Chapter 9

Measuring accomplishments in the areas of science, technology, and innovation in terms of gender criterion

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Abstract

The chapter gives an overview of the methodological guidelines and recommendations used in the practice of public statistics for gender described in the following areas: science, technology, and innovation activities. Analysis was carried out on the limitations and possibilities of using patent information for the study of gender relations in the context of technological creativity. The chapter also refers to the more important partial research undertaken as part of a large research programme on productivity of scientific and technical men and women. The current development of measuring the effects of scientific, scientific-technical, and innovative activity in terms of the roles ascribed to women and men in society, and that could have a significant impact on the course and nature of that activity, does not aid in its present form in obtaining answers to the question of whether the social roles and relationships men and women affect their creativity and innovation. The transition from the economy of capital, labour and allocation to an economics of innovation and intangible resources has necessitated the development of new methodologies, techniques and tools for data collection and methods of quantification of phenomena and processes related to innovative activity.

Key words: gender, creativity, measurement methods, innovative activities

Introduction

The development of policy and public statistics in the field of science, technology and innovation is a derivative of significant changes in the factors governing economic development. Innovation (technical, process, social) has finally become important characteristics through which we can currently explain the reasons for different levels of economic development. And the concepts of the "knowledge-based economy," "information economy," "creative economy" or "intellectual capital" have permanently entered the catalogue of main categories of economic study. In economic policy they are growing to paradigms for building competitive advantages.

The transition from the economy of capital, labour and allocation to an economics of innovation and intangible resources has necessitated the development of new methodologies, techniques and tools for data collection and methods of quantification of phenomena and processes related to innovative activity. Innovation as a factor of development arises from a complex structure:

– It is the result of cooperation between people with different skills, creativity, interests and capabilities.
– It requires the initiation of interactive and dynamic structures of co-operation in the innovation process.
– It is created by cross-breeding and fusion of a number of areas of expertise far greater than before.
– It arises from the interaction of people with different needs, expectations, social attitudes, and risk appetites.
– In the economic dimension the results of the innovation process are a particularly sought good, becoming the object of market exchange.
– universities, government laboratories, and companies differentiate in time their strategies and programmes for action.

In the context of the growing importance of: multidisciplinary research, the binding of science and industry, commercialization of the results of the innovation process, or the growing scale of public intervention aimed at stimulating attitudes and innovation activity, traditional data collection and development of indicators does not provide rapid responses to the power of the influence of the processes of innovation on economic and social development. When the above set of issues and research problems combine with the process of growing awareness of the obstacles and limitations of the prejudices and stereotypes of gender, often based on the belief of the crucial role of biology in shaping the individual, their behaviours, attitudes, needs, then to design a transparent mental construct about the relationships between sex and the broader concept of gender in conjunction with economic efficiency becomes an intellectually daunting challenge.

This chapter is a synthetic reflection on the methodological achievements in the field of possibilities and limits of quantification of the category of gender in the area of scientific, technological and innovation (A+T+I) activity. It should help in resolving the problem concerning the perspectives that are possible to capture by scientific research, i.e. micro-, meso-, and macro-economic perspectives within the framework of the research task "Innovative Gender" as a New Source of Progress.

9.1. Development of statistics on academia, technology and innovation

Technological changes (in the context of innovation) have become the subject of intense empirical research and data collection in this area since the mid-1950s (Gomulka, 1998). In the 1980s and 90s a wide range of conceptual work was undertaken to develop models and analytical approaches for the study of technological change. But even in the 80s Pavitt (1984) and Pavitt, Robson and Townsend (1989) based the vast majority of their work on their own survey forms and expert opinion in their applied research procedures. Characteristics of contemporary research approaches were:

1) focus on the specific (single) cases,
2) relatively short time horizon for the analysis,
3) the collection under examination was subject to significant changes over time, and
4) the scope of the study did not extend beyond a single sector of the economy,
5) consequently, it was difficult to achieve reliability and time-space comparability.

The need to measure scientific and technical activities was recognized by the OECD as early as the 1960's. The first methodological guide (for official statistics services) was the manual on the measurement of R&D activity of 1963 the *Frascati Manual*. In 2002, the 6th edition of the manual was published under the full title *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development* (OECD, 2002). This guide is dedicated to the measurement of workload and resources (inputs) engaged in R&D. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units (OECD, 2002, p. 17).

Currently, in order to obtain knowledge on the innovation activities of industrial enterprises in the European Union, within the framework of the international research program *Community Innovation Survey* (CIS) national statistical offices carry out studies to assess the level of innovation in enterprises employing more than 9 employees. The methodological side of the study is inspired by the recommendations of the manual Oslo Manual (2005). The indicators used in the CIS study are aggregated in 12 thematic groups.

The development of methodologies of measurement results in the fields of science, technology and innovation took place simultaneously with the emerging paradigms of development, followed by the development of science and industrial policy, and later innovation policy. The increasing involvement of the state in these areas necessitated the need to evaluate the efficiency and effectiveness of the implementation of these processes. Table 9.1 presents the evolutionary development in terms of measuring the methodical effects of activity S+T+I.

The need for research on the diversity of the participation of women and men in S+T+I activities was raised explicitly in the *Third European Report on Science & Technology Indicators* (European Commission, 2003, p. 257):

> ... Although female participation in science has increased in recent decades, women are still rarely seen in top scientific positions, such as professorships or other high-level research positions. Career opportunities in science are determined by a number of complex factors, which cannot easily be described using simple statistical indicators. Internal factors – those that depend on the organisation, operation, and structuring of the scientific community itself – form an essential part of the explanation. The internal factors interact with external factors, which are determined and shaped by society at large – such as existing gender roles inside and outside the family, the changing status of women with regard to education and the labour market, and the political frameworks that support equal opportunities.

The report attempted to establish new indicators and review the presence of women in science and technology. It should be emphasized that the data in the area of science and technology with regard to gender have been collected by the European Union at the transnational level since 2001.

Table 9.1. Development of S+T+I indicators

Years	Groups of indicators
2nd decade of the 21st century	expenditure on R&D, patent statistics, balance of payments in technology, high-tech products, bibliometrics, statistics on human resources, surveys of innovative activity in the manufacturing sector, a review of production technologies, innovations described in the technical literature, budgetary support of innovative activities, investments in intangible assets, indicators for ICT, productivity, venture capital, tax incentives, biotechnology and nanotechnology statistics, statistics on commercialization of research, statistics on internationalization and globalization, knowledge-based economy, intellectual capital
1990s	expenditure on R&D, patent statistics, balance of payments in technology, high-tech products, bibliometrics, statistics on human resources, survey of innovative activity in the manufacturing sector, a review of production technologies, innovations described in the technical literature, budgetary support for innovation, investment in intangible assets, indicators in the field of ICT, productivity, venture capital
1980s	expenditure on R&D, patent statistics, balance of payments in technology, high-tech products, bibliometrics, statistics on human resources surveys of innovation activities
1970s	expenditure on R&D, patents statistics, balance of payments in technology
1950s–60s	expenditure on R&D

Source: D. Archibugi, G. Sirilli G. (2001), "The direct measurement of technological innovations in business," [in:] *Innovation and Enterprise Creation: Statistics and indicators*, Luxemburg: European Commission, after: M. Górzyński (2005), *Przegląd wskaźników monitorowania systemów wspierania innowacyjności w krajach UE i wybranych krajach pozaeuropejskich – wnioski i rekomendacje dla Polski*, Warszawa: Polska Agencja Rozwoju Przedsiębiorczości; L. Kozłowski (2009), *Statystyka nauki, techniki i innowacji w krajach UE i OECD. Stan i problemy rozwoju,* Warszawa: Ministerstwo Nauki i Szkolnictwa Wyższego.

The largest research programs in the area of S+T+I in association with gender include:

1) horizontal differences between men and women in sectors and areas of science and technology – *The index of dissimilarity*,

2) vertical inequalities in women's careers and empowerment in the field of science and technology (the percentage of women with a higher scientific degree and in senior positions in academic institutions), the *Equally Distributed Equivalent Percentage*,
3) analysis of the differences in scientific productivity between men and women, through research in patent and bibliometric data.

Jaffé (2006), mentioning the significant participation of women in the development of science and technology, highlights the inadequate level (but also possibility) of quantification of this share. However, the last decade has seen an increase in the proposals for the methodological measurement of scientific and technological achievements within the category of "gender" (Bunker-Whittington and Smith-Doerr, 2005; Naldi et al., 2005; Frietsch et al., 2008; Frietsch et al., 2009). Empirical results of international comparative studies show a clear regularity in the lesser involvement of women in the creation of: scientific knowledge (Larivière et al., 2013), and industrial knowledge (Bunker-Whittington and Smith-Doerr, 2005; Frietsch et al., 2008; Frietsch et al., 2009).

Analysis of bibliometric and patent data is increasingly being used to measure the performance of men and women in the field of science and technology. This is confirmed by the review of previous studies involving gender in science and technology made by Frietsch et al. (2009). The subject of analysis are:

1) staff in research and development institutions, including by gender,
2) representation of women in science and engineering in the United States on the basis of publication data,
3) changes in the careers of women in science and engineering between 1975 and 1995 using mainly publication data,
4) the academic career and interviews with employees of different research units to determine the extent and causes of the differences in patenting between the sexes,
5) differences in the number and quality of publications between women and men,
6) differences in productivity between men and women, through the analysis of publications and citations,
7) the impact of having a family on the productivity of researchers,
8) the impact of motherhood on networking and also indirectly on productivity,
9) the relationship between the degree of an individual's specialization in the research area and productivity,
10) differences in the productivity of researchers of both sexes, through the analysis of publications,
11) the inputs and outputs of the research process as applied to women,
12) productivity and publication habits by gender,
13) differences in co-operation networking and co-authorship by gender,
14) women's participation in the development of science and technology with using analysis of patents and publications,
15) the contribution of women in technological development using patent data.

This list of previous research clearly shows that the data on publications and patent data are widely used to carry out studies on the presence of women in the field of science and technology and gender differentiation in both patent activity and publishing.

Generally, however, it should be emphasized that the changing way of practising science, the nature of R&D and innovation activities do not facilitate good knowledge of the nature of the phenomenon of innovation or the process of innovation. The data and indicators used thus far only allow for an understanding of certain elements of the innovation process, in particular those concerning input. A major limitation is lack of information in the fields of output and impact.

The method of collecting data on innovation and innovative activities widely used in the European Union is surveying companies in various aspects of the innovation process in industry and services and the amount of resources allocated to innovation. This approach enables analysis of innovation in conjunction with other economic variables (such as output, added value, or employment), both at the enterprise and industry levels. (This perspective on data collection is recommended and described by the Oslo Manual[5]).

Currently, the elementary indicators of innovation are:

1) the share of companies in the population studied (enterprises in the industry, or the region), which introduced technological innovations (process, product) and/or non-technological innovations (organizational, marketing) within a defined period of time,
2) the share of companies in the population studied (enterprises in the industry, or the region) that perform R&D in a systematic way,
3) the impact of product innovations on the size/dynamic/return of sales,
4) the impact of process innovations on changes in the cost of the production process and the size/structure of employment,
5) the impact of innovation on productivity,
6) the intensity of cooperation in R&D activity, and the implementation of its results,
7) the share of employees in R&D in the economically active population/in total employment,
8) input on innovation in enterprises per person/in relation to GDP.

In official statistics practice, in studies on innovation, and the recommendations of the OECD methodology, the category of gender is in fact reduced to the category of sex.

The OECD (2006, p. 150), Oslo Manual Guidelines for collecting and interpreting innovation data, Third edition, recommends: "collection of data on human

5 Examples of national data collection as part of the European research *Community Innovation Survey* programme are. Report on research and development (PNT-01); Report on research and development (R&D) as well as measures appropriations or outlays on research and development in units of government and local authorities (PNT-01/a); Report on innovation in industry (PNT--02); Report on research and development in nanotechnology research units (PNT-05); Report on activities in the field of nanotechnology in enterprises (PNT-06).

resources from the perspective of both its composition (by qualification, type of work, and sex) and the management of these resources."

The OECD (2002, p. 113), Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development, recommends:

- "data on the number of employees (i.e. headcount data) are also the most appropriate way to collect additional information about the staff working in the field of R&D, such as data on their age and sex,
- to better understand the structure of R&D personnel and its place in the wider resource of scientific and technical personnel, it is recommended to collect data on the number of researchers and – where possible – including those belonging to other categories of R&D personnel, broken down by sex and age,
- the ideal database should cover total national human resources in the field of S&T at certain moments of time, broken down by occupational status and sector and type of employment, it should also include information on inflows (mainly graduates and immigrants) and outflow (mainly retirement and emigration) of S&T personnel. Both the resources and flows should be included in the division into area of science and technology, categories of age and sex, and possibly into categories national or ethnic origin."

Although one of the many socioeconomic objectives of the OECD research on social identity, (gender), including discrimination and related issues, methodological recommendations in the area of measuring innovation to some extent meet the category of sex, but in practice do not take into account gender, i.e. the roles ascribed to women and men in society, and which may have an impact on the course and the nature of creativity and innovation.

Thus, the study of innovation in the current formula does not give the answer to the question of whether gender translates into creativity and innovation. In the author's opinion, patent information still provides more opportunities in this field. It reached maximum depth in such processes as compared with other alternative methodological approaches. Its main advantage is the high flexibility of aggregation and disaggregation of the processes studied. It is not, however, devoid of drawbacks.

9.2. Patent information in the study of creativity and innovation

A patent application is: an economic event; one of the many steps in the process of innovation; and (often) the culmination of research and development work. The right of protection obtained is a potential resource of commercial activities for organizations that can evolve into a production factor. A patent is not an innovation. But its indirect nature means that patent information represents a kind of bridge between the results of R&D activity (i.e. the creativity) and enterprise deployment activities (i.e. the innovation).

Methodological discussion on the scope and methods of use of patent statistics in economic research is not extensive in comparison with the methodological discussions in the areas of innovation or bibliometrics. Nevertheless, a catalogue of several fundamental rules for the design of a survey procedure taking gender into account emerges from it.

The information contained in collections of patent information can be divided into three main pillars:

1) technical specifications and the potential value of the new solution (technical classification, the number of citations in other patents, the number of licences granted, the rhythm of change enabled by the patent as a result of market transactions),
2) the development of the invention (the group structure of the inventors, their affiliations, the structure and nature of the applicants, the development progress of the "triadic family"[6]),
3) the history of the application: the filing date (in a given country, in other modes of protective proceedings, etc.), date of publication, date of refusal or withdrawal, the date of the grant of the patent, and the monopoly expiry date (non-payment or non-extension of the patent).

Patent documentation, called the patent literature, requires a standardized bibliographic description of its content (formal and pragmatic considerations). The standard bibliographic patent document recommended by the World Intellectual Property Organization is Standard ST.9.[7] The main goal of unifying the attributes of patent description is to increase the availability and efficiency of searching the patent literature (calculated in the tens of millions of documents).

Rapid technological development in the field of IT infrastructure for data repositories,[8] including collections of patent information, is a powerful accelerator increasing the quality, intensity and effectiveness of research.[9] An important advantage of patent information collections is their availability in the long term (even counted in decades). This provides great opportunities for their use in research. The content of patent databases and long-time series describing them enable the aggregation of data at any level.

6 The "triadic patent family" refers to an invention, which was filed simultaneously in different modes: EPO, JPO and USPTO and obtained a patent in the group of the most economically developed countries in the world. At the core of this concept is the assumption of outstanding significance of technical and economic importance of industrial property rights.

7 http://www.wipo.int/export/sites/www/standards/en/pdf/03-09-01.pdf.

8 There are two basic models of communication and sharing of digital objects (records) in information systems. The first is remote access, in which metadata is introduced to the system repository in the process of harvesting – these resources remain in the provider's repository and can be transferred to the user; the second is a direct placement of the material in the system's repository database.

9 The first to discover the potential were Scherer (1965) and Schmookler (1966) indicating the directions of research. With the advent of technological capabilities (electronic data files), empirical verification of suitability is starting: Griliches (1984, 1990), Griliches, Pakes, and Hall (1987) Schankerman and Pakes (1986) were the first to operate on data from European countries.

One of the most important attributes of patent information is the information on the creator of a new solution. The standard bibliographic record of the description enables a multi-layered analysis of the inventors (women/men) in conjunction with a range of other data. The creator(s) of a technical solution claimed in the patent can be scrutinized in the following dimensions:

1) sex (in the case of a single person indicated as the creator in the patent documentation),
2) structure of the development team by sex (two women, two men, etc.),
3) group structure according to sex and country (region) of origin[10] (Polish woman, a Norwegian woman, a Polish man, a man from Germany),
4) priority of the inventors – the order of inventors in the patent descriptions is not accidental, it is often due to the involvement of individual team members in the development of the new solution,
5) heterogeneity of the development team in terms of patent applications and their success (in the form of patents granted),
6) heterogeneity of the development team in terms of the intensity of citation of the solution in other, subsequent patents,
7) structure of the development team combined with the field of technology which embraces the new solution,
8) heterogeneity and the size of the team in conjunction with the geographical scope of protection (national, regional),
9) heterogeneity of the development team in terms of economic exploitation of the solution (by using information on licences granted for this solution).

For countries where the proportion of individuals acting as operator of an application for patent protection is large (e.g. in Poland), the above analysis schema can be used for individuals (women/men) occurring not in the role of inventors but as applicant and patentee.

Information is provided in different modes; but in practice actual access to the full set of metadata is very difficult. Following are selected barriers identified by the author to access to complete sets of data:

1) part of the collection of patent literature remains on paper media,
2) national patent offices do not provide the functionality and tools to acquire metadata automatically and wholesale,
3) digital repositories of accumulated public patent documents have a fairly simple architecture, and limited functionality available to their users,
4) Patent reporting of national and regional patent organizations transferred to the statistical offices is generic, superficial, and further their visibility in the public statistics does not allow for serious research,
5) against the limitations identified above are commercial distributors; acquisition of patent information in their issue is professional, functional, but also costly for the end user.

10 In addition to male and female names, residential addresses are an important component including post codes.

The main international patent databases maintained and provided by various international organizations include:

1) The European Patent Register, European Patent Register and Espacenet – databases run by the European Patent Office,
2) Patentscope – a database maintained by the World Intellectual Property Organization,
3) DEPATISnet – the database and information service of the German patent system,
4) USPTO – full-text database documentation for applications and patents granted in the United States,
5) Thomson Innovation – a commercial database that allows you to explore extensive and structured sets of applications and patents granted.

Others, often of a thematic nature are: Cippix® (chemistry); GenomeQuest (biology); LexisNexis; MicroPatent; and Delphion (integrates USPTO, EPO, and WIPO databases); "JP-Nete;" KPA Search In KIPRIS – Free Services.

From the point of view of the Research Task carried out, taking into account the above considerations, it seems possible to apply the following criteria to looking at gender in terms of creativity as the first phase of the innovation process:

1) terms of applications (divided into successive phases and modes of notification procedures[11]),
2) geographical coverage of protection (international, European, national, regional),
3) technology area (usually using a hierarchical International Patent Classification or other classifications such as Thomson Reuters DWPI℠ Classification, or WIPO IPC/TECH Concordance Table),
4) the applicant/co-applicant (if the applicant is not the inventor, the inventor and the basis for the right to obtain a patent is indicated in the application filed),
5) addresses: of applicants and inventors (postal codes enabling precise geographical location in the economic space).

In the years 1994–2013, the Polish Patent Office granted approx. 53 thousand binding patent monopolies in Poland. Working with such a large collection of bibliographical metadata requires the use of automated techniques for grouping objects using: dictionaries of male and female names (separately for the inventors

11 Depending on the territorial scope in which you want to protect your invention, a patent may be obtained as follows: (1) nationally, on the basis submitting an invention to the Polish Patent Office, after formally verifying the correctness of the application and on payment of applicable administrative fees charged by the PPO; the patent protection granted nationally (national patent) extends only to a given territory (one country); (2) European, a patent granted on the basis of a single application to the European Patent Office under the provisions of the Convention on the Grant of European Patents; after granting a European patent it protects the invention in the countries mentioned in the application (a bundle of national patents); (3) under the Patent Cooperation Treaty (PCT), on the basis of a single application of "international" lodged in: The Polish Patent Office, the European Patent Office, or directly at the International Bureau of the World Intellectual Property Organisation (IB WIPO). In the latter two cases, the application can be made only if a previous application was filed under the national procedure.

and applicants); post codes (standard recognized separately in the case of inventors and headquarters address/addresses of applicants); typical university abbreviations and common organizational and legal forms of enterprises (University, University of Technology, Ltd., Joint Stock Company, PLC, etc.) and the use of concordance tables for analyzing gender, not only in terms of dynamic, and space, but also from the perspective of the area of technology.

Conclusion

The collection of objects and their further setting in context (i.e. giving them meaning and content) is a key step in the process of cognition. In the scientific layer, the way manner of organizing the data collection process, processing, inference, and presentation determines the approach or departure from the truth. At the application layer (economic policy) this allows you to manage the area of uncertainty associated with the decision-making process; it is intended to support: resource allocation, monitoring of performance, identification and/or indications for social development trends, and forecasting.

The current development of measuring the effects of academic, scientific-technical, and innovative activity in terms of the roles ascribed to women and men in society, and that could have a significant impact on the course and nature of that activity, does not aid in its present form in obtaining answers to the question of whether the social roles and relationships men and women affect their creativity and innovation. In the author's opinion, only the comprehensive collections of patent information allow us to quantify the effects of gender relations in scientific and technical works simultaneously on several levels of economic analysis. The effects of the entire complex process of innovation in terms of gender relations still require a dedicated measurement methodology to be defined which is capable of being performed primarily at the microeconomic level. Subsequent chapters are examples of the approach derived here.

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