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A NEW APPROACH TOWARDS THE MEASUREMENT OF INNOVATION AND TECHNOLOGICAL ACTIVITIES

Abstract

Innovation activities contribute essentially to competitiveness and growth. Technological infrastructure and innovation capabilities affect not only the regional growth, but also the whole periphery and economy, as well. This paper attempts to analyze the background of innovation statistics and in particular to examine the measurement and also the statistical estimation of innovation activities. The question addressed in this paper, is whether the recent slow-down in productivity can be explained by the slow-down of innovation activities. It attempts to model and measure technical change, in order to measure the corresponding effects of economic growth. Then, the characteristics of innovation process are broadly examined: nature, sources along with the main affecting factors. The paper concludes by summarizing the major findings of the discussion and pointing to some directions for future research. On this context, it also aims to emphasize and to review the appropriate techniques, the most common methods and the particular problems.

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1. Introduction

Scientific and technological innovation may be considered the transformation of an idea into a new or improved product introduced to the market, into a new or improved operational process used in industry and commerce, or into a new approach to a social service. The word «innovation» can have different meanings in different contexts and the one chosen will depend on the particular objectives of measurement or analysis. So far, international norms for data collection proposed in the Oslo Manual have been developed only for technological innovation. Technologically products may indicate the new or improved products and processes. The meaning of the label «technological», as applied to products and processes, and its precise scope in surveys and studies, can be unclear. It is not always easy to distinguish between the special meaning attributed here and the dictionary definitions of the word which may differ subtly between countries, as well as the nuances of the word to which respondents may react.

This paper deals with the measurement of innovation activities. Three main topics related to such difficulties will be discussed in this paper:

- how definitions of technological innovation should be applied; several factors should be actually taken into account, including: the relation between technological and non-technological innovations;
- what the characteristics of innovation and technological activities; and also
- how we can apply and measure the main indexes and estimate the effects through these variables.

2. Innovation and Technological Activities

Joseph Schumpeter is often mentioned as the first economist having drawn attention to the importance of innovation and having defined five types of innovation, ranging from introducing a new product to changes in industrial organisation. The Oslo Manual clarifies the definition of the two more technical definitions, but it still appears that «innovation» is not easy to define precisely.

In principle, according to Schumpter's theory, we may consider that innovation can result from technology transfer or the development of new business concepts. It can be therefore technological, organisational or presentational. It is clear there are links between research and innovation, with the research laboratory being the optimal starting point.

The distinction between a technologically new product and a technologically improved product may pose difficulties for some industries, notably in services.

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

A technological product and process innovating firm is one that has implemented technologically new or significantly technologically improved products or processes during the period under review, (OECD Oslo Manual, Second Edition, December 1996). Technological product and process innovation activities are all those scientific, technological, organizational, financial and commercial steps which actually, or are intended to, lead to the implementation of new or improved products or processes. Some may be innovative in their own right, others are not novel but are necessary for implementation.

UNESCO has developed a broad concept of STA (Scientific and Technological Activities) and included in its «Recommendation concerning the International Standardisation of Statistics on Science and Technology» (UNESCO, 1978). In addition to R&D, scientific and technological activities comprise scientific and technical education and training (STET) and scientific and technological services (STS). The latter include, for example, S&T activities of libraries and museums, translation and editing of S&T literature, surveying and prospecting, data collection of socio-economic phenomena, testing, standardisation and quality control, client counselling and advisory services, patent and licensing activities by public bodies. R&D (defined similarly by UNESCO and OECD) is thus to be distinguished from both STET (Scientific and Technical Education and Training) and STS (Scientific and Technological Services). Table 1 illustrates the main categories and classifications of innovation activities

Table 1.

Main Categories and Classifications of Innovation Activities

Main Categories and Classifications
R&D R&D is «classic» innovation investment: scientific research and development that produces new knowledge in the form of ideas or products that can be marketed by firms.
Design Investment in design has been described by some macroeconomists as «non-scientific R&D». These designs may be critical in the innovation process, as they play an important role in new product and service development. This category is also assumed to include those investments aimed at developing new services and financial products.
Organizational improvement Organizational innovation drives the efficiency and effectiveness of organizations. Investing in this type of knowledge is critical to stay competitive and be able to leverage innovative ideas and commercially exploit them.
Training & skills development Investment in workforce skills turns out to be one of the most important sources of investment. Therefore the investment in training and skills development is critical to the innovative capacity of firms; it is particularly important for service innovations: the most significant investment to realize these may be in human capital.
Software development Resources invested in developing software and databases create a valuable asset.
Market research & advertising Market research is at the front end of innovation aiming to identify the market potential for new products companies must at the outset anticipate future demand. This category captures other investments made to develop brands in order to take products to market. Both are strategic elements of the innovation process.
Other (Copyright development and mineral exploration) Investment in new knowledge of exploitable mineral sources and copyrighted ideas both lead to assets that firms can commercially exploit and which are frequently capitalized in firms' financial accounts. These two apparently dissimilar types of asset are grouped together to reflect the way they are treated in the national accounts, but represent the smallest category of investment measured.

Source: NESTA (2009), *The Innovation Index Measuring the UK's investment in innovation and its effects,* Index report: November 2009, United Kingdom.

The most widely used definitions of research and innovation activities are provided by the *Frascati-Manual*. In an effort to standardize definitions and data collection on research expenditures, the Organisation of Economic Cooperation and Development (OECD) has proposed in the so-called *Frascati Manual* (1981, and 1989) that: «Research and Experimental Development comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge.... and the use of this stock of knowledge to devise new applications». From a statistical point of view, while when measuring research and innovation activities there are two inputs:

- (a). The people who work in research activities and
- (b). The expenditures related to research and technological activities.

Research data usually refer to research expenditures (such as gross research expenditures) or innovation criteria (such as the number of external patent applications and the national patent applications) and to the scientific criteria (such as research and scientific personnel).

The output of R&D or science and technology (S&T) in general can be measured in several ways. Innovation surveys are an attempt to measure outputs and the effects of innovation process in which R&D plays an important role. A manual of innovation surveys has been issued and revised by OECD.

Gross domestic expenditure on research and development (GERD) is total intramural expenditure on research and development performed on the national territory during a given period. (as defined in the OECD Frascati and Oslo Manuals).

Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development. (United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics).

Expenditure on research activities may be spent within the statistical unit (*intramural*) or outside (*extramural*). According to the OECD, *intramural expenditures* are defined as: «All expenditure on research activities performed within a statistical unit or sector of the economy, whatever the source of funds. Expenditures made outside the statistical-unit or sector but in support of intramural R&D (such as, purchase of supplies of R&D) are included. In addition, for R&D purposes, both current and capital expenditures are measured, while depreciation payments are excluded».

R&D is an activity during which there are significant transfers among units, organizations and sectors. R&D activities are usually classified under the following three headings:

- (a). *Basic research*, which can be defined as: «Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view».
- (b). *Applied research,* which is: «Original investigation undertaken in order to acquire new knowledge, which however is directed primarily towards a specific practical aim or objective».
- (c). *Experimental development,* which can be defined as: «Systematic word, drawing on existing knowledge gained from research and practical experience, that is directed to producing new materials, products and devices, to installing new processes, systems and services and also to improve substantially those already produced or installed».

The European Commission uses slightly different variation of these definitions and makes the following classification:

- (a). *Fundamental research* which is similar to the Basic Research as defined by OECD (in Frascati Manual, (1981) and (1989));
- (b). *Basic industrial R & D* which is concerned with the development of industrial technology;
- (c). *Applied R&D* which refers to the application of technologies to the new products.

Beside R&D, six fields of innovative activities may often be distinguished in the innovation process:

- (a). *Tooling-up and industrial engineering* cover acquisition of and changes in production machinery and tools and in production and quality control procedures, methods, and standards required to manufacture the new product or to use the new process.
- (b). *Manufacturing start-up and preproduction development* may include product or process modifications, retraining personnel in the new techniques or in the use of new machinery, and trial production if it implies further design and engineering.
- (c). *Marketing for new products* covers activities in connection with launching of a new product. These may include market tests, adaptation of the product to different markets and launch of advertising, but will exclude the building of distribution networks for market innovations.
- (d). *Acquisition of disembodied technology* includes acquisition of external technology in the form of patents, non-patented inventions, li-

censes, disclosure of know-how, trademarks, designs, patterns, and services with a technological content.

- (e). *Acquisition of embodied technology* covers acquisition of machinery and equipment with a technological content connected with either product or process innovations introduced by the firm.
- (f). *Design* is an essential part of the innovation process. It covers plans and drawings aimed at defining procedures, technical specifications, and operational features necessary to the conception, development, manufacturing and marketing of new products and processes. It may be a part of the initial conception of the product or process, as for instance, research and experimental development, but it may also be associated with tooling-up, industrial engineering, manufacturing start-up, and marketing of new products.

Measurement of the *personnel employed on research activities* involves, firstly, the identification of what types of personnel should be initially included, and, secondly, the measurement of research activities in the full time equivalent. Personnel is a more concrete measure and, since labour costs normally account for 50–70 per cent of total R&D expenditures, it is also a reasonable short-term indicator of efforts devoted to R&D. Personnel can be defined as: «All the persons directly on R&D, as well as those providing direct services such as R&D, managers, administrators and clerical staff. In particular, *Research personnel* can be considered either as the number of *researchers, scientists and engineers*, or the *technicians and equivalent staff*».

According to OECD (Oslo and Frascati Manuals):

- (a). *Researchers, scientists and engineers* are usually those who are: «Engaged in the conception or creation of new knowledge, products, processes, methods and systems».
- (b). *Technicians and equivalent staff* include those: «Who participate in R & D projects by performing S&T tasks normally under the supervision of scientific and engineers».

The measurement of personnel employed in R&D involves three exercises:

- identifying which types of personnel should be initially included;
- measuring their number;
- measuring their R&D activities in full-time equivalent (person-years).

Technicians in R&D and equivalent staff are people whose main tasks require technical knowledge and experience in engineering, physical and life sciences (technicians), or social sciences and humanities (equivalent staff). They participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers. (United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.

Human capital is productive wealth embodied in labour, skills and knowledge, Human development is the process of enlarging people's choices. Their three essential choices are to lead a long and healthy life, to acquire knowledge and to have access to the resources needed for a decent standard of living. Additional choices, highly valued by many people, range from political, economic and social freedom to opportunities for being creative and productive and enjoying personal self–respect and guaranteed human rights. (defined in the OECD Frascati Manual)

Technological balance can be considered as what measures a country's balance of payments and receipts concerning the sale and purchase of knowledge and technological information. The technology balance of payments (TBP) registers the commercial transactions related to international technology and know-how transfers. It consists of money paid or received for the use of patents, licenses, know-how, trademarks, patterns, designs, technical services (including technical assistance) and for industrial research and development (R&D) carried out abroad, etc. The coverage may vary from country to country and the TBP data should be considered as only partial measures of international technology flows. (OECD: Frascati and Oslo Manuals). Technology Balance of Payments (TBP) registers the international flow of industrial property and know-how. The following operations are included in the TBP: patents (purchases, sales); licences for patents; know-how (not patented); models and designs; trademarks (including franchising); technical services; finance of industrial R&D outside national territory.

The «contribution to the trade balance» makes it possible to identify an economy's structural strengths and weaknesses via the composition of international trade flows. It takes into account not only, but also imports and tries to eliminate business cycle variations by comparing an industry's trade balance with the overall trade balance. It can be interpreted as an indicator of «revealed comparative advantage», as it indicates whether an industry performs relatively better or worse than the manufacturing total, whether the manufacturing total itself is in deficit or surplus. If there were no comparative advantage or disadvantage for any industry *i*, a country's total trade balance (surplus or deficit) should be distributed across industries according to their share in total trade. The «contribution to the trade balance» is the difference between the actual and the theoretical balance, as expressed in the following equations:

$$(X_i - M_i) - (X - M)\frac{(X_i + M_i)}{(X + M)}$$

where $(X_i - M_i)$ = observed industry trade balance

and $(X - M)\dfrac{(X_i + M_i)}{(X + M)}$ = theoretical trade balance

R&D is an activity involving significant transfers of resources among units, organisations and sectors and especially between government and other performers. It is important for science policy advisors and analysts to know who finances R&D and who performs it. The main disadvantage of expressing R&D input series in monetary terms is that they are affected by differences in price levels between countries and over time. It can be shown that current exchange rates often do not reflect the balance of R&D prices between countries and that in times of high inflation general price indexes do not accurately reflect trends in the cost of performing R&D.

3. Approaching the Leading Indicators

Measurement of innovation and technological change has played a major role in the analysis and understanding of the links between entrepreneurship and innovation. Measures of technological change have typically involved one of the three major aspects of the innovative process:

- (a). A measure of the inputs into the innovative process, such as R&D expenditures, or else the share of the labor force accounted for by employees involved in R&D activities;
- (b). An intermediate output, such as the number of inventions which have been patented; or
- (c). A direct measure of innovative output.

The summary indexes, the overall index of technological achievement, and the technological adaptive capacity index were calculated by aggregating some 34 separate variables, with the weights used in the aggregation calculated by principal components analysis. This approach distinguishes these indexes, which even though they are based on similar underlying base data, use arbitrary weighting schemes with limited theoretical or empirical bases. A number of existing measures of technological achievement or technological progress emphasize inputs into technological advancement (numbers of scientists and engineers, R&D expenditure, or levels of R&D personnel), including, in some cases, even more indirect inputs, such as the general level of education of the population and governance factors that facilitate the absorption of technology (UNCTAD 2005). Other measures focus on an output that is, on indicators of technological performance, such as the shares of high-tech industries in exports and in manufacturing value added (UNIDO 2002).

The index of competitive industrial performance is published by the United Nations Industrial Development Organization (UNIDO 2002) and is calculated as a simple average of four basic indicators: manufacturing value added per capita, manufactured exports per capita, share of medium- and high-tech activities in manufacturing value added, and share of medium- and high-tech products in manufactured exports.

Investment in knowledge is defined and calculated as the sum of expenditure on R&D, on total higher education from both public and private sources and on software. Simple summation of the three components would lead to overestimation of the investment in knowledge owing to overlaps (R&D and software, R&D and education, software and education). Therefore, before calculating total investment in knowledge, the data must be reworked to derive figures that meet the definition. The R&D component of higher education, which overlaps R&D expenditure, has been estimated and subtracted from total expenditure on higher education (both public and private sources). Not all expenditure on software can be considered investment. Some should be considered as intermediate consumption. Purchases of packaged software by households and operational services in firms are estimated. The software component of R&D, which overlaps R&D expenditure, is estimated when information from national studies and subtracted from software expenditure is used. Due to a lack of information, it was not possible to separate the overlap between expenditure on education and on software; however, the available information indicates that this overlap is quite small. A more complete picture of investment in knowledge would also include parts of expenditure on innovation (expenditure on the design of new goods), expenditure by enterprises on job-related training programs, investment in organisation (spending on organisational change, etc.), among others. However, due to the lack of available data, such elements could not be included. Knowledge-economy is closely related to the Information Technology (IT) and Information Communication Technology (ICT). *IT* covers both hardware and software. Their development and diffusion is believed to have had a major impact on the pattern of production and employment in a wide range of industries. In the case of hardware, it may be interesting not only to know when a company innovates by first introducing a technologically new or improved piece of IT equipment but also the IT proportion of its total stock of equipment including subsequent purchases of further machines of the same model.

The amount of tax subsidy to R&D is calculated as 1 minus the B index. The B index is defined as the present value of before-tax income necessary to cover the initial cost of R&D investment and to pay corporate income tax, so that it becomes profitable to perform research activities. Algebraically, the B index is equal to the after-tax cost of an expenditure of USD 1 on R&D divided by one minus the corporate income tax rate. The B index is a unique tool for comparing the generosity of the tax treatment of R&D in different countries. However, its computation requires some simplifying assumptions. It should therefore be examined together with a set of other relevant policy indicators. Finally, these calculations are based on reported tax regulations and do not take into account country-specific exemptions and other practices. B indexes have been calculated with the assumption that the «representative firm» is taxable, so that it may enjoy the full benefit of the tax allowance or credit. For incremental tax credits, calculation of the B index implicitly assumes that R&D investment is fully eligible for the credit and does not exceed the ceiling if there is one. Some detailed features of R&D tax schemes (for instance, refunding, carry-back and carry-forward of unused tax credit, or flow through mechanisms) are therefore not taken into account. The effective impact of the R&D tax allowance or credit on the after-tax cost of R&D is influenced by the level of the CITR. An increase in the CITR reduces the B index only in those countries with the most generous R&D tax treatment. If tax credits are taxable (as in Canada and the United States), the effect of the CITR on the B index depends only on the level of the depreciation allowance. If the latter is over 100% for the total R&D expenditure, an increase in the CITR will reduce the B index. For countries with less generous R&D tax treatment, the B index is positively related to the CITR. The after-tax cost is the net cost of investing in R&D, taking into account all the available tax incentives. $\mathrm{B}index = \frac{(1-A)}{(1-\tau)}$, where A = the net present discounted value of depreciation allowances, tax credits and special allowances on R&D assets; and t = the statutory corporate income tax rate (CITR). In a country with full write-off of current R&D expenditure and no R&D tax incentive scheme, $A = t$, and consequently $B = 1$. The more favourable a country's tax treatment of R&D, the lower its B index.

The index of innovation capability is published by the United Nations Conference on Trade and Development (UNCTAD 2005) and consists of an unweighted average of an index of human capital (calculated as a weighted average of tertiary and secondary school enrollment rates and the literacy rate) and a technological activity index (calculated as an unweighted average of three indicators: R&D personnel, U.S. patents granted, and scientific publications, all per million population).

The technology achievement index is published by the United Nations Development Program (UNDP 2001) and combines (a) the indicators of human skills (mean years of schooling in the population age 15 and older and enrollment ratio for tertiary-level science programs); (b) the diffusion of old innovations (electricity consumption per capita and telephones per capita) and of recent innovations (Internet hosts per capita and high- and medium-tech exports as a share of all exports); and (c) the creation of technology (patents granted to residents per capita and receipts of royalties and license fees from abroad). The index is constructed as simple averages of these indicators within subgroups and then across groups.

The national innovative capacity index (Porter and Stern 2003) focuses on government-and firm-level policies associated with successful innovation. It is composed of four sub indexes: proportion of scientists and engineers in the population, innovation policy, innovation linkages and what they call the cluster innovation environment. The overall index is calculated as an unweighted sum of the four sub indexes, but the weights assigned to each indicator in the sub indexes are determined by the coefficients obtained from a regression of the number of U.S. Patent and Trademark Office patents on the relevant indicators controlling for total population, the proportion of scientists and engineers employed, and the stock of international patents generated by the country between 1985 and 1994.

The Knowledge Innovation Index using around 109 structural and qualitative variables for 146 countries to measure their performance on four Knowledge Economy pillars: Economic Incentive and Institutional Regime, Education, Innovation, and Information and Communications Technologies.

The Technological Achievement Index (TAI), a composite index of technological achievement, reflects the level of technological progress and thus the capacity of a country to participate in the network age. A composite index helps a country situate itself relative to others, especially those farther ahead. Many elements make up a country's technological achievement, but an overall assessment is more easily made based on a single composite measure than on dozens of different measures. Like other composite indices in *Human Development Reports* such as the Human Development Index (HDI), the TAI is intended to be used as a starting point to make an overall assessment, to be followed by examining different indicators in greater detail. The index aims to capture technological achievements of a country in four dimensions:

- creating new technology;
- diffusing recent innovations;
- diffusing existing technologies that are still basic inputs to the industrial and the network age; and
- building a human skill base for technological creation and adoption.

The Technological Achievement Index (TAI) focuses on outcomes and achievements rather than on effort or inputs such as numbers of scientists, R&D expenditures, or policy environments. The TAI is not a measure of which country is leading in global technology development, but focuses on how well the country as a whole is participating in creating and using technology. The methodology used to calculate the TAI is similar to the HDI: a simple average of the dimensions of the index, which in turn is calculated based on the selected indicators. The TAI has eight indicators, two in each of the four dimensions.

Technology creation, measured by the number of patents granted to residents per capita and by receipts of royalties and license fees from abroad per capita.

Diffusion of recent innovations, measured by the number of Internet hosts per capita and the share of high-technology and medium-technology exports in total goods exports.

Diffusion of old innovations, measured by telephones (mainline and cellular) per capita and electricity consumption per capita.

Human skills, measured by the mean years of schooling in the population aged 15 and older, and the gross tertiary science enrolment ratio.

Another Index is the Social Science Citation Index (SSCI). This database was used to find scientific papers that give insights into the processes of innovation, technological change and growth in regions.

The innovation system can be defined as a network of actors and institutions that develop diffuse and use innovations (Malerba et. Al., 1997). On the other hand, there is a clear correlation between the share of enterprises receiving public funding and the business R&D expenditure (% of the GDP) at geographic and firm level, (Toivanen et al, 1997; Busom, 2000; Czarnitzki et al, 2003). In order to measure the progress in that policy area, we proposed to use the following indicators: «Share of enterprises that received any public funding» (Source: CIS). The indicator shows a breakdown by source of funding making a distinction between the «share of enterprises that received funding from local or regional authorities» and the «share of enterprises that received funding from central government» (including central government agencies or ministries).

The indicators for creation of technology are patents granted per capita and royalty and license fees received from abroad per capita. Diffusion of recent innovations is calculated from the number of Internet hosts per capita and the share of high- and medium-technology exports as a percentage of all exports. Indicators for diffusion of old technology are telephones (land line and cellular) per capita and electricity consumption per capita. Human skills are calculated based on the average number of years of schooling and the gross enrolment ratio at the tertiary level in science, mathematics and engineering.

The Technology Index (TI) published in the Harvard Competitiveness Reports focuses on the enabling policy environment for technological innovation and diffusion.

The Index of Technological Progress (ITP) developed by Rodriguez and Wilson focuses only on information telecommunications technologies.

The index of Research intensity (RI) in high technology industries is the ratio of Manufacturing R&D expenditures over the manufacturing production.

The index of Export specialisation in high technology industries is the ratio of high-technology exports over the manufacturing exports.

RCA (Revealed Comparative Advantage Index) for the Information Communication Technologies (ICT) manufacturing industry in an individual country *k* relative to the total world is calculated as follows:

$$\mathrm{RCA}_{\mathrm{ICT}}^{\mathrm{k}} = \frac{\dfrac{X_{ICT}^{k}}{X_{manufacturing}^{k}}}{\dfrac{X_{ICT}^{World}}{X_{manufacturing}^{World}}}$$

where *X* denotes exports.

RTB (Revealed Technological Advantage Index) for the ICT services industry in an individual country *k* is calculated as follows:

$$\mathrm{RTB}_{\mathrm{ICT}}^{\mathrm{k}} = \frac{(X_{ICT}^{k} - M_{ICT}^{k})}{(X_{ICT}^{k} + M_{ICT}^{k})}$$

where *X* and *M* denotes exports and imports respectively.

RTB (Revealed Technological Advantage Index) is a country's share of patenting in a particular sector relative to its share of all patents and it's calculated as follows:

$$\mathrm{RTB} = \frac{\dfrac{P_i^X}{P_i^{TOT}}}{\dfrac{\sum_i P_i^X}{\sum_i P_i^{TOT}}}$$

where P_i^X is the total number of patents in sector X in country i and P_i^{TOT} is the total number of patents in all sectors in country i. The Standardized Revealed Technological Advantage Index is equal to: $\frac{(RTA-1)}{(RTA+1)}$.

The most widely used method of measuring intra-industry trade is the Grubel-Lloyd Index (GLI). Using disaggregated trade data, the extent of intra-industry trade in product class I in country j can be expressed as:

$$\mathrm{GL_i} = 1 - \frac{|X_{ij} - M_{ij}|}{X_{ij} + M_{ij}}$$

where X_{ij} represents exports of product class *i* by country *j* and M_{ij} represents imports of product class *i* by country *j*. The Grubel-Lloyd Index is zero when trade is entirely inter-industry, (for instance either imports or exports of a product is equal zero), and is 1 when trade is entirely intra-industry, (for instance either imports or exports of a product is equal to each other).

The European Regional Innovation Scoreboard (ERIS) used a composite indicator – the Revealed Regional Summary Innovation Index (RSII) which is calculated as the weighted average of the re-scaled values for Regional National Summary Innovation Index and the Regional European Summary Innovation Index. It locates *local* leaders by taking into account both the region's relative performance within the EU and the region's relative performance within the country (Danciu Aniela, Goschin Zizi, 2010). The Innovation Index was designed to measure a broad range of innovative activity, from the R&D that lies behind innovative technologies to the service design and organizational innovations and by linking investment in innovation clearly to productivity improvement, it underscores the central importance of innovation to economic growth, (NESTA, 2009)

The variables related to technological achievement and those related to technological absorptive capacity are reported in the following Table 2–12.

Table 2.

Indicators for the Summary Index and the Overall Index of Technological Achievement (TAI)

Scientific innovation and invention
• Scientific and technical journal articles by population • Patents granted by the United States Patent and Trademark Office by population • Patents granted by the European Patent Office by population
Penetration of older technologies
• Electrical Power Consumption kilowatt-hours/capita • International outgoing telephone traffic percent of GDP per 1,000 people • Main lines per 100 inhabitants • Air transport, registered carrier departures worldwide percent of GDP per 1,000 people • Agricultural machinery: tractors per 100 hectares of arable land • Exports of manufactures percent of merchandise exports • Medium-tech exports percent of total exports
Penetration of recent technologies
• Internet users per 1,000 people • Personal computers per 1,000 people • Cellular subscribers per 100 inhabitants • Percentage of digital mainlines • High-tech exports percent of total exports

Exposure to external technology
• FDI net inflows percentage of GDP • Royalties and license fee payments percent of GDP • Imports of high-tech goods percent of GDP • Imports of capital goods percent of GDP • Imports of intermediary goods percent of GDP

Source: World Bank.

Note*:* BACI – Banque analytique de commerce internationale, CEPII – Centre d'Etudes Prospectives et d'Informations Internationales, EPO – European Patent Office, FDI – foreign direct investment, GDP – gross domestic product, USPTO – United States Patent and Trademark Office.

Table 3.

Indicators for the Summary Index and the Overall Index of Technological Absorptive Capacity (ITAC)

Macroeconomic environment
• General government balance as percentage of GDP • Annual CPI inflation rate • Real exchange rate volatility
Financial structure and intermediation
• Liquid liabilities percent of GDP • Private credit percent of GDP • Financial system deposits percent of GDP
Human capital
• Primary educational attainment percent of population aged 15 and over • Secondary educational attainment percent of population aged 15 and over • Tertiary educational attainment percent of population aged 15 and over
Governance
• Voice and accountability • Political stability • Government effectiveness • Regulatory quality • Rule of law • Control of corruption

Source: World Bank.

Table 4.

Indicators for the European Innovation Scoreboard (EIS) 2008–2010

ENABLERS
Human resources & Input Innovation drivers • S&E and SSH graduates per 1000 population aged 20–29 (first stage of tertiary education) • S&E and SSH doctorate graduates per 1000 population aged 25–34 (second stage of tertiary education) • Population with tertiary education per 100 population aged 25-64 • Participation in life-long learning per 100 population aged 25-64 • Broadband penetration rate (number of broadband lines per 100 population) • Youth education attainment level (% of population aged 20–24 having completed at least upper secondary education)
Finance and support & Knowledge Creation • Public R&D expenditures (% of GDP) • Venture capital (% of GDP) EVCA / • Private credit (relative to GDP) IMF (2007) • Broadband access by firms (% of firms) • Business R&D expenditures (% of GDP) • Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures) • Share of enterprises receiving public funding for innovation • Share of university R&D expenditures financed by business sector
FIRM ACTIVITIES
Firm investments • Business R&D expenditures (% of GDP) • IT expenditures (% of GDP) • Non-R&D innovation expenditures (% of turnover)
Linkages, Innovation & Entrepreneurship • SMEs innovating in-house (% of SMEs) • Innovative SMEs collaborating with others (% of SMEs) • Firm renewal (SME entries plus exits) (% of SMEs) • Public-private co-publications per million population • Innovation expenditures (% of total turnover) • Early-stage venture capital (% of GDP) • ICT expenditures (% of GDP) • SMEs using non-technological change (% of all SMEs)
Throughputs • EPO patents per million population • Community trademarks per million population • Community designs per million population • Technology Balance of Payments flows (% of GDP)

OUTPUTS
Innovators & Intellectual Property • SMEs introducing product or process innovations (% of SMEs • SMEs introducing marketing or organizational innovations (% of SMEs) • Resource efficiency innovators, unweighted average of: • Share of innovators where innovation has significantly reduced labour costs (% of firms) • Share of innovators where innovation has significantly reduced the use of materials and energy (% of firms) • EPO patents per million population • USPTO patents per million population • Triadic patent families per million population • New community trademarks per million population • New community designs per million population
Economic effects & Applications • Employment in medium-high & high-tech manufacturing (% of workforce) • Employment in knowledge-intensive services (% of workforce) • Medium and high-tech manufacturing exports (% of total exports) • Knowledge-intensive services exports (% of total services exports) • New-to-market sales (% of turnover) • New-to-firm sales (% of turnover) • Exports of high technology products as a share of total exports • Sales of new-to-market products (% of total turnover) • Sales of new-to-firm not new-to-market products (% of total turnover) • Employment in medium-high and high-tech manufacturing (% total workforce)

Source: European Innovation Scoreboard, (2006, 2009, & 2010).

Note: Enablers capture the main drivers for innovation that are external to the firm as (European Innovation Scoreboard, 2009 & 2010):

- Human resources the availability of high skilled and educated people
- Finance and support the availability of finance for innovation projects and the support of governments for innovation activities.

Firm activities capture innovation efforts that firms undertake recognizing the fundamental importance of firms'activities in the innovation process (European Innovation Scoreboard, 2009 & 2010):

- Firm investments cover a range of different investments firms make in order to generate innovations.
- Linkages and entrepreneurship captures entrepreneurial efforts and collaboration efforts among innovating firms and also with public sector.
- Throughputs capture the Intellectual Property Rights (IPR) generated as a throughput in the innovation process and Technology Balance of Payments flows.

Outputs capture the outputs of firm activities as (European Innovation Scoreboard, 2009 & 2010):

- Innovators capture the number of firms that have introduced innovations into the market, or, within their organizations covering technological and non-technological innovations.
- Economic activities capture the economic success of innovation in employment, exports and sales due to innovation activities.

Table 5.

EU27–US–Japan Indicators

ENABLERS
• S&E graduates per 1000 population aged 20-29 • Population with tertiary education per 100 population aged 25-64 • Researchers per 1000 population • Public R&D expenditures (% of GDP) • Venture capital (% of GDP) • Broadband subscribers per 1000 population
FIRM ACTIVITIES

• Business R&D expenditures (% of GDP)
• IT expenditures (% of GDP)
• Public-private co-publications per million population
• EPO patents per million population
• PCT patents per million population
• Trademarks per million population, average of:
    • Community trademarks per million population
    • Trademark applications (residents) per million population
• World Development Indicators
• Technology Balance of Payments flows (% of GDP)

OUTPUTS
• Employment in medium-high & high-tech manufacturing (% of workforce) • Employment in knowledge-intensive services (% of workforce) • Medium and high-tech manufacturing exports (% of total exports) • Knowledge-intensive services exports (% of total services exports)

Source: European Innovation Scoreboard, 2009.

Table 6.

A Proposal for Innovation Policy Framework

1. Research & Innovation governance and strategic intelligence for policy-making. • Development of long term vision, studies and strategies in the field of R&D and Innovation policies • Definition of regional targets priorities for public and private investments in R&D and Innovation • Implementation of R&D and innovation governance structures (including specific regulation) • Encouraging transnational cooperation in R&D and innovation.

2. Research & innovation friendly environment, including regulatory framework, taxes and regional aid. • Grants to public sector R&D and Innovation Institutions • Grants supporting business R&D and Innovation including aid for researchers • Increase access to sources of finance for R&D and Innovation including tax incentives • Improving the regulatory environment, administrative simplification and public procurement
3. Technology and knowledge transfer to enterprises and development of innovation poles and clusters and cooperation between public research and industry • Developing public private partnerships for R&D and Innovation (Research Centers, Universities Business) • Promoting centers & networks of excellence, regional research driven clusters and innovation poles • Improving R&D cooperation and technology transfer • Strengthen innovation intermediaries
4. Creation and growth of innovative enterprises • Funding facilities for innovative enterprises and start-ups including leveraging private funding • Supporting the promotion of innovation skills and the recruitment (identification) of innovators • Specific monitoring and R&D programs aimed to innovative enterprises • Disseminating the importance of business innovation culture
5. Intellectual property. • Improvement of Intellectual Property Right regimes • Supporting the Intellectual Property protection at public and private level • Commercialization and transfer of IPR • Promote the use of IPR for Start -ups
6. Regional infrastructures for research and innovation. • Encouraging the R&D and Innovation system. • Promotion of R&D services for enterprises • Infrastructures for start -ups and innovative enterprises • Supporting infrastructures for R&D and Innovation (ICT, training…)
7. Human resources in research and innovation. • Enhancing the mobility of researchers both at national and international level • Developing suitable conditions to attract researchers • Raising young people’s interest in science, research and innovation • Cooperation between University and Enterprise (teaching and research)

Source: Korres (2011).

Following the build-up of the EIS composite innovation index, the regional innovation indexes have been calculated as a weighted average of the average performance for Enablers, Firm activities and Outputs (INNOMETRICS, 2009):

- CI Enablers =Average of normalized transformed scores for the indicators Tertiary education, Life-long learning, Public R&D expenditures and Broadband access
- CI Firm activities = 8/11 * average of normalized transformed scores for the indicators Business R&D expenditures EPO patents + (plus) 3/11 * average of normalized transformed scores for the indicators Non-R&D innovation expenditures, SMEs innovating in-house and Innovative SMEs collaborating with others, (where the weights of 8/11 and 3/11 represent the share of non-CIS and CIS indicators in the EIS).
- CI Outputs = 4/9 * average of normalized transformed scores for the indicators

Employment in medium-high & high-tech manufacturing and Employment in knowledge-intensive services + (plus) 5/9 * average of normalized transformed scores for the indicators Product and/or process innovators, Marketing and/or organizational innovators, Resource efficiency innovators, New-to-market sales and New-to-firm sales, (where the weights of 4/9 and 5/9 represent the share of non-CIS and CIS indicators in the EIS).

- CI RIS (RII) = 9/29 * CI Enablers + 11/29 * CI Firm activities + 9/29 * CI Outputs, (where the weights represent the share of the indicators captures in Enablers).

Table 7.

Technology Achievement Index

Countries	Technology Achievement Index
Finland	0.93 % of GDP
Sweden	0.93 % of GDP
France	0.81 % of GDP
Germany	0.81 % of GDP
United States	0.77 % of GDP
Netherlands	0.74 % of GDP
Switzerland	0.73 % of GDP
Norway	0.72 % of GDP
Austria	0.71 % of GDP

Countries	Technology Achievement Index
Australia	0.71 % of GDP
Denmark	0.71 % of GDP
Japan	0.59 % of GDP
New Zealand	0.59 % of GDP
Italy	0.53 % of GDP
Canada	0.52 % of GDP
United Kingdom	0.52 % of GDP
Belgium	0.46 % of GDP
Ireland	0.31 % of GDP
Weighted average	0.7 % of GDP

Source: World Bank

Table 8.

The Knowledge Economy Index (KEI)

Rank	Country	KEI	KI	Economic Incentive Regime	Innovation	Education	ICT
1	Denmark	9.52	9.49	9.61	9.49	9.78	9.21
2	Sweden	9.51	9.57	9.33	9.76	9.29	9.66
3	Finland	9.37	9.39	9.31	9.67	9.77	8.73
4	Netherlands	9.35	9.39	9.22	9.45	9.21	9.52
5	Norway	9.31	9.25	9.47	9.06	9.60	9.10
6	Canada	9.17	9.08	9.45	9.44	9.26	8.54
7	United Kingdom	9.10	9.06	9.24	9.24	8.49	9.45
8	Ireland	9.05	8.98	9.26	9.08	9.14	8.71
9	United States	9.02	9.02	9.04	9.47	8.74	8.83
10	Switzerland	9.01	9.09	8.79	9.90	7.68	9.68
11	Australia	8.97	9.08	8.66	8.88	9.69	8.67
12	Germany	8.96	8.92	9.06	8.94	8.36	9.47
13	Iceland	8.95	8.76	9.54	8.07	9.41	8.80
14	New Zealand	8.92	8.97	8.79	8.66	9.78	8.46
15	Austria	8.91	8.78	9.31	9.00	8.48	8.85
16	Belgium	8.80	8.77	8.87	8.93	9.14	8.25
17	Luxembourg	8.64	8.37	9.45	9.00	6.61	9.51
18	Taiwan, China	8.45	8.79	7.42	9.27	7.97	9.13
19	Singapore	8.44	8.03	9.68	9.58	5.29	9.22
20	Japan	8.42	8.63	7.81	9.22	8.67	8.00

Rank	Country	KEI	KI	Economic Incentive Regime	Innovation	Education	ICT
21	Estonia	8.42	8.31	8.76	7.56	8.32	9.05
22	France	8.40	8.64	7.67	8.66	9.02	8.26
23	Hong Kong, China	8.32	7.92	9.54	9.04	5.37	9.33
24	Spain	8.28	8.18	8.60	8.14	8.33	8.07
25	Slovenia	8.15	8.17	8.10	8.31	8.31	7.88
26	Israel	8.01	7.93	8.24	9.40	6.86	7.54
27	Hungary	8.00	7.88	8.35	8.21	7.73	7.70
28	Czech Republic	7.97	7.90	8.17	7.78	8.23	7.70
29	Korea, Rep.	7.82	8.43	6.00	8.60	8.09	8.60
30	Italy	7.79	8.18	6.62	8.00	7.96	8.59
31	Lithuania	7.77	7.70	7.98	6.70	8.40	7.99
32	Latvia	7.65	7.52	8.03	6.63	8.35	7.58
33	Portugal	7.61	7.34	8.42	7.41	6.95	7.66
34	Malta	7.58	7.18	8.78	7.95	5.86	7.74
35	Cyprus	7.50	7.47	7.60	7.81	6.65	7.95
36	Slovak Republic	7.47	7.37	7.78	6.89	7.26	7.95
37	Poland	7.41	7.38	7.48	7.03	8.02	7.09
38	Greece	7.39	7.58	6.82	7.57	8.21	6.94
39	Aruba	7.38	7.26	7.74	7.73	7.03	7.01
40	Croatia	7.28	7.28	7.26	7.67	6.56	7.62
41	Barbados	7.16	7.58	5.92	7.63	8.09	7.00
42	Chile	7.09	6.53	8.76	6.85	6.48	6.27
43	Bulgaria	6.99	6.94	7.14	6.43	7.65	6.74
44	Qatar	6.73	6.63	7.05	6.45	5.37	8.06
45	United Arab Emirates	6.73	6.72	6.75	6.69	4.90	8.59
46	Uruguay	6.49	6.54	6.35	5.37	7.79	6.45
47	Romania	6.43	6.25	6.98	5.74	6.47	6.55
48	Malaysia	6.07	6.06	6.11	6.82	4.21	7.14
49	Bahrain	6.04	5.80	6.75	4.29	5.82	7.30
50	Costa Rica	6.03	5.84	6.60	6.25	5.19	6.07
51	Ukraine	6.00	6.58	4.27	5.83	8.15	5.77
52	Kuwait	5.85	5.63	6.50	4.98	4.93	6.96
53	Serbia	5.74	6.32	4.01	6.15	5.83	6.99
54	Brazil	5.66	6.11	4.31	6.19	6.02	6.13
55	Dominica	5.65	5.47	6.19	3.67	6.40	6.34
56	Armenia	5.65	5.37	6.48	6.25	6.36	3.52

Rank	Country	KEI	KI	Economic Incentive Regime	Innovation	Education	ICT
57	Trinidad and Tobago	5.59	5.49	5.88	6.10	4.43	5.95
58	Macedonia, FYR	5.58	5.66	5.34	4.67	5.42	6.88
59	Argentina	5.57	6.50	2.78	6.89	6.64	5.96
60	Russian Federation	5.55	6.82	1.76	6.88	7.19	6.38
61	Turkey	5.55	5.07	6.98	5.83	4.46	4.92
62	Jordan	5.54	5.39	5.99	5.59	5.62	4.95
63	Thailand	5.52	5.66	5.12	5.76	5.58	5.64
64	Mauritius	5.48	4.63	8.01	3.63	4.03	6.23
65	South Africa	5.38	5.33	5.55	6.85	4.68	4.45
66	Oman	5.36	4.77	7.15	4.94	4.47	4.90
67	Mexico	5.33	5.42	5.06	5.82	4.88	5.56
68	Saudi Arabia	5.31	5.10	5.94	3.97	4.89	6.43
69	Georgia	5.21	5.15	5.36	5.22	6.46	3.78
70	Panama	5.16	5.10	5.35	5.35	4.90	5.06
71	Moldova	5.07	5.30	4.38	4.79	6.05	5.08
72	Kazakhstan	5.05	5.17	4.70	3.68	7.07	4.76
73	Belarus	4.93	6.19	1.15	5.79	8.02	4.74
74	Jamaica	4.90	5.19	4.01	5.03	4.13	6.41
75	Colombia	4.84	5.02	4.27	4.48	5.09	5.50
76	Lebanon	4.81	4.93	4.42	4.53	4.92	5.35
77	Peru	4.79	4.88	4.49	3.87	5.61	5.16
78	Mongolia	4.72	4.67	4.86	3.21	6.43	4.37
79	Bosnia and Herzegovina	4.58	4.68	4.26	3.11	5.70	5.24
80	Guyana	4.57	4.97	3.34	4.78	5.94	4.21
81	China	4.47	4.66	3.90	5.44	4.20	4.33
82	Tunisia	4.42	4.54	4.04	4.65	4.08	4.88
83	Cuba	4.36	5.37	1.31	5.14	8.36	2.61
84	Kyrgyz Rep.	4.29	4.23	4.49	2.93	6.35	3.40
85	Namibia	4.28	3.37	7.01	3.14	2.65	4.34
86	Fiji	4.20	4.47	3.40	5.03	4.25	4.12
87	Venezuela, RB	4.18	5.41	0.48	5.46	5.33	5.46
88	Sri Lanka	4.17	4.04	4.56	4.13	5.00	2.98
89	Philippines	4.12	4.03	4.37	3.80	4.69	3.60
90	Egypt, Arab Rep.	4.08	4.24	3.59	4.44	4.35	3.92

Rank	Country	KEI	KI	Economic Incentive Regime	Innovation	Education	ICT
91	El Salvador	4.06	3.74	5.02	3.29	3.37	4.56
92	Paraguay	4.00	4.15	3.56	3.90	4.25	4.29
93	Albania	3.96	3.92	4.09	2.82	4.97	3.96
94	Ecuador	3.90	4.55	1.94	4.00	4.52	5.12
95	Botswana	3.88	3.37	5.38	4.06	2.65	3.41
96	Dominican Republic	3.85	3.77	4.09	2.91	4.39	4.03
97	Azerbaijan	3.83	4.05	3.18	3.64	5.01	3.49
98	Iran, Islamic Rep.	3.75	4.67	0.99	4.56	3.80	5.65
99	Morocco	3.54	3.35	4.12	3.72	1.95	4.37
100	Vietnam	3.51	3.74	2.79	2.72	3.66	4.85
101	Bolivia	3.46	3.61	3.01	2.95	4.81	3.08
102	Cape Verde	3.35	3.01	4.37	2.16	3.03	3.85
103	Indonesia	3.29	3.17	3.66	3.19	3.59	2.72
104	Uzbekistan	3.25	3.95	1.13	3.35	6.15	2.35
105	Algeria	3.22	3.57	2.18	3.59	3.66	3.46
106	Tajikistan	3.22	3.33	2.88	2.01	5.53	2.46
107	Honduras	3.21	3.09	3.59	3.16	2.97	3.13
108	Syrian Arab Republic	3.09	3.57	1.65	3.17	3.10	4.43
109	India	3.09	2.95	3.50	4.15	2.21	2.49
110	Guatemala	2.89	2.69	3.50	2.01	2.75	3.31
111	Nicaragua	2.81	2.60	3.46	2.09	3.09	2.61
112	Swaziland	2.78	2.87	2.51	4.17	1.97	2.45
113	Kenya	2.77	2.69	2.99	3.83	1.83	2.41
114	Senegal	2.57	2.16	3.79	2.85	1.00	2.63
115	Ghana	2.46	1.97	3.93	2.02	1.78	2.12
116	Mauritania	2.36	1.94	3.64	2.24	0.89	2.68
117	Uganda	2.36	1.76	4.18	2.33	1.18	1.76
118	Pakistan	2.34	2.48	1.91	2.88	1.17	3.39
119	Zimbabwe	2.25	2.96	0.12	3.55	2.38	2.94
120	Madagascar	2.21	1.47	4.45	2.11	1.11	1.18
121	Yemen, Rep.	2.20	2.04	2.66	2.67	1.79	1.67
122	Tanzania	2.17	1.54	4.05	2.10	1.17	1.36
123	Zambia	2.12	1.85	2.92	2.02	1.69	1.84
124	Mali	2.06	1.37	4.16	1.79	0.83	1.48
125	Lesotho	2.05	1.89	2.54	2.76	1.76	1.15
126	Benin	2.05	1.78	2.87	2.73	1.01	1.59
127	Angola	2.00	2.11	1.69	3.62	0.79	1.91

Rank	Country	KEI	KI	Economic Incentive Regime	Innovation	Education	ICT
128	Lao PDR	1.94	2.09	1.47	2.00	2.25	2.03
129	Nigeria	1.84	2.12	0.99	2.29	1.83	2.23
130	Sudan	1.78	2.22	0.48	1.86	1.28	3.52
131	Nepal	1.74	1.62	2.11	2.27	1.79	0.80
132	Burkina Faso	1.71	1.09	3.58	1.78	0.31	1.18
133	Cameroon	1.71	1.91	1.12	2.65	1.38	1.68
134	Malawi	1.69	1.19	3.17	2.00	0.92	0.67
135	Cote d'Ivoire	1.65	1.75	1.37	2.28	1.09	1.87
136	Mozambique	1.58	1.08	3.06	1.67	0.30	1.27
137	Cambodia	1.56	1.54	1.63	2.07	1.93	0.62
138	Bangladesh	1.48	1.55	1.28	1.60	1.53	1.53
139	Djibouti	1.47	1.30	1.99	1.68	0.88	1.32
140	Myanmar	1.34	1.69	0.31	1.30	3.06	0.70
141	Ethiopia	1.30	0.91	2.48	1.39	0.59	0.75
142	Eritrea	1.27	1.29	1.18	2.03	0.71	1.13
143	Rwanda	1.14	0.85	2.02	1.22	0.67	0.64
144	Guinea	1.07	1.22	0.62	1.51	1.09	1.05
145	Sierra Leone	0.96	0.87	1.22	1.47	0.58	0.55
146	Haiti	n/a	n/a	2.41	1.54	n/a	3.16
1	Western Europe	8.76	8.78	8.71	9.27	8.29	8.78
2	G7	8.72	8.91	8.15	9.19	8.75	8.80
3	Europe and Central Asia	6.45	6.69	5.71	6.99	6.62	6.46
4	East Asia and the Pacific	6.41	6.71	5.52	8.49	5.00	6.64
5	All Countries	5.95	6.19	5.21	8.11	4.24	6.22
6	Middle East and North Africa	5.47	5.68	4.86	7.57	3.75	5.71
7	Latin America	5.21	5.37	4.71	5.80	5.05	5.27
8	Africa	2.71	2.72	2.68	4.31	1.38	2.45
9	South Asia	2.58	2.55	2.65	3.29	1.92	2.45
1	High Income	8.23	8.30	8.02	9.02	7.47	8.42
2	Upper Middle Income	5.66	5.85	5.08	6.03	5.63	5.89

Rank	Country	KEI	KI	Economic Incentive Regime	Innovation	Education	ICT
3	Lower Middle Income	3.78	4.04	3.01	4.96	3.32	3.85
4	Low Income	2.00	1.98	2.05	2.52	1.61	1.82

Source: United Nations

Note: By default, the table is sorted by the Knowledge Economy index (KEI) index. Countries may miss certain key variables – a pillar index is not calculated if more than one variable from the pillar is missing. Correspondingly, KEI/KI indexes are not calculated if any of the pillar indexes are missing.

Table 9.

Indicators for the Regional Innovation Scoreboard

	Numerator	Denominator	Interpretation
Human Resources in Science and Technology – Core (% of population)	Number of persons who have successfully completed education at the third level in a S&T field of study and who are employed in S&T	Total population as defined in the European System of Accounts (ESA 1995)	Data on Human Resources in Science and Technology (HRST) can improve our understanding of both the demand for, and supply of, science and technology personnel
Participation in life-long learning per 100 population aged	Number of persons involved in life-long learning	Reference population is all age classes between 25 and 64 years inclusive	Individuals need to continually learn new ideas and skills or to participate in life-long learning.
Public R&D expenditures (% of GDP)	Difference between GERD (Gross domestic expenditure on R&D) and BERD (Business enterprise expenditure on R&D)	Gross domestic product as defined in the European System of Accounts	Trends in the R&D expenditure indicator provide key indications of the future competitiveness and wealth of the EU. Research and development spending is essential for improving production technologies and stimulating growth.
Business R&D expenditures (% of GDP)	All R&D expenditures in the business sector	Gross domestic product as defined in the	The indicator captures the formal creation of new knowledge within

	Numerator	Denominator	Interpretation
	(BERD)	European System of Accounts (ESA 1995)	firms. It is particularly important in the science-based sector (pharmaceuticals, chemicals and some areas of electronics) where most new knowledge is created in or near R&D laboratories.
Employment in medium-high and high-tech manufacturing (% of total workforce)	Number of employed persons in the medium-high and high-tech manufacturing sectors	Total workforce includes all manufacturing and service sectors	An indicator of the manufacturing economy that is based on continual innovation through creative, inventive activity. A better indicator than using the share of manufacturing employment alone, since the latter will be affected by the hollowing out of manufacturing
Employment in high-tech services (% of total workforce)	Number of employed persons in the high-tech services sectors. (post and telecommunication, information technology including software development and R&D services	Total workforce includes all manufacturing and service sectors.	The high technology services provide services directly to consumers, such as telecommunications, and inputs to the innovative activities of other firms in all economy. It can increase productivity throughout the economy and support the diffusion of a range of innovations.
EPO patents per million population	Number of patents applied for at the European Patent Office (EPO), by year of filing.	Total population as defined in the European System of Accounts	The capacity of firms to develop new products will determine their competitive advantage. One indicator of the rate of new product innovation is the number of patents.

Source: 2006 European Regional Innovation Scoreboard, p. 4.

Regarding the collection of innovation data, there are two main approaches to collecting data about innovations:

- (a). The «subject approach» survey starts from the innovative behaviour and activities of the firm as a whole. The idea is to explore the factors influencing the innovative behaviour of the firm (strategies, incentives and barriers to innovation) and the scope of various innovation activities, and above all to get some idea of the outputs and effects of innovation. These surveys are designed to be representative of each industry as a whole, so the results can be grossed up and comparisons can be made between industries.
- (b). The other survey approach involves the collection of data about specific innovations (usually a «significant innovation» of some kind, or the main innovation of a firm) – the «object approach». This starts by identifying a list of successful innovations, often on the basis of experts' evaluations or new product announcements in trade journals. The suggested approach is to collect some descriptive, quantitative and qualitative data about the particular innovation at the same time as data is sought about the firm.

Various research and technological indicators attempt to explain *technological relationships* at a specific point of time or for a whole period. The aim is to measure the nature, the capacity and the efficiency of scientific and technological activities both at a national level and at a sectoral level. High Technology products are defined as the sum of the following products: Aerospace, computers, office machinery, electronics, instruments, pharmaceuticals, electrical machinery and armament. The total exports for the EU do not include the intra-EU trade.

Technological indicators related to *output measures* are more meaningful than those related to *input measures* (such as the number of scientists and engineers which are involved in research activities or the number of research institutions), since the later say little about the achieved research.

Finally, with regard to *non-technological innovation*, it covers all those innovation activities which are excluded from technological innovation; that is it includes all innovation activities of firms which do not relate to the introduction of a technologically new or substantially changed good or service or to the use of a technologically new or substantially changed process. Major types of non-technological innovation are likely to be organisational and managerial innovations. Purely organisational and managerial innovations are excluded from technological innovation surveys. These types of innovation will only be included in innovation surveys if they occur as part of some technological innovation project. The minimum set of data that need to be collected in an innovation survey is:

- the type of non-technological innovation;

- economic benefits flowing from a non-technological innovation activity;
- expenditures on non-technological innovation activity;
- the purpose of the non-technological innovation activity; and
- the source of ideas/information for the non-technological innovation activity.

4. Conclusions

As a driving force, innovation points firms towards ambitious long-term objectives. Innovation also leads to the renewal of industrial structures and is behind the emergence of new sectors of economic activity. In brief, innovation is:

- the renewal and enlargement of the range of products and services and the associated markets;
- establishment of new methods of production, supply and distribution;
- introduction of changes to management, work organisation, and working conditions and skills of the workforce.

This paper has attempted to identify the R&D activities and investigate estimation-methods, techniques of scientific and technological activities and measurement problems. According to 'International Standardization of Statistics on Science and Technology', we can estimate the most important inputs and outputs of scientific and technological activities and also the Scientific and Technical Education and Training and Scientific and Technological Services. The term of «Research and Development Statistics» covers a wide range of statistical series measuring the resources devoted to R&D stages, R&D activities and R&D results. It is important for science policy advisors to know who finances R&D and who performs it.

Technological progress has become virtually synonymous with long- run economic growth. It raises a basic question about the capacity of both industrial and newly industrialized countries to translate their seemingly greater technological capacity into productivity and economic growth. Usually, there are difficulties with the estimation the relation between technical change and productivity. Technological change may have accelerated but, in some cases, there is a failure to capture the effects of recent technological advances in productivity growth or a failure to account for the quality changes of previously introduced technologies.

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