Economic Statistics and Scientometrics

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Abstract

This paper provides scientometricians with a brief overview of the history of economic statistics and its international standards. Part of the latter is the Frascati family of standards in science and technology input statistics. Some recommendations are given for improvements in these standards. Proposals are developed to relate research inputs as defined in the Frascati manual and bibliometrically measured outputs.

1. Introduction

The core of scientometrics consists of indicators of scientific output: publications and citations. They can be detailed by authors and their attributes as well as by attributes of the publications. Output data form a rich source of information on the global research enterprise. However, to compare the efficiency of institutions and nations and to analyze science and research policy, a link is needed with data on *inputs:* research cost and research labor. One might refer to this as *denominator* information, as it is needed to compute numbers of publications and citations per euro or per unit of labor. Moreover, contextual information is needed on institutions regions and the national economy. Both denominator and context data are in the domain of economic, and to some extent social, statistics, which is often unfamiliar to scientometricians. The present paper provides scientometricians with a pocket guide to the field and reflects on the potential for work on linking input and output data.

The paper consists of four sections. The first is on the historical development. The field of economic and social statistics has a long and rich history. To describe it adequately would require at least a book rather than a single section in a brief paper. Instead, section 2 sketches a bird's eye view that should give a little background to bibliometricians and scientometricians who never had the opportunity to look into the subject. A strong intellectual structure has gradually been achieved in a sustained and concerted international effort. At the heart of economic statistics now is the System of National Accounts which integrates all

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separate statistics into a single coherent framework. The system has been codified in international standards which are generally followed quite well by most national statistical offices. Related to this system are a number of major statistical classifications that are of importance to scientometricians. Section 3 is therefore devoted to an introduction to the system of National Accounts and the related international standards. Using this as background, section 4 describes the Frascati manual for R&D statistics and the related manuals in the field of science and technology. Finally, section 5 describes further work that may be done from a scientometrics perspective, both on the international standards and on the linkage of input and output research data.

2. Introduction to the development of economic statistics

One can pick several dates for the start of the collection of economic and social statistics, but usually reference is made to William Petty (1665, 1676) and Gregory King (1696) in England and Vauban (1707) in France. Extensive background information on the blossoming of science in England in these days is given by Merton (1938). In the fiercely competitive commercial climate of mercantilism in the seventeenth and early eighteenth centuries, there was interest in knowing the money value of national income in order to how much government revenue could be obtained. Thus these authors were interested in breakdowns of national income that were useful from the point of taxation. This tradition of economic statistics far outdates the start of the social sciences: it would not be until 1776 that Adam Smith published his Wealth of Nations. The relation between economic statistics and the funding of government runs in two directions. Not just are economic statistics needed to determine how many taxes can be levied, but taxation itself is a major source of economic statistics. For centuries, data on international trade were obtained from the levying of import duties. At early stages of economic development this was a particularly easy source of revenue, all it required were some sleepy customs officers in the ports. Other indirect taxes are also fairly easy to levy and the statistics they generate as a by-product are quite old too. Examples are data on sales of beverages and data on trade in property. Only in the twentieth century, after prosperity had increased substantially in some countries, did systematic direct taxation (taxes on personal and corporate incomes) become possible and generated systematic data on income distribution and, when social security systems were in place, labor.

Social statistics have a similar history. This field began with censuses with the purpose of providing rulers with information on the size of the population and their property, naturally with taxation purposes in mind but also to obtain lists of men that could be drafted into military service. Censuses for these purposes are quite old, possibly going back as far as five thousand years. Perhaps the best known ancient census is the one ordered by the Roman emperor Augustus as mentioned in the New Testament in the story of the birth of Jesus. Modern censuses gradually started in a number of advanced countries in the first half of the nineteenth century, typically with a census every 10 years. Further social statistics with a long tradition are the demographic survival tables, going back to Graunt (1662) who worked from the public health perspective with the purpose of reigning in the bubonic plague; and again Petty (1665) and King (1696). Thus demographic statistics led the way in social statistics, followed of course by educational statistics as soon as nineteenth century governments began to consider the funding of education as their responsibility.

The nineteenth century also saw the establishment of the first government statistical offices. The first wave was around 1840. In Britain, the office of the registrar general was established in 1836 and first conducted a census in 1841. Its successors eventually were the Office of Population Censuses and Surveys (1970) and the Office for National Statistics (1996). In post-Napoleonic France, the Bureau de la Statistique Générale de la France became the first office, growing out of the work of a government official who had been doing statistics since 1828. In the US, the Constitution had made a decennial census mandatory right from the start, as a basis for the allocation of seats in the House of representatives. The first one was conducted in 1890 by US Marshalls. The Census Office, later renamed Bureau of the Census, was established in 1840. In Germany, statistical offices of some states were established early in the nineteenth century (Prussia, 1805; Bavaria, 1808 and Württemberg, 1820) and in 1834 the Central office of German customs union stated the collection of statistics. By the end of the century, more government statistical offices had been established. In Germany, the Kaiserliches Statisches Amt replaced the office of the customs union in 1872, immediately after the foundation of the German national state in 1870. In the US, the Bureau of Labor (Statistics) was established in 1884, eventually collecting data on labor, prices and consumer expenditure. In smaller advanced countries central statistical offices also were established by this time, e.g., the Central Bureau of Statistics in The Netherlands in 1890.

Thus, though the collection of statistical data by government agencies had been solidly established at the start of the twentieth century, the total amount of statistical information was still rather limited. It remained possible to summarize it all in a single volume by a single author, such as Mulhall's (1884) Dictionary of Statistics. This situation did not change very much before 1930. Then two major things happened. First, the League of Nations was established in 1922 and gradually started to publish international statistics. The first issue of its Statistical Yearbook refers to 1926; the first issue of its World Economic Survey to 1931/32. Similarly, the International Labor Organisation was established in 1919 and also started to publish international statistical data. Second, the Great Depression greatly increased the role of governments in the economy, not just through the New Deal in the US but also in Europe, where even conservative governments took action. Both the international statistical publications and the more active economic policies made it painfully clear that economic statistics were not up to the demands then made on them. The data were not only fragmented and conceptually inconsistent both within and between countries, but were also quite insufficient from the point of view of the empirical modeling of the economy that was gradually being developed by the pioneers in econometrics that wanted to model the business cycle. This challenge was met head on by young men who would turn out to become giants in the economics profession: the later Nobelists Simon Kuznets and Wassily Leontiev in the US, John Hicks and Richard Stone in the UK, Ragnar Frisch in Norway and Jan Tinbergen in The Netherlands. Together they developed, during the 1930s and 1940s, the system of national accounts and input output tables that would become the core of the current system of international economic and social statistics.

After the Second World War, the new United Nations continued the international statistical work of the former League of Nations but took it one crucial step further: the UN organized the development of international statistical standards to harmonize the data internationally. Gradually, these standards began to be the basis of the actual data collection by the national statistical offices. This development was strengthened by the Marshall aid the US gave to help western Europe rebuild its economy. To monitor and plan this aid, the Organization for Economic Cooperation and Development (OECD) was established in Paris. Later, newly developed countries such as Japan and Korea also became members. After the end of the Marshall aid the main role of the OECD became intellectual: joint development of ideas about economic and, to a degree, social policies; empirical evaluations, country reports and so on. A major part of this role is the development of guidelines for statistics. The usual sequence of events is that within the OECD the first work on a field is done, and a manual is developed for the benefit of national agencies. These manuals also establish a preferred format for the reporting of statistical data to the OECD, which then find their way into OECD statistical publications and data bases. Subsequently, the OECD work is often built upon by global organizations like the UN, UNESCO and ILO to develop their own guidelines for a field. Their statistical offices then use them as a reporting framework for their publications, covering a far larger number of countries, and they are also used by agencies such as the World Bank or the IMF that may make following some of these guidelines mandatory as a condition for countries to receive aid. Most countries sooner or later start to implement the UN guidelines of their own accord; in case of EU countries this process is sped up by the EU which usually adjusts the guidelines somewhat to its own needs and then makes reporting on their basis mandatory for the member countries, using the legislative powers established in the European treaties.

3. The System of National Accounts

At the centre of all economic and social statistics is the System of National Accounts (SNA). The first version was published by the UN in 1953, based on the report of a 1947 League of Nations subcommittee led by Richard Stone. It was substantially revised in 1968 and again in 1993. Minor revisions (mainly dealing with advances in data collection and estimation methods) were made in other years, most recently 2008. In the US a system of national accounts, called 'Flow of Funds Accounts' was developed separately a bit later by Morris Copeland on the basis of his institutionalist money flow description of the economy (cf. some papers in Dawson, 1996), but the essence similar to the SNA. At the heart of all national accounting is a double identity:

production = income = expenditure

This identity implies that there are three methods to estimate national income: the income method, which estimates and aggregates the incomes of all actors in an economy; the expenditure method which adds all their expenses; and the production method which consolidates all outputs. The word consolidate is used here to indicate that product flows between actors are deducted. Each of these methods, when applied in isolation, has its own strengths and weaknesses. However, the salient characteristic of the SNA is that relations between flows are spelled out at the level of actors and groups of actors, making it possible to consider the identities not just at the national level but also at the micro and meso level. Thus the strengths of each method can be put to work and the weaknesses avoided, and data from many sources used to obtain the best possible estimates. This process is referred to as statistical integration or balancing. Statistical integration can be applied at any level where definitions and identities link data from different sources.

A good example are the input output tables, the production part of the National Accounts. The core of these tables is the identity

Intermediate use of goods and services + imports + use of production factors (e.g., wages, use of capital) + operating surplus (≅ profits) =
Intermediate delivery of goods and services + investment in capital + final consumption exports + net additions to stocks

This identity can be detailed to the level of an industry and the variables in the identity can be broken down to the level of groups of goods or services. Similarly, income and expenditure identities can be drawn up and detailed to the level of sectors (e.g. households, government, business, and subgroups of these sectors; and to breakdowns of the income and expenditure categories, e.g. for the household sector the income component 'compensation of employees' by type of labor, and the expenditure component final consumption by categories of goods and services. Thus the SNA provides a complete framework to specify, at a detailed level, many flows in the economy in a consistent way; for an elaboration of the meso-structure of this framework cf. Al and Van Bochove (1987). The SNA framework uses a number of building blocks and tools. We will discuss the five most important ones briefly: the type of information, boundaries, units, classifications, definitions and tables.

Type of information

The central information type in the SNA is the transaction: a flow of value between economic actors, measured in monetary terms, at current prices; an elaboration of the transactions based core of the SNA is provided in Van Bochove and Van Tuinen (1986). That transactions are the central information type is a consequence of the fact that the identities on which the system is based are in monetary terms. However, the modern SNA also accommodates other information types.

Two information types that are closely related to the transactions are stocks and transactions at constant prices. The former have become an integral part of the system since balance sheets were integrated into the 1993 version. Balance sheets record the possessions and debts of economic actors at the end of the year; changes in these stocks are caused by the balance of the flows during the year. The balance sheet data are not computed as widely as transactions data because they are far more difficult to measure directly. Transactions in constant prices are obtained by deflating the transactions at current prices with deflators ('price indices'). To obtain price data, statistical offices develop a sample of goods and services, selecting these as homogeneously as possible, and measure their prices in a survey at a sample of all relevant units: production units for producers' prices, retail units and other units that sell directly to households for household expenditure prices, and so on. Per product the average of the sampled prices is taken and the resulting average product prices are weighted to national and sector totals using weights obtained from the detailed national accounting system, e.g., the share of a product in total production or total household consumption. The integrated nature of the SNA makes it possible to derive deflators of variables for which no price indices can be computed, such as incomes: put simply, income can be deflated with the price indices for expenditure; in cases like this, one finds the term 'implicit deflator' in the accounts.

In addition to transactions, stocks and constant price data, many other information types can and often are added to the accounts. Since many years, many countries have included labor volume data: the amounts of labor corresponding to transactions such as wages and salaries, compensation of employees, and so on. The amount of labor can be measured in various ways, but most common is the number of full time equivalents.

Boundaries

In any data collection, the boundary of what is measured is essential in determining the scope. Thus in the Web Of Science and Scopus there is a 'publication boundary', drawn by the choice of the publications covered. This boundary reflects the idea that international peer reviewed journals are covered; thus no books are included and until recently only a few national language publications were indexed. In the SNA, a very central place is taken by the 'Production Boundary'. It is a delineation of productive activities. Because of the double identity between production, income and expenditure, this delineation also determines which transactions are included in income and expenditure. It even determines which actors are covered since only actors that are relevant for production, income and expenditure are included. The description of the boundary given in the SNA itself is rather formal and leaves a lot of questions open to the uninitiated. A more intuitive description starts with the core of productive activities in a market economy: the production of goods and services that are sold for money, except for activities which are in themselves illegal (e.g., production of hard drugs). Added to this core is the public sector production that is not sold for money; its value is set equal to its cost. Also added is production that is not sold for money but bartered (it is valued at the price of similar produce that is sold for money), and some special cases intended to achieve comparability with services sold for money. Thus, there is a very major imputation for the housing services rendered by owner-occupied dwellings (necessary to achieve comparability with rented homes) and a smaller one for own account production of capital goods in industry.

It is important to note that tax evasion and other evasions of registration do not remove activities from the coverage of the SNA. Actually, national accountants devote a lot of effort to estimating the size of these activities and factoring them in.

There is another increasingly important boundary in the SNA: the 'Asset Boundary'. As the SNA describes not just current flows, but also stocks, it is necessary to distinguish assets separately: goods, raw materials, financial titles and other things of which stocks are to be recorded. In the latest version of the SNA (2008), an important change is that R&D is included in the assets. The basic thought is that R&D is an addition to the stock of knowledge, or, put differently, that there is a stock of knowledge that is the cumulative result of R&D. In turn, the concept of the stock of knowledge derives from endogenous growth theory; elsewhere (Van Bochove, 2012) I argue that this concept is fallacious, since new knowledge often replaces existing knowledge instead of adding to it.

Units

The SNA distinguishes two central types of units. To describe production it uses the *'establishment'*. As the name suggests, establishments are situated in a single location; moreover, their production is mainly in a single economic activity (industry), though they can have some ancillary production in other economic activities. This definition immediately implies that the delineation of the establishment depends on the classification of economic activities (industries) and of locality. Households can also be an establishment, as when they sell or barter their own produce or own the house they live in (cf. the owner-occupied dwelling imputation in the production boundary). The second unit is the *'institutional unit'*, used to describe income and expenditure. Institutional units are capable in their own right of owning assets, incurring liabilities and engaging in economic activities. Thus they are incorporated and unincorporated enterprises, self-employed, households in their role as consumers and income recipients, government institutions, and private non-profit institutions. Institutional units often are legal units but may also be conglomerates of legal units. A large R&D performing corporation typically is an institutional unit, and the R&D department may be a separate establishment. Originally, the SNA was reluctant to distinguish separate R&D performing units, but in the 2008 version there is an explicit recommendation to do so whenever data availability allows it. If this is actually implemented, it means that most R&D will be perfectly visible in the national accounts of the individual countries.

Classifications

International statistical classifications have been developed separately, for their own purposes, but the SNA has had a harmonizing influence on them. Currently, the main international classifications are:

The *International Standard Industrial Classification (ISIC)*: the classification of productive economic activities into industries based on shared characteristics of the production process and used for classifying establishments and their production. First published by the UN in 1949, the most recent version dates from 2008.

The *Harmonized [Coding and Description] System (HS)*. This is a classification of international merchandise trade, developed by the world Customs Organization. It was first published in 1992 and has replaced the earlier Standard International Trade Classification.
The *Central Product Classification (CPC)*, the product classification used by the SNA itself. It is used both for international trade and for domestic production and trade, and is linked to the HS.

The *Institutional sector classification* is not a classification in the strict sense. Instead, the SNA simply refers to the Institutional sectors of the economy. There are five sectors: Non-financial corporations, Financial corporations, Government units, Non-profit institutions serving households and Households. Each of these is subdivided into subsectors and in some cases further or alternative breakdowns have been developed. These institutional sectors have a venerable intellectual history: their origin can be traced to the manner in which the great nineteenth century economist Alfred Marshall (1890) analyzed the economy by archetypical economic actors such as the business man, the banker and the consumer or household. British national accounting pioneers such as Meade and Stone (1941) used this intellectual framework. For an elaboration of the intellectual origins of the sectors, cf. Van Bochove and Bloem (1987, p. 372).

The *Classifications of expenditure according to purpose*:

Classification of the Functions of Government (COFOG)

Classification of Individual Consumption According to Purpose (COICOP)

Classification of the Purposes of Non-Profit Institutions Serving Households (COPNI)

Classification of the Outlays of Producers According to Purpose (COPP)

These classifications were developed specifically for the SNA. In a simple form they date back to the 1968 version, but they were elaborated in the 1993 SNA and finalized in 2000 (cf. UN, 2000). These classifications do not look at the (physical) nature of the goods and services purchased by an expenditure (as the CPC and HS do), nor at the production process by which they are made, but at the socio-economic objective or function for which the expenditures are made. It may seem funny that there are four separate classifications, with some overlap between them. This has historical reasons and, as in case of other classifications, it seems reasonable to predict that sometime in the future a single fully integrated classification will be achieved. Even so, in the overlap the categories distinguished are identical, meaning that for practical purposes the four are in fact already close to being a single classification.

The *International Standard Classification of Education*. This classification was developed by the UNESCO (the United Nations Educational, Scientific and Cultural Organization) in the early 1970s. The current edition (UNESCO 2006) was approved in 1997. The ISCED contains a classification of education by level (7 levels, from pre-primary education up to the second stage of tertiary education) and by field (25 fields). The classification is of course used to classify students in educational statistics and household statistics; in that case current education or training is classified; it is also used in labor market statistics, in which case the highest level of educational attainment is usually classified; in economic statistics it is used to classify the educational institutions.

The *International Standard Classification of Occupations (ISCO)*. The responsibility for this classification rests with the International Labour Organisation, ILO. In our brief narrative of the history of economic statistics we already encountered the ILO in the nineteen thirties. Thus it is considerably older than its parent organization the UN. In fact, the ILO was founded in 1919 by the Versailles treaty that ended the First World War. The first version of the ISCO was approved in 1958, later versions are from 1968 and 1988, while the latest version was approved in 2008 and published in book form in 2012. Occupations as classified in the ISCO are characteristics of jobs, namely the type of skills required. ISCO distinguishes 10 major groups and details these further into sub-major groups, minor groups and unit groups. The classification is based on four skill levels and on characteristics of the job that are associated with the economic activity (industry) where they occur and with the nature of the work performed. Thus the classification attempts to distinguish homogeneous groups of jobs.

The classifications mentioned here are part of what is called an *'International Family of Economic and Social Classsifications'*, maintained by the UN. In this family, linkages between the members are to be made as explicitly as possible. The family includes some other classifications maintained by the same organizations (such as that by Status in Employment), as well as classifications of the World Health Organization, of Diseases and of Disabilities.

Concepts / definitions.
Naturally, a statistical system as all encompassing as the SNA must contain a huge number of concepts and their operational definitions. Because the SNA is such a large integrated system, rigorous and consistent sets of definitions are needed and, in a sense, forced on the national accountants by the structure of the system itself. Since almost all other economic and social and social statistics are now linked to the SNA, these statistics usually start out from the definitions in the SNA and build on them.

It is impossible to mention even a minor part here. Therefore we will just, by way of an example, touch very briefly on a pair of concepts that is of particular importance to science and technology statistics: national income and gross domestic product (GDP). Both are an indicator of the total income or production of a nation and can hence be used to normalize scientific output or expenditure on R&D, e.g., in measures such as the share of R&D expenditure in national income. The two concepts differ slightly. Loosely, GDP is the income generated by production on the territory of nation, while national income is the income received by the households and other institutional units that are residents of that nation. The term gross indicates that the value loss ('depreciation') of capital and other long lived productive assets are not deducted. 'Net' would mean that they are, but net national income and net domestic product are used rarely, which is fortunate because the computation of depreciation is rather shaky.

Tables and family members

The original standard format of tables in the SNA is the T-table: the standard two column double entry bookkeeping table with expenditure on the left and receipts on the right; both columns must add up to the same total, meaning that in one of the two columns there is a balancing item, computed as the residual needed to achieve the equality of the totals. An example of such a balancing item is 'saving' on an income and expenditure account.

T-tables are well suited to display the total transactions of a group of actors with all other actors, but less so to display all the bilateral transactions separately: that requires cumbersome long columns in the tables. Clearly, a matrix format, with a number of rows and columns equal to the number of sectors multiplied by the number of transaction categories, is much more suitable. Essentially, a matrix is simply a combination of the T-tables for all individual sectors; the restriction that the two columns of the T-table add up to the same total now translates into the requirement that the total of column i is the same as the total of row i, since both pertain to the same sector and the same transactions. An alternative is to make a number of smaller separate matrix of the format sector x sector, one for each transaction category.

A great advantage of the matrix representation is that it can also be used for analytical purposes. To illustrate this, consider the input-output table. This table has rows and columns for every industry as well as some extra rows presenting (for each industry) wages, entrepreneurial incomes, depreciation of fixed assets and imports; and extra columns with each industry's final deliveries to household consumption, investments, government consumption, exports, and (net) inventory changes. The intersection of the row of one industry and the column of another is the intermediate delivery from the former to the latter. The whole matrix can be normalized by dividing it by an appropriate total, in such a way that only coefficients with values between zero and one remain. These can, applying some matrix algebra, be used to answer 'what if' questions such as: if exports would have been ten per cent higher, how much more wages would then have been paid and how much more imports would have been required in each industry, taking account of all intermediate deliveries generated in the process? This procedure is a reasonable approximation as long as the changes and periods considered are not too large. Using the tables in such a way was what they were originally designed for in the early Soviet Union when national production planning was attempted; this type of work was imported into the US by the later Nobelist Wassily Leontiev and used during the Second World War for the materials planning of the wartime US economy.

In the current SNA, the system of matrices has been greatly expanded to accommodate all kinds of phenomena in addition to the transactions-based heart of the system. Perhaps the best known extensions are the social accounting matrices (SAM's): these specify income and expenditure of detailed groups of households, and add data on phenomena like nutrition, health, housing, demography. They are a tool in designing development programs that are effective in reducing poverty, malnutrition, and so on. However, extra tables do not need to be in the form of matrices, they can take any form.

SAMs are an example of extensions of the SNA with smaller or larger related systems, which could be considered as members of an SNA 'family'. One generic term for extra tables or family members was first introduced in the French SNA and is now more generally used: 'satellite accounts'. In principle, any form of tables can be used and they can cover any type of subject as long as they follow the same sectoring and industrial classification or product classification as the transactions tables in the heart of the system. They may even provide an alternative sectoring, as long as that is linked to the core sectoring by a specific bridge table.

A special family member that is of some importance, at least intellectually, to scientometrics is the system of Labour Accounts. Labor Accounts bring all data on labor together in a consistent system that is linked to the labor data in the SNA. Thus there are various measures for labor-volume, such as head counts, full time equivalents, hours actually worked and hours paid, and so on. Similarly, a range of concepts in money terms are given and linked, from contractual earnings to total labor cost. There is not yet any international standard for labor accounting but a number of individual countries compile them (Buhmann et al. 2002). A nice example of the application of this and other SNA family members, and the relations between them, to a specific subject is Alfieri (2004).

4. The Frascati Family

The SNA and the corresponding classifications are the core of the international statistical system. In addition to that core, there are international guidelines for specialized fields. These provide internationally standardized definitions and classifications for their field, as well as guidance on data collection methodology. Usually, they are the basis for the data requests of international agencies to national statistical authorities and for their multi-country publications. In the field of science and technology, the OECD has played a central role, although UNESCO has also contributed. The OECD developed, as early as 1962, a manual for the collection of science and technology indicators, the Frascati manual, named after the Italian town where the expert team led by Christopher Freeman met. A number of revisions have followed, the latest version of the manual dates to 2002, with some additional documents issued more recently (OECD, 2002, 2007, 2012a). A history of the manual and its influence is given by Godin (2008). The subtitle of the manual indicates that it is a 'standard practice' for 'surveys on research and experimental development' but it is in fact a bit more than that: in addition to being a survey manual, it contains guidance for R&D statistics irrespective of how they are collected. We will briefly describe the contents of the manual in the same format we used for the SNA in the preceding section. In doing so, we pay special attention to the relations between Frascati and the SNA.

Type of information

In the words of the manual itself, it 'deals exclusively with the measurement of human and financial resources devoted to research and development', or input data. Again, this is a bit too modest. The manual provides definitions of key concepts that are useful in the compilation and publication of other data. An example is the distinction between basic research, applied research, and experimental development (pp. 77-79). Two inputs into R&D are dealt with in the manual: R&D expenditures and R&D personnel.

Boundaries

The manual deals with R&D and gives detailed delineations with related activities, such as higher education, routine engineering, software production, administrative support in institutions doing R&D, scientific and technological activities such as library work, standard data collection as in statistical offices, and so on. R&D personnel includes PhD students, R&D managers, administrators and clerical staff.

Units

The manual first states that both the unit from which the data can be obtained (the 'reporting unit') and the unit to which the data pertain (the 'statistical unit') will differ between sectors and countries. However, per sector more specific recommendations are made. The manual is not yet harmonized with the latest version of the SNA: whereas the latter recommends the construction of a separate statistical unit (an establishment) for R&D, Frascati still recommends to use the total enterprise within which the R&D is done as the statistical unit. This should not make much difference in the value of R&D inputs, but it means that in statistical reporting based on the latest SNA the industry distribution of R&D will be different from that in Frascati-based R&D statistics.

Sectors and other classifications

Frascati distinguishes a Business enterprises sector, a Government sector, a Private non-profit sector, a Higher education sector and a 'sector' Abroad. Apart from the labels and aggregations, the only major difference with the SNA is separate Higher education sector, which includes university medical centers; in the SNA higher education is included in several other sectors. This seems to violate institutional reality as the higher education sector is quite different institutionally from other sectors; international comparability of other sectors is hurt because the share of private universities differs per country, affecting the allocation of higher education to other sectors. Moreover, the lack of uniform international national accounting data on the higher education sector makes it difficult to trace the economic role of this increasingly strategic sector.

Frascati recommends sub-sectoring of a different nature in the various sectors. For the Business enterprises sector, sub-sectoring is by main economic activity according to a modified version of the ISIC (obtained by aggregation of categories at the first, second and sometimes third level). The manual recognizes that a sub-sectoring of government should be based on COFOG (cf. section 2, Classifications of expenditure according to purpose), but considers the current version inadequate for R&D and thus provides no sub-sectoring. For the private non-profit sector (mostly non-university research institutes), a sub-sectoring is given into six major *fields of science*, with some further breakdowns. This sub-sectoring is also recommended for the higher education sector. It was revised a few years later in a separate document (OECD, 2007) into a complete two-digit Field of Science and Technology Classification. The sector 'abroad' should contain the international research units on a country's territory, such as CERN in Switzerland, ESA establishments in various European countries, ITER in France, ESO in Chili, and so on.

Other classifications

In addition to the sectoring, the manual gives some (modifications of) classifications for expenditure on R&D and R&D personnel.

Functional distributions are classifications on the basis of the nature of the R&D activity rather than on who performs it. We already mentioned the breakdown by ‘type of research’: basic research, applied research and experimental development. Frascati cites the UNESCO (1984) manual to spell out how this distinction should be made in the social sciences and humanities (p. 81). For the business sector, R&D should be further classified by ‘product field’. This is identical to the modified ISIC classification mentioned in the subsectoring, but with the difference that here the classification is according to the industry that will *use* the R&D results instead of the industry conducting the R&D. In a similar way, the classification by field of science and technology is to be used as a functional distribution for expenditure and possibly personnel of the non-enterprise sectors. Finally, there is a functional distribution by socio-economic objective, originally developed by the EU to classify its R&D expenditure. This is the breakdown recommended for ‘Government budget appropriations for R&D’ (GBOARD). It has 12 categories that combine the functions of government and some special categories such as Exploration and exploitation of space and Social structures and relationships (pp. 144-147).

Personnel classification: the manual recommends a breakdown of R&D personnel by occupation, using a modified version of part of the ISCED. This amounts to three groups only: Researchers, Technicians, and Other supporting staff. This is the breakdown of R&D personnel that is the basis of most international data. In addition, the manual recommends use of a modified (but only slightly) form of the ISCED, for a breakdown of R&D personnel by educational attainment level.

Concepts/Definitions

The core of the Frascati manual deals with R&D expenditure. A central breakdown is between intramural expenditure, within a unit or sector irrespective of the source of funding, and extramural expenditure. The manual gives a breakdown of expenditure into the usual SNA categories of current and capital expenditure and describes in detail how various categories such as instruments and software should be treated. In addition to definitions of expenditure as such, the manual also gives a framework for the sources of funds, defining the flows of funds between actors. Concepts like ‘Public general university funds’ (GUF), government no-strings-attached university block funding, are defined here (p. 117).

The most influential definition in the whole manual is a concept that is clearly rooted in the SNA, Gross Domestic Expenditure on R&D, frequently simply referred to as GERD. The ratio of the concept to the gross domestic product is probably the most frequently cited concept in all R&D and scientometric statistics. It is often used scoreboards of a country’s competitiveness and national R&D spending targets have been formulated in term of the ratio by both the EU: the target of 3% R&D spending in 2010 set by the 2001 Barcelona European Council; when this target had been missed, the European Commission set the same target for 2020. The target is made up of a private sector component of 2% and a public sector component of 1%; the latter is measured by the GBOARD concept we already encountered above. Interestingly, China also set a 3% GERD target for 2010, missed it and reconfirmed it for a later date. In case of China, the main cause of missing the target was not a lack of growth of R&D spending but a continued extremely rapid growth of the GDP denominator of the target.

The current definitions and concepts of university funding in Frascati are unsatisfactory. In science and innovation policy, a basic discussion is whether publicly funded research should be targeted and directed by governments, possibly linked to business R&D, or should be left free for the research institutes and researchers to decide upon. As I recently showed (Van Bochove, 2012), this may make a substantial difference to the rate of economic growth. To provide data on this subject requires a breakdown of government funding by the degree of control that governments or funding agencies exercise over the use of the funds. A first exploration of this was recently made by van Steen (2012). However, just breaking down government funding is not enough to achieve international comparability: in Anglo-Saxon countries, major research universities have huge private endowments that play a role comparable to that of government block funding (GUF) funding in other countries. Thus, there is an urgent need for a complete and practical classification of all university funds by the degree of control that the universities have over their use, irrespective of the source of the money.

Implementation of Frascati

The fact that a manual says so does not necessarily imply that statistical offices do so. Usually there is a time-lag between the drafting of a recommendation and its actual implementation, and in some cases government statisticians continue to hold on to their own national practices after an international recommendation has been issued. It is way beyond the scope of this paper to review the extent to which individual countries actually collect data according to the manuals; some information on this subject is given by Luwel (2004) and an impression can also be obtained by glancing at the OECDs data or the EU's innovation scoreboard.

Even if data are collected in strict obedience to the Frascati recommendations, this does not mean that it is easy to compare them internationally. Expenditure data may differ purely because price levels in countries are different. To correct for this, one can use purchasing power parities (PPP's). These are deflators for spatial differences in price levels; the methodology is similar to that for temporal deflators briefly described above. The OECD (2012) gives PPP's for GDP, using weights from the national accounts.

Even more severe are the comparability problems in case of labor input data. There are substantial international differences the share of part-timers. This is partially corrected if, as Frascati recommends, full-time equivalents are used. However, there are also substantially international differences in the number of hours worked per year by full timers. These can be corrected by using ILO data. But then a further problem is that in research people often work more hours than their contract stipulates. These conceptual problems are compounded by severe measurement problems. In universities most people do not work on research full-time but they also work on education and administration. This could be measured if time registering systems with uniform definitions were used routinely, which they are not. Therefore use has to be made of keys to allocate time to the three components. These keys could be derived from dedicated time use surveys, but the latter are expensive, unpopular and therefore infrequent and unreliable. As a consequence, international comparisons of expenditure on R&D per unit of R&D labor should be taken with a pinch of salt. In fact, to a degree expenditure data are afflicted with the same problem: statisticians need to separate university expenditures on research from those on education. Again, to do this properly would require non-existent data on the share of the time of the staff that is spent on research. So instead, sometimes the same keys are used as in case of labor and sometimes estimates are based not on expenditures but on funding. But then the latter does not fully solve the problem either in case of General University Funds or their endowments-based equivalent:

management within the universities often has freedom to spend these funds as they please, and may spend them on education or other non-research activities.

Other members of the Frascati family.

The OECD has issued a number of other manuals in the field of research and innovation that, jointly with the Frascati manual, are referred to as the Frascati Family. They are the Canberra manual, the Oslo Manual (1992, 1997, 2005) and the Manual on Patent Statistics (1995, 2009). There also is a Manual on Technology Balance of Payments which we will not discuss here.

Canberra

The Canberra manual (OECD, 1995) deals with the 'human resources devoted to science and technology'. In a sense, this manual is the descendent of a UNESCO manual, the manual for Statistics on Scientific and Technological Activities (UNESCO, 1984), of which the preliminary version dates to 1979. At its website, UNESCO warns that this manual is now merely of historical interest and should be used for research only. In this manual, UNESCO defined scientific and technological activities as R&D, scientific and technological education and training at the third level (which means: tertiary and post-tertiary education, or bachelor, master and post graduate degrees), and scientific and technological services. An abstract definition is: 'the systematic generation, advancement, diffusion and application of scientific and technological knowledge' (p. 9). It has turned out, however, that the measurement of these activities as a whole, and specifically the scientific and technological services, is impractical. Instead, the Canberra manual focuses on the availability of human resources for these activities, and narrows that down to the people who are actually or potentially employed in occupations that require at least a first university degree and technicians of a similar level, in a science and technology field of study. Thus Canberra is in essence a manual on labor force statistics, zooming in on the highest educated part of the labor force and distinguishing two major groups: University level HRST and Technician level HRST.

The definition of HRST implies that two groups belong to it: those with the formal educational qualifications at the indicated level, and those who, without these formal qualifications, work in jobs requiring skills at that level. The definition also mentions that only people with the required qualification or job level in S&T fields are included. This suggests that people with qualifications in some fields are excluded. However, the manual hesitates at actually doing so and includes all fields in what it calls ‘complete coverage’. Only when a distinction is made between core coverage and complete coverage, is the field of study of actual influence and are people with a PhD in the humanities excluded.

Clearly, this delineation of HRST requires an operational definition combining educational attainment and occupation and this is duly given in terms of groupings from ISCED and ISCO. The manual provides a stock-flow scheme of changes in a nation’s HRST, and recommends breakdowns by some personal characteristics (age, gender, national origin), and the collection of contextual information (total population, total employment, and so on). Also, HRST specific variables are recommended, such as salaries. Linkages are given to Frascati with respect to units and so on.

Oslo

The Oslo manual (OECD, 2005) provides guidelines for the collection and interpretation of innovation data. It is, more than other of the guidelines discussed so far, theory driven. The theory is summarized in the first chapter after the introduction. Fortunately, this chapter ends with a section where the question ‘What can be measured?’ is central and is followed by a chapter where careful and practically useful definitions are given. They include a definition of innovation as such (‘implementation of a new or significantly improved product, or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations’). From this, a definition of innovation activities is derived; it includes ‘R&D that is not directly related to the development of a specific innovation’, implying that all R&D as defined in the Frascati manual is included in the innovation activities of the Oslo manual. Also, a definition of innovative firms is derived. The definition already suggests a breakdown of innovations in some types, and these are indeed properly defined: product, process, marketing, and organizational innovations.

Next, the manual considers units and recommends the use of enterprises as the primary statistical unit and the establishment as secondary unit for some special cases. This is reasonable, as innovation may well take the form of a reorganization of an enterprise into new establishments, but at the same time it is desirable to have linkages to the statistics on production and hence establishment data. The manual does, however, not refer to the enterprise definition in the current version of SNA.

The Oslo manual recommends several classifications of the units; naturally by economic activity and size, but also by characteristics that are especially relevant for innovation: whether the enterprise is part of a multinational, a purely national company or a public enterprise; and by some characteristics found to be important in the empirical innovation literature: capital intensive, labor intensive or knowledge intensive; geographic location, export intensity, cooperation with other enterprises and public institutions. In the next chapter again reviews theory, particularly on innovation linkages and diffusion, and recommendations are given about how to measure these linkages. This chapter gives a much used table about the sources for transfers of knowledge and technology (internal sources, external market sources, public sources such as universities and general information sources including patent disclosures and professional literature. Finally, the manual has major chapters on data collection which have become the basis for many national innovation surveys.

Patents

The final member of the Frascati family that we shall briefly discuss is the Patent Statistics Manual OECD (2009). This manual is rather different from the other three, because it is not the basis for data collection by surveys, as Frascati and Oslo, or for rearrangement of survey and census based data, like Canberra, but instead provides guidance for the use of patent databases. Thus it is much closer to the practice of scientometrics and might, in fact, be considered to be part of scientometrics. The document gives a succinct and lucid overview of the legal and economic foundations of patents, the patent databases, the analytical uses of patent based indicators. It describes how patent systems work, goes into technicalities of patents relevant for patent based statistics and gives useful classifications for patents. Chapter 6 should be quite familiar to scientometricians as it is on the use and analysis of citations in patents. The two final chapters provide indicator formulas for the use of patents to measure, respectively, internationalization of science and technology and the value of patents. The patent manual belies the image of international manuals as dry and boring documents: it is easy to read, very informative and can be recommended to all scientometricians unfamiliar with patent analysis as a quick and gratifying way to brush-up on the subject.

5. Further work.

Further work seems needed in three areas: elimination of differences between international standards, extension of the Frascati family, and exploration of the practical possibilities to link research output data with denominator data at the micro level.

Revision of international statistical standards.

We identified a number of differences between Frascati and Oslo on the one hand and the latest SNA version on the other; it would be valuable if these discrepancies were solved in a future revision of these standards. In addition, we identified some issues where Frascati might be improved somewhat. The list of the issues we noted is:

- Statistical units: Frascati should adopt the new SNA approach where a separate establishment is defined for R&D whenever data availability permits it.
- Sectors: in the next revision of the SNA it would be advisable to follow Frascati and define a separate higher education sector. Since this sector has quite distinctive funding mechanisms, this would be in better agreement with SNA principles than current practice and it would enhance the usefulness of National accounts for analysis of innovation and growth.
- Clearly, a revision of Frascati should provide a complete link to the latest version of the ISIC.
- In the next revision of SNA it is advisable to revise the classification of functions of government COFOG in such a way that it becomes more useful for R&D reporting. Perhaps this could be done by taking the extent to which intra- or extramural R&D is a usual part of government work into account when delineating functions of government.
- In a revision of Frascati and the compilation of international R&D statistics by the OECD it is worthwhile to pay special attention to treaty-based international research organizations such as CERN, ESO, ESA, EMBL, ITER and also to major non-treaty international cooperative ventures such as the ISS, joint interplanetary exploration missions, and so on. This type of organizations and projects appear to be ever more important in many ways (scientifically, economically for the host countries, in terms of job opportunities for young researchers). Data on this ‘international research sector’ should be easily available in both national and international statistics.
- In a revision of Frascati attention is needed for university funding with the purpose of facilitating international comparisons of the freedom that universities have to determine their own research agenda. This requires a classification of funds by the degree of control the universities have over their spending.
- In the next version of the Oslo manual an explicit linkage with the enterprise definition of the SNA seems desirable and in a revision of the SNA it could be considered to provide a

subsectoring of non-financial enterprises based on Oslo's delineation of innovative enterprises.

A scientometrics manual?

It is remarkable that the Frascati manual pays no attention at all to the measurement of the output of research. The naïve observer might expect that there would be a separate manual on this or even chapters in the Frascati manual itself. Of course, there are 'handbook collections', notably Moed, Glänzel and Schmoch (2004), but there is nothing like the OECD Patent manual described above. Yet this would give an impulse to the field because it would make it possible for statistical offices to add some output data to the input data they now publish. It would also give an impulse to setting of joint standards in the field. The scientometric community and the OECD could jointly explore the possibilities to generate such a manual.

Linkage of output and input data

It should be clear from our discussion about the implementation of Frascati that linking output and input data is not easy. Some things can be achieved at the national level: total publication output divided by total expenditure on basic and applied research. Similarly, it is possible to compute total university publishing divided by total university expenditures, though as mentioned above even at this level the problems of adequate measurement of research expenditure are severe. This is even more so at lower aggregation levels where denominator data would be invaluable. In ranking universities and assessing institutes or fields it would be marvelous if numbers of publications per euro or per hours worked could be computed, using Frascati concepts, but this is exceedingly difficult[2]. As a consequence, published university rankings lack this information, detracting from their value.

The lack of linkage between input and output data means that science and research policy are partially conducted in the blind: the main policy instruments influence only inputs (allocation of funding, salaries and other employment conditions, and so on) directly and not the outputs measured by scientometricians. Therefore the lack of linkage between inputs and outputs

[2] An even more advanced approach is to estimate production functions related output to all inputs separately. This approach derives from economics; but there output can be measured in money terms. Because scientific output is not sold in the market, it is not valued in money. Instead, there are a number of indicators each of which approaches some aspect of output. Consequently, these indicators have to be related jointly to available input indicators, requiring complicated methodologies. For an introduction to this approach cf. Bonaccorsi and Daraio (2004).

means that the effectiveness of policy instruments cannot be measured directly. Clearly, it is important to make some progress in establishing such linkage. The most natural way to do this is at the micro level, either of *institutions* or of *individual research workers*.

In case of *institutions* one would like to have

- Frascati-based input data for individual businesses and public sector research institutions, linked to
- numbers of publications of authors working in these institutions and their citation impact.

Scientometricians by now have a lot of experience in the second point, linking authors to institutions. The data mentioned in the first point are in fact readily available in statistical offices, viz. the micro data generated by the Frascati based R&D surveys. Consequently, establishing the linkage could be achieved by a cooperation of statistical offices and scientometric groups. The potential privacy complications could be solved by doing the actual linkage within the statistical office and publishing just aggregate data and results of statistical analysis. The most effective way to generate progress is if international organizations like OECD and EU take the lead in stimulating this type of cooperative projects.

In case of individual research workers the problem is more complex. One would need data on their publications and citations (classified by field of science and so on), which is easy by now, but also on Frascati variables such as hours worked, salary, source of funds, education. In addition, one would like to have further information on the individuals involved (country of origin, other mobility aspects, sex, age). One way to do this is to draw a sample of active researchers and survey them. However, this is expensive and yields only short term data; obtaining longitudinal data by following the researchers for a longer time is very expensive. Yet this is the only way major science policy issues can be resolved since the effects of science policy instruments take a lot of time. There may be a way out in at least the countries where statistical offices hold large data bases of individuals. In Scandinavia maintaining national person registers is actually a task of these offices but in the Netherlands the statistical office also has access to the national registers and, moreover, has developed a methodology to link them to information from other registers (e.g. on taxes, employment, social security, education) and to large scale surveys of individuals. For a brief introduction cf. van Bochove (1996) and Schulte Nordholt *e.a.* (2004). Thus again it seems that the most natural way to make real progress would be a cooperation between scientometrics research teams and some statistical offices. And again, most likely such progress requires some stimulus from the EU or OECD.

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