, policy evaluation and target setting, the use of R&D expenditures as input to a capital stock of R&D in the System of National Accounts (SNA), and unit level analysis of R&D activity. Measurement, whether through surveys, the use of administrative data, or combinations of the two, requires a statistical infrastructure including registers of institutions, methodological support, means of linking data sets to enhance analytical capacity, and quality assurance standards. All of these are discussed, but, recognising that countries have quite different infrastructures and measurement challenges no specific formal recommendations are made. Sources are provided to support the development of statistical measurement.

6.1. Introduction

6.1 Many considerations drive the methodology and procedures used to measure R&D performance. R&D activity tends to be concentrated in relatively few entities, particularly in the Business enterprise sector. While R&D activity is highly concentrated, it occurs throughout the economy and the identity of performers changes over time. Both the concentration and breadth of its occurrence have implications for guidelines on sampling strategy. In addition to these characteristics, the objectives of R&D statistical programmes are multidimensional, including: aggregate indicators to support science policy; expenditures providing input to a capital stock of R&D in the System of National Accounts; and micro-level data to support – under restrictions with regard to data protection – unit-level analysis where the units may include business enterprises, government, higher education and private non-profit institutions. These sometimes conflicting objectives influence the sampling and processing strategies.

6.2 The measurement of the performance of R&D is governed by the statistical infrastructure available, including registers of survey units, experienced statisticians, and the extent to which there is legislation that authorises compulsory surveys and enables the linkage of survey data to other data sources to support policy-relevant analysis. This chapter presents methodologies and procedures that draw upon statistical infrastructures and provides guidance on measurement, data quality and the transfer of data to international organisations. This manual does not make recommendations about specific methods for surveys or data analysis, as the variety of national circumstances is too great to permit the preparation of standard rules of approach to respondents, or of standard questionnaires or sampling techniques.

6.3 Data on R&D may come from a variety of sources, including, but not necessarily limited to, direct measurement through surveys and administrative data sources. Administrative data may include both financial data from revenue agencies as well as other types of administrative sources, such as company records. Use of administrative data is discussed in Section 6.4. In some cases, estimates are required to supplement surveys and administrative data sources. An example of this would be the modelling (or indirect estimation) of R&D expenditures in the Higher education sector. Statistical offices decide on the sources of data used based on their availability, quality, appropriateness and cost. This varies across countries.

6.4 The direct collection of data has a distinct advantage in that the concepts and definitions used can align completely with those contained in this manual.

However it comes at a cost, both directly in terms of data collection, and indirectly through the cost incurred by respondents in completing survey questionnaires.

6.5 For the purpose of this chapter, “R&D surveys” may refer to data collected directly through a statistical survey, through administrative data sources, or through a combination of the two.

6.2. Units

6.6 The target population, for R&D surveys, is the set of institutional units that are R&D performers (or funders). This population can be classified to the institutional sectors that perform or fund R&D. These are the Business enterprise, Government, Higher education and Private non-profit sectors. This manual focuses on collecting data from R&D performers; there is also a need for data on the funding of R&D that addresses the requirements of the System of National Accounts (SNA), as well as a need to distinguish exchange and transfer funding (discussed in Chapter 4). The target population of performers may not be sufficient to support statistics on funders. Similarly, a target population of funders may not support statistics on performers.

6.7 It is recommended that the sampling unit for R&D surveys should be the institutional unit.

Institutional unit

6.8 The institutional unit is a national accounting concept and is defined as “an economic entity that is capable, in its own right, of owning assets, incurring liability, and engaging in economic activities and transactions with other entities” (Chapter 3 and EC et al., 2009: 61, para. 4.2).

Statistical unit

6.9 A statistical unit is an entity about which information is sought and for which statistics are ultimately compiled. A survey frame will be composed of statistical units. The statistical units selected as part of the sample may have a weight (i.e. the inverse of the probability of selection) that will be applied to develop estimates of the population from which the sample is drawn.

6.10 A statistical unit may have a number of attributes. These could include:

- *Frascati Manual* (FM) sector (i.e. Business enterprise, Government, Higher education, Private non-profit)
- SNA sector (i.e. Corporations, General government, NPI)
- a principal (used interchangeably with ‘main’ in this manual) economic activity (the principal economic activity allows the unit to be classified using, for example, the *International Standard Industrial Classification of All Economic Activities, Revision 4* (United Nations, 2008))
- geography
- size (e.g. number of employees, turnover, etc.).

6.11 Various possible types of statistical units are discussed in Chapter 3, including enterprise groups, enterprises and establishments. While this nomenclature is developed for the Business enterprise sector, it can be applied to other institutional sectors.

6.12 In this chapter the preferred term is the “institutional unit”, with “enterprise” being used interchangeably with “institutional unit” only in the Business enterprise sector.

Reporting unit

6.13 In this manual, the reporting unit is the entity from which data are reported. Within a given statistical unit, there may be different units at which level the desired data are available and can be reported. For example, data on the geographic distribution of R&D activity by an enterprise may be available from reporting units at the establishment level. Data on fields of R&D (FORD) for a higher education institution may be available at the level of individual departments. In the case of administrative data, the reporting unit corresponds to the unit that is represented by the individual record. A single collection point may be the conduit for gathering data for multiple reporting units.

Relationship between units

6.14 In general, reporting units will correspond to individual institutional units or groups of them. There are exceptions, particularly in cases where it is easier for respondents to report on a different basis. This may take place for a group of institutional units in the case of international transactions and at the level of individual government ministries and university departments (in the cases where these units do not fulfil all of the conditions of being institutional units).

6.15 Related institutional units may be brought together into a group of institutional units (enterprise group in the Business enterprise sector). This level should be able to produce consolidated income statements and balance sheets for the entire group of institutional units.

6.16 In the case of simple structures, a single legal entity may correspond to a single institutional unit. In more complex structures, there may be many-to-one or many-to-many relationships between legal entities and enterprises.

6.17 How these complex structures are addressed will differ from country to country, and no attempt is made here to prescribe specific approaches.

6.3. Institutional sectors

Business enterprise

6.18 The Business enterprise sector is defined in Chapter 3, Section 3.5. Business performers of R&D have two distinguishing characteristics. First, they may form a rare subset of the total Business enterprise sector population.

Second, they may not perform R&D continuously. This creates challenges in the development and maintenance of survey frames (Chapter 7).

6.19 Some business enterprises may perform R&D occasionally, while others may perform it continuously. It is important that both types of enterprises be included in the survey frame. It is recommended that, at a minimum, all business enterprises likely to be performing R&D either continuously or occasionally be included in R&D survey frames (Chapter 7, Section 7.3).

6.20 The sampling unit for the Business enterprise sector will generally be the institutional unit or enterprise. The desired attributes of the sampling unit include: principal (main) economic activity, size, geography and ownership, and control. The reporting unit will be dependent on the entity that is best able to report. This may involve combinations of enterprises or establishments (Chapter 3, Box 3.1).

6.21 The sample may be drawn from a co-ordinated frame that contains information on both SNA sectors and Frascati sectors, as discussed in Chapter 3. The use of such a frame assists in ensuring that the SNA sectoring of R&D units is done on a consistent basis while also allowing units to be selected from Frascati sectors. In the Business enterprise sector, an example would be a university providing formal education programmes that sold its output at an economically significant price. It would be classified to the Higher education sector for Frascati purposes, and the corporations sector for SNA purposes. If linked to a business register, it would also assist in the integration of R&D survey data with other types of data to support micro-level analysis.

6.22 There are different ways of developing a frame of business units. Where current and historical information or administrative data are available, R&D performing and funding units should be identified on the survey frame. If these indicators are not available, alternate means of identifying these units could be the first stage of a two-stage sample design for R&D surveys. Another method of assessing the coverage is to conduct a pre-contact on units that are likely to be performing or funding R&D (i.e. targeted industries). More information for countries starting R&D surveys is found in UNESCO-UIS (2014).

6.23 Other sources of data could be used to improve survey coverage. These external sources should be assessed to ensure that they are of an adequate level of quality to determine if they could be used to supplement the survey frame. If so, they should be used to flag business enterprises that are performing or funding R&D.

6.24 It is recommended to:

- include in R&D surveys of the Business enterprise sector all firms known or very likely to perform (or fund) R&D
- identify R&D performers not known / uncertain to perform R&D by surveying a sample of all other firms.

6.25 The survey frame should include all business enterprises performing (or funding) R&D. There may be budget or respondent burden constraints on sampling and stratification that should be documented as part of data quality reporting.

Government

6.26 The Government sector is defined in Chapter 3, Section 3.5.

6.27 While this manual's recommended statistical unit is the enterprise equivalent, in this case the Government sector, for practical purposes, the sampling unit will generally be the department, ministry or agency, even if the unit does not have all of the characteristics of an institutional unit (i.e. the ability to hold and control assets). This choice of sampling unit does not mean that financial flows between government departments are extramural (see Glossary and Chapter 4, Section 4.3 on identifying fund flows between sectors). The desired attributes of the sampling unit for the Government sector include: principal (main) economic activity, geographic location and level of government. The reporting unit will be dependent on the entity that is best able to report. This may include the whole of government in the case of sub-national or municipal governments.

6.28 There may be several ways of updating lists of R&D performing and funding units such as legislation, budget and related funding actions, as well as registers, directories of R&D performing units, research associations, bibliometric sources, and requests for updates from administrative bodies.

6.29 If available, the survey frame could be linked to a central business register. This would assist in the integration of data from various sources. It would also reduce the risk of double counting.

6.30 Particular attention should be paid to the use of administrative data in the identification of R&D performing and funding institutions.

6.31 It is especially difficult to identify R&D activities at the local (municipal) government level owing to the large number of units, the small number of likely R&D performers and the difficulties in the interpretation of the concept of R&D. Lists of R&D performers usually do not include these units. If local governments undertake a significant amount of R&D activity, then consideration could be given to including R&D performers in large local governments. Given the nature of many sub-national forms of government, it may not be core to the government department or agency mission to conduct R&D, but to address a specific problem as identified by the legislature or the department. Therefore, some R&D activities may be occasional. A more detailed discussion of the Government sector is found in Chapter 8.

Higher education

6.32 The Higher education sector is defined in Chapter 3, Section 3.5. The surveys and estimation procedures should cover all universities, colleges

of technology and other institutions providing formal tertiary education programmes, whatever their source of finance or legal status, and research institutes, centres, experimental stations and clinics that have their R&D activities under the direct control of, or are administered by, tertiary education institutions.

6.33 This sector does not have a direct counterpart in the SNA group of institutional sectors. There is guidance on the cross-classification of the Higher education sector with SNA sectors in Table 3.1 in Chapter 3. Higher education sector institutions are found in all SNA sectors and are treated separately because of the high degree of policy relevance of R&D performed within this group of institutions.

6.34 The sampling unit for the Higher education sector is the higher education institution (corresponds to the institutional unit). The desired attributes include geographic location and economic sector. The reporting unit may be individual faculties or departments. It will be the level in the institution that is best able to report expenditures and funding flows. Attention should be paid to hospitals that perform R&D and may be part of the Higher education sector.

6.35 Surveys of the Business enterprise, Higher education, Government and Private non-profit sectors should ensure that research hospitals are included in the survey frame and that they are correctly assigned to a sector (Chapter 3).

6.36 In some jurisdictions, there may need to be a distinction between the research hospitals that conduct R&D and the charitable foundations associated with these hospitals that fund R&D. Where university hospitals are financially integrated with higher education institutions, they may be treated together as a single sampling unit. If they are separate units with separate accounts and administrations, they may be treated as two separate sampling units.

6.37 Care should be taken to ensure coherent treatment of R&D units under joint management by two or more entities, by persons receiving salaries from different entities, and by persons employed by other institutions. This applies to units in all sectors, but it is more of an issue with R&D units in hospitals.

6.38 Chapter 9 provides more guidance on measuring R&D activity in the Higher education sector.

Private non-profit

6.39 The sector is defined in Chapter 3, Section 3.5. The additional sources for identifying possible survey respondents are mainly the same as for the Government sector. Frame information may be less comprehensive and could be completed by information from tax authorities, researchers or research administrations. This sector may be more relevant for gathering data on R&D funding.

6.40 In general, the sampling unit for the Private non-profit sector will be the institutional unit. The desired attributes of the sampling unit are: principal (main) economic activity, size, geographic location and control. The reporting

unit will be dependent on the entity that is best able to report. This may include combinations of units. Chapter 10 provides more guidance on measuring R&D activity in the Private non-profit sector.

6.4. Survey design

Sampling plan

6.41 Compared to other activities, R&D activity is a rare event and relatively concentrated in a small number of institutional units. For these populations where large units account for a significant proportion of the overall estimate, a separate sampling stratum should be created. This is sometimes referred to as a “take all” stratum, where these large units are sampled with certainty. Such units will have sampling weights of one. Smaller units may be selected with a probability of selection smaller than one. The sampling plan in this section is not prescriptive, as the Business enterprise and Private non-profit sectors are quite different from the Government sector or the Higher education sector. The survey design and the sampling plan must take account of the national context and practices.

6.42 To stratify the sample, it is important to choose the size variable that best represents the population. The previous year’s data, or some other proxy for R&D, may be preferable to other size variables (e.g. turnover, overall budget appropriation or persons employed) if there is little correlation between these variables and R&D expenditures or funding. For units that are continuous performers of R&D, the previous year’s data are preferable.

6.43 In determining the optimal sample size for stratified samples, it is important to account for the desired level of precision in the estimates. The sample size should also be adjusted to reflect the expected non-response rate, the expected rates of misclassification of units, and other deficiencies in the survey frame used for sampling.

6.44 A stratified sample may contain “take all” and “must take” strata where units are selected with a probability of 100%. Units selected with certainty are expected to be the most important R&D performers or funders. A “must take” stratum is used for complex respondents that may have more than one industry classification, location or jurisdiction. A stratified sample may also contain a “take-some” stratum with a probability of less than one. A probability sample is preferred for these strata, as it allows for the calculation of sample error, as a quality measure, and helps to reduce the risk of bias.

6.45 If sufficient auxiliary data exist to identify a unit in an existing register as an R&D performer, then a frame can be constructed by identifying those known performers. If auxiliary information is not sufficient or is lacking, it may be necessary to use a two-phase sample design. In this case, a large sample is selected in the first phase to identify statistical entities that are involved in R&D, then a sub-sample is selected from the first phase sample.

6.46 Given the sectoral breakdown of R&D activity, it is possible that multiple frames are used. In this case, it is important that the frame membership for each unit is managed. If combining multiple frames, institutional units should be included only once in the combined frame. If R&D institutional units could be flagged on a centralised business register, it may reduce the possibility of the duplication and possible double counting of R&D activity.

Design of data collection methodology

6.47 Direct data collection can occur by various modes, including by a paper questionnaire, by telephone, or by web-based collection, provided there are sufficient security measures in place to protect sensitive data, or by interview in countries where computers, telephones and postal services are not widely available. Data may also be collected from administrative sources.

6.48 In the case of direct data collection, consideration should be given to the cost and the response burden associated with the survey.

6.49 Regardless of the mode used, the survey questionnaire should include the minimum number of core questions to provide the required data on R&D. The questionnaire should be as short as possible (without sacrificing the collection of needed core data), logically structured and clear, and should make reference to definitions and instructions. Consideration should be given to the use of electronic questionnaires that can embed this information in the questions. Electronic questionnaires may contain edits that will help the respondent to report complete and coherent data. Data editing is a means to detect and correct reporting errors (logical inconsistencies) in the data. For example, the insertion of a letter into a numeric field should be identified by an editing process, and the questionnaire is then said to have “failed the edit”.

6.50 The data collection methodology should consider the person filling out the questionnaire. The respondent can be the R&D manager or, more likely, is in the accounting or finance unit of the R&D unit. Each has its advantages and disadvantages. The R&D manager can better identify the R&D activity and better understand the concepts contained within this manual. However, the financial officer may be better placed to report detailed financial information. A human resources officer may be best placed to respond to R&D personnel questions, if these are included in R&D surveys. Reporting responsibility may involve all of these areas.

6.51 The collection strategy must therefore consider the possibility that the questionnaire may have to “travel” through an organisation in order to provide a complete response. Nevertheless, it is preferable to identify a single point of contact for the enterprise or institution. If not already known, a pre-collection interview may be required to identify the person best suited to coordinate the completion of the questionnaire. This is especially important in the case of complex institutional units.

6.52 In addition to collecting spending and personnel data for the reporting period that has just ended (t), compilers of R&D statistics are recommended to collect budgeted expenditure data for the following year, the year in which the collection is taking place ($t+1$). Compilers may also collect information on expenditures budgeted for the year following the collection ($t+2$). However, care should be exercised in the interpretation of these budget results, as they represent only the expected behaviour of businesses, and there may be significant revisions between expected and actual data. The recommendation for the collections of budget expenditure data for the year following the year of the data collections, and not data on personnel, is based on experience of unreliable results for personnel. For expenditures, the collection of data on budgeted spending is preferable to estimating expenditures based on past R&D performance, or concurrent measures of economic performance, such as sales.

Administrative data and survey design

6.53 If the concepts, definitions and coverage used by administrative data sources are sufficiently close to those contained in this manual, then the administrative data sources may be used as a primary source of information. If there are discrepancies between the concepts used by the administrative data source and this manual, then the administrative dataset may still be used as an auxiliary source of information to assist in the imputation of missing or inconsistent information. Imputation is a procedure for entering a value for a specific data item where the response is missing or unusable. The uses of administrative data will vary across countries based on their availability and quality.

6.54 The presence of administrative data will also influence the design of the data collection. For example, if there is a register of applicants for R&D tax credits, the resulting administrative data could be used to estimate the R&D performance for performers of small amounts of R&D, reducing the burden on these units. This is not an option for countries without R&D tax programmes.

6.55 There are a number of ways in which administrative data may be used in the compilation of estimates. If the concepts contained within the administrative programme are sufficiently similar to those contained within this manual, then the administrative dataset may be used for direct data replacement. This data replacement could occur both in the case of planned data replacement as well as in the case of a partial or complete non-response by the respondent. Apart from data replacement, administrative data may be used for sampling frame maintenance. These data may also be useful in data validation (i.e. by examining whether or not the survey trends align with the trends found in the administrative data). If there is sufficient correlation between a variable in the administrative dataset and one found in the survey data, then the administrative data may be used as an auxiliary variable in a calibration estimator. A description of various uses can be found in Australian Bureau of Statistics (2005).

6.56 There are a number of considerations that should be made in assessing the utility of administrative data. The coverage of the administrative data should match the population of R&D funders and performers. The timeliness of the administrative data should be considered, including through an assessment of how long the revenue/regulatory authority takes to complete its work on the input data. The definitions and concepts of the administrative data should be the same as those found in this manual. The quality of the administrative data should be compared to the standards and expectations of a survey. If, for instance, there is a high edit failure rate, the quality of the administrative data may be insufficient. If the programme that generates the administrative data is subject to frequent changes, then the relationship between the concepts in the administrative data and the concepts contained in this manual may not be consistent over time. This may limit the usefulness of the administrative data source. The stability of the administrative data source over time is important. There needs to be adequate legal or regulatory authority to access the data for statistical purposes. Finally, the administrative data should be sufficiently documented so as to permit their use.

Questionnaire design considerations

6.57 Questionnaires, either paper or electronic, have a significant impact on respondent behaviour, respondent relations and data quality. Questionnaires should strive to minimise response burden and make it as easy as possible for the respondent to reply. A well-designed questionnaire should help to reduce the amount of edit and imputation performed, thus easing post-collection processing.

6.58 As much as possible, the words and concepts contained in the questionnaires should mean the same thing for survey-taking organisations and respondents. It should not be incumbent on survey respondents to interpret the data requirements of the survey, but rather questions should be posed in such a manner that they are understood well by the respondent, even if post-collection transformation of these variables is required to align them with the concepts contained within this manual. For this reason, it is appropriate to have different questions for businesses and for public sector institutions, if they have different accounting standards and terminology.

6.59 In order to aid respondents, instructions should be short, clear and easy to find. Definitions for the concepts should be made easily available. Inclusions and exclusions should be clearly explained within the survey instruments. Electronic questionnaires should embed a limited amount of consistency and range edits to aid the respondent in accurately completing the questionnaire. Whatever the mode, the wording and the routing options that govern the skipping of questions through the survey questionnaire should be the same.

6.60 In order to ensure that questionnaires are well understood by respondents, it is recommended that they be tested before collection. These tests could include qualitative tests (i.e. focus groups or cognitive testing) or

pilot surveys. In the case of electronic collection, it is important that the final collection application is tested on a variety of users and operating systems to ensure that the content is well understood and that the application is functional. Methods for testing questionnaires can be found in Couper et al. (2004).

6.61 R&D surveys are usually designed as stand-alone collection instruments. If R&D surveys are combined with other collection instruments, care should be taken to ensure that the coverage of the combined instrument remains inclusive and representative of all R&D activity and that there is no reduction in data quality. While there are examples of R&D surveys combined with innovation surveys and there is discussion of combining them with capital expenditure surveys, stand-alone R&D surveys are recommended.

6.5. Collection

6.62 The burden imposed upon the respondent should be minimised. Of particular importance to respondents in the Business enterprise sector is maintaining the confidentiality of data, where R&D expenditures represent important strategic decisions.

6.63 In the process of collecting data, there may be the generation of *paradata* or information related to the survey process. Examples of *paradata* may include whether or not the unit is in the sample; a response follow-up history; and the mode of collection. The use of *paradata* after a survey cycle may assist in improving the survey instrument in future iterations.

6.64 A data collection process should strive to minimise the burden and cost and maximise timeliness, the response rate and accuracy. Web collection is emerging as the preferred mode type. However, it is important that multiple modes of collection be made available, especially in countries where electronic or postal collections are not likely to work. Collection strategies should be flexible enough to allow for a change in the mode of collection (i.e. collection of information by telephone where a respondent has not replied to a request to complete the questionnaire on-line or on paper). If multiple modes are used to collect survey data, a post-collection study on possible mode effect biases might be suggested.

6.65 A pre-contact may be a useful exercise to confirm frame information before collection. This pre-contact may include: contact information on the respondent (including e-mail addresses); an industrial or activity classification of the institutional unit; and confirmation that it is involved in R&D activity.

6.66 For large, complex organisations, consideration should be given to special reporting relationships if this helps respondents to complete the questionnaire. This may include: identification of a single point of contact for collection; customisation of the reporting unit; and modification of the collection instrument to make it easier for respondents to relate their own financial and human resource management systems to the survey questions. It is anticipated that this type of treatment would be focused on institutional units that make significant contributions to the overall estimate.

6.67 Given the complexity involved in the measurement of R&D expenditure, consideration should be given to the development of interviewer manuals and training so as to enable interviewers to answer respondents' questions. Some of these tools may be shared directly with the respondent, particularly in the case of electronic collection. These tools may include: explanatory notes; hypothetical examples and documentation on the treatment of different cases.

6.68 Once data are received, a preliminary set of edits should be conducted, and a follow-up should be performed with respondents where these edits fail. In the case of electronic questionnaires, these edits may be embedded in the questionnaire itself, reducing the need for interviewer follow-up.

6.69 Response rates should be monitored throughout the collection. In situations where the response rates are low, as a quality assurance measure a sub-sample of non-responding units may be contacted after collection to determine whether there is any non-response bias in the estimates (i.e. the respondents are more or less likely to be R&D performers). This information could be collected directly (i.e. a telephone follow-up) or indirectly, through the use of administrative data.

6.70 Also, at the end of the survey process, paradata may be used to assess the effectiveness and cost efficiency of the collection operation. This type of analysis may be used to streamline and improve survey operations.

6.6. Integration of data

6.71 If datasets are integrated (i.e. in the case of firm-level analysis), then it is important that there is a linking key that allows for the datasets to be combined. These linking keys are typically found on a central business register. If this type of activity is undertaken, then the linkage rates between the datasets should be monitored as a quality measure. If the non-linkage rates are unacceptably high, this may indicate the inability to use this linked dataset.

6.7. Editing of collected data and imputation

6.72 The collected data is edited to identify possible errors and either to validate a record or variable or to correct for errors and inconsistencies. It is important that edits do not generate bias in the aggregate estimates. It is possible to over-edit a record if the editing has a negligible impact on the final survey estimate and care should be taken to avoid this in the editing strategy.

6.73 Edits should be automated and reproducible. An automated process allows for increased accuracy and scope. Care must be taken in the development of automated systems not to over-edit the data. In examining and correcting for edit failures, consideration should be given to the use of selective editing where the focus of follow-up is the units that contribute most to the estimate of a particular domain. Edit failure rates should be tracked, as they provide information on how to improve the questionnaire or other aspects of collection. Tracking should include manual edits when they occur.

6.74 Imputation is used to assign valid values for missing or inconsistent data. Imputation typically occurs after collection (including follow-up with respondents) and an initial manual review of questionnaires. Imputation can be used to handle both a complete questionnaire non-response (i.e. unit non-response) as well as non-response for a particular variable (i.e. item non-response). After imputation is completed, the micro-data file should contain only complete and internally consistent data. Imputation processes should be automated, objective and reproducible.

6.75 A number of imputation methods are available to replace missing or inconsistent information. Deterministic imputation methods include:

- logical imputation
- mean imputation
- ratio imputation
- nearest neighbour imputation.

6.76 Other methods are available, and their use will depend on the practice of the institution doing the collection.

6.77 If there is a sufficient relationship between the available administrative data and missing or inconsistent survey data, then the administrative data may be used as a direct replacement.

6.78 Given the variability of R&D as an investment activity, it is preferable to use imputation methodologies that make use of data available from the respondent (either directly or through the use of auxiliary data) over the use of information from other responding units (e.g. nearest neighbour imputation).

6.79 Metadata should be retained to identify the variables and records that have been imputed, as well as the methods used for imputation. Imputation rates are an important indicator of data quality, and domains that have a high weighted imputation rate should be treated with caution. To support this decision, the sampling variance due to imputation is required.

6.8. Estimation

6.80 All units in the sample will have a design weight based upon the units' probability of selection into the sample. The design weight is equal to the inverse of the probability of selection. For a two-stage sample, this is equal to the product of the weights for each stage.

6.81 Design weights may be adjusted to reflect the actual number of units responding. This strategy should be used only if it is believed that non-respondents and respondents share similar characteristics. Methods of estimation are discussed in Lundström and Särndal (2005).

6.82 If there is an administrative dataset available that contains auxiliary data that are highly correlated with a questionnaire variable (e.g. total R&D expenditures), the design weight may be adjusted by calibrating the weights.

In a calibration estimator, the weights are adjusted to achieve known control totals. Specific methods available include: regression and ratio and raking-ratio estimators.

6.83 The use of a calibration estimator may be preferred, as it will allow for increased precision in the estimates. It may also improve the coherence between different data sources.

6.84 The precision of the estimate should be measured through the estimation of the standard error.

6.9. Output validation

6.85 There are a number of steps that should be conducted to validate and certify estimates coming from R&D surveys.

6.86 It is important that the reporting units in the sample remain representative of the population of R&D performers. Checking for the population coverage can be assessed by examining response rates. Using response rates weighted by the value of R&D expenditures can provide feedback on the proportion of the estimate accounted for by actual data.

6.87 In order to assure continuity of the estimates, data from R&D surveys should be compared to previous cycles, and explanations should be available for differences.

6.88 Data should be compared with other comparable data sources. If there are discrepancies, these should be explored, leading to improvements in the estimate or to an explanation of differences.

6.89 The final estimates should be validated against expectations and domain intelligence. Again, discrepancies should be explored, leading to improvements in the estimate or to an explanation of differences.

6.10. Reporting to the OECD and other international organisations

6.90 National authorities carry out R&D surveys to obtain data relevant to national concerns in the framework of national institutional arrangements. Differences may exist between national practices and the international norms laid down in this or other manuals. Nevertheless, every effort to reduce the impact of such differences should be made when reporting these data to the OECD or to other international organisations by making adjustments or estimates, even if this means that the R&D data in international sources will differ from those in national documents. If national authorities are unable to make such adjustments on their own responsibility, they might help the relevant organisations to make informed estimates. Where such adjustments cannot be made, full technical notes should be submitted. Discrepancies are generally of two kinds:

- explicit differences in approach between national R&D surveys and that recommended in this manual

- “implicit” differences between national economic or educational classifications used in the country’s surveys and the international classifications recommended in this manual.

6.91 It is important to identify and report both kinds of differences and any break in series. When changes in any aspect of the survey process (e.g. sample design and unit classification, data collection methods, survey instrument design, question construction or definitions) result in known breaks in the historical data series, such breaks should be openly identified and conveyed to data users. Whenever it is possible to provide a measure of the likely impact of the break (e.g. percent of reported totals) or to chain link current and future estimates with past estimates, this should be done.

6.92 National authorities should provide indicators of data quality for the published aggregates. These may be based upon standard errors as well as response rates. They may be provided globally as well as for individual domains of estimation. Coverage statements should include how the survey population was constructed, maintained and assessed. Variable imputation rates should be provided. These rates assist in determining data quality and question construction. Some concepts may be unfamiliar or difficult for respondents, and the questionnaire design needs to be reviewed to account for these weaknesses regularly. Cell level suppression due to confidentiality may be useful to anonymise a population too rare or too concentrated to support the detail requested. Timeliness should be considered, as should revision rates.

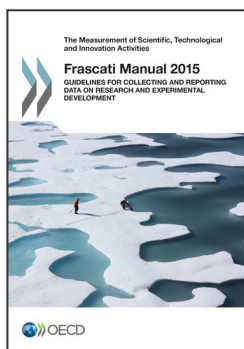
6.11. Concluding remarks on data quality

6.93 This chapter has provided a range of approaches to measuring R&D in the main institutional sectors of this manual and to producing results of reproducible quality, using commonly accepted data quality measures. Practitioners can find discussions of data quality in Snijkers et al. (2013), Lyberg et al. (1997) and also www.oecd.org/std/qualityframeworkforoecdstatisticalactivities.htm and <http://unstats.un.org/unsd/dnss/QualityNQAF/nqaf.aspx>. The range of approaches is intended to offer both options for data collection to countries with limited statistical infrastructure and points for discussion for those with a highly developed statistical system. In all cases, statistical methods and supporting technologies and practices change over time, and users of this manual are encouraged to monitor, and use, best practices for their statistical environment.

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