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Editorial Board

Title

REVIEWING STATISTICAL METHODS IN INNOVATION ACTIVITIES: NEW AND OLD LESSONS

Author(s)

George M. Korres
Associate Professor,
University of Aegean,
Department of Geography,
Greece.

Efstratios Papanis
Assistant Professor,
University of Aegean,
Department of Sociology,
Greece.

Aikaterini Kokkinou
University of Glasgow,
Department of Economics,
United Kingdom.

Panagiotis Giavrimis
Lecturer,
University of Aegean,
Department of Sociology,
Pamfilis 17, 81100
Mytilene, Greece.

Abstract:

Innovation activities contribute essentially to the regional dimension of growth. Technological infrastructure and innovation capabilities affect not only regional growth, but also the economy as a whole. Research and Development (R&D) and technical change are both directly related to industrial infrastructure conditions, modernization process, productivity levels, and regional socio-economic growth. In the last decades, new measures and indices have been introduced regarding R&D expenditure, innovation activities, patents etc., namely estimating innovation inputs and outputs. However, there are a lot of problems and questions regarding the measurement of innovation activities at regional level. This paper attempts to analyse the framework of innovation statistics, particularly examining the specific issues and perspectives regarding statistical methods applied in innovation activities estimation.

Key words and phrases: Growth, Innovation Activities, Statistical Methods

1. Introduction:

Innovation is a complex and multifaceted phenomenon. Technological innovation – even in the broad meaning of the Oslo Manual – is only a part of the set of activities firms carry out to sustain or advance their competitiveness. Regarding the statistical point of view, it is not an easy task to identify when technological innovation activities take place, nor to collect data on activities related to innovation, including scientific research. It is not surprising that several problems have been recorded during the implementation of statistical surveys on innovation, the two most important being the following:

- proposed definitions on technological innovation may not have been fully understood by firms,
- data on technological innovation of firms appear to be substantially different from those referred to manufacturing firms and should be carefully interpreted.

According to the Oslo Manual, the definition of technological innovation includes: "the set of knowledge, professional skills, procedures, capabilities, equipment, technical solutions required to manufacture goods or provide services ”. Innovation in process includes “the adoption of technologically new methods in production of goods and services. Several changes concerning equipment, production organisation or both may be required ”.

Three main topics related to such difficulties will be discussed in this paper:

- how the definitions of technological innovation should be applied; several factors should be actually taken into account, including the relation between technological and nontechnological innovations;
- what are the characteristics of research and development (R&D), and also
- how we can apply and estimate the main implications and the effects through these variables

2. Innovation statistics:

Oslo Manual (OECD, 1997) defines technological product and process innovations as those implemented in technologically new products and processes, or significant technological improvements in products and processes. An innovation is implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation).

Innovation indicators measure aspects of the industrial innovation process and the resources devoted to innovation activities. They also provide qualitative and quantitative information on the factors that enhance or hinder innovation, on the impact of innovation, on the performance of the enterprise and on the diffusion of innovation. The commonly used variables for S-R&T activities are: a) R&D expenditures, b) R&D personnel, c) High technology Exports, d) Technological Balance (flows and outflows) and e) Patents of new technologies.

Table 1 illustrates some of the main types of variables in relation to the measurement of scientific and technological activities and also the sources from which they derived. However, R&D statistics are not adequate. In the context of the knowledge-based economy, it has become increasingly clear that such data need to be examined within a conceptual framework that relates them both to other types of resources and to the desired outcomes of given R&D activities. Similarly, R&D personnel data need to be viewed as part of a model for the training and use of scientific and technical personnel.

Table 1: Type of Variables &Sources for Measurement of Scientific & Innovation Activities

Type of Main Variables	Titles and Sources
Research and Development (R&D)	Frascati Manual: "Standard Practice of Research and Experimental Development" and also Frascati Manual Supplement: "Research and Development Statistics and Output Measurement in the Higher Education Sector".
Technology Balance of Payments	OECD: "Manual for the Measurement and Interpretation of Technology Balance of Payments Data"
Innovation	Oslo Manual: OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data
Patents	OECD-Patent Manual: "Using Patent Data as Science and Technology Indicators"
Scientific and Technical Personnel	OECD-Canberra Manual: "The Measurement of Human Resources Devoted to Science and Technology"
High Technology	OECD: "Revision of High Technology Sector and Product Classification"
Bibliometrics	OECD: "Bibliometric Indicators and Analysis of Research Systems, Methods and Examples" (Working Paper – Yoshika Okibo).
Globalisation	OECD: "Manual of Economic Clobalisation Indicators"
Education Statistics	OECD: "OECD Manual for Comparative Education Statistics"
Education Classification	OECD: "Classifying Educational Programmes: Manual for Implementation in OECD countries"
Training Statistics	OECD: "Manual for Better Training Statistics: Conceptual Measurement and Survey Issues"

Source: OECD (1994).

The term R&D covers three activities: basic research, applied research and experimental development. *Basic research* is "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view". *Applied research* is also "original investigation undertaken in order to acquire new knowledge". It is, however, directed primarily towards a specific practical aim or objective. *Experimental development* is "systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to substantially improve those already produced or installed". R&D covers both formal R&D in R&D units and informal or occasional R&D in other units.

Table 2: The three types of research in social sciences and humanities

Basic Research	Applied Research	Experimental Development
Study of causal relations between economic conditions and social development	Study of the economic and social causal of agricultural workers rural districts to towns	Development and testing of a programme of financial assistance to prevent rural immigrants to large cities.
Study of the social structure and the socio-occupational mobility of a society.	Development of a model using the data obtained in order to foresee future consequences of recent trends in social mobility	Development and testing of a programme to stimulate spread mobility among certain social and ethnic groups
Study of the role of the family in different civilizations past and present	Study of the role and position of the family in a specific country or a specific region at the present time for the purpose of preparing relevant social measures	Development and testing of a programme to maintain family structure in low income working groups
Study of the reading process in adults and children.	Study of the reading process for the purpose of developing new method of teaching children and adults to read	Development and testing of a special reading programme among immigrant children
Study of the international factors influencing national economic development.	Study of the national factors determining the economic development of a country in a given period with a view to formulating an operational model for modifying government foreign trade policy.	----
Study of specific aspects of a particular language.	Study of the of the children aspects of a language for the purpose of devising a new method of teaching that language or of translating from or into that language.	----
Study of the historical development of a language.	----	----
Study of sources of all kinds (i.e. manuscripts, documents, buildings), in order to better comprehend historical phenomena..	----	----

Source: OECD/Eurostat (1997).

3. Measurement for Leading Indicators on Scientific and Research Activities:

The main expenditure aggregate used for international comparison is gross domestic expenditure on R&D (GERD), which covers all expenditures for R&D performed on national territory in a given year. It thus includes domestically performed R&D which is financed from abroad but excludes R&D funds paid abroad, notably to international agencies (Table 3).

Table 3. Gross domestic expenditure on R&D (GERD) as % of GDP

	2002	2003	2004	2005	2006	2007	2008	2009
EU (27 countries)	1.87	1.86	1.82	1.82	1.85	1.85	1.9	:
EU (15 countries)	1.93	1.92	1.89	1.89	1.92	1.93	1.99	:
Belgium	1.94	1.88	1.86	1.83	1.86	1.9	1.92	:
Bulgaria	0.49	0.5	0.5	0.49	0.48	0.48	0.49	:
Czech Republic	1.2	1.25	1.25	1.41	1.55	1.54	1.47	:
Denmark	2.51	2.58	2.48	2.46	2.48	2.55	2.72	:
Germany	2.49	2.52	2.49	2.49	2.53	2.53	2.63	:
Estonia	0.72	0.77	0.85	0.93	1.14	1.11	1.29	:
Ireland	1.1	1.17	1.23	1.25	1.25	1.28	1.43	:
Greece	:	0.57	0.55	0.59	0.58	0.58	:	:
Spain	0.99	1.05	1.06	1.12	1.2	1.27	1.35	:
France	2.23	2.17	2.15	2.1	2.1	2.04	2.02	:
Italy	1.13	1.11	1.1	1.09	1.13	1.18	1.18	:
Cyprus	0.3	0.35	0.37	0.4	0.43	0.44	0.46	:
Latvia	0.42	0.38	0.42	0.56	0.7	0.59	0.61	:
Lithuania	0.66	0.67	0.75	0.75	0.79	0.81	0.8	:
Luxembourg	:	1.65	1.63	1.56	1.65	1.58	1.62	:
Hungary	1	0.93	0.87	0.94	1	0.97	1	:
Malta	0.26	0.26	0.53	0.57	0.61	0.58	0.54	:
Netherlands	1.72	1.76	1.81	1.79	1.78	1.71	1.63	:
Austria	2.14	2.26	2.26	2.45	2.47	2.54	2.67	2.78
Poland	0.56	0.54	0.56	0.57	0.56	0.57	0.61	:
Portugal	0.76	0.74	0.77	0.81	1.02	1.21	1.51	:
Romania	0.38	0.39	0.39	0.41	0.45	0.52	0.58	:
Slovenia	1.47	1.27	1.4	1.44	1.56	1.45	1.66	:
Slovakia	0.57	0.57	0.51	0.51	0.49	0.46	0.47	:
Finland	3.37	3.44	3.45	3.48	3.48	3.48	3.73	3.91
Sweden	:	3.85	3.62	3.6	3.74	3.61	3.75	:
United Kingdom	1.79	1.75	1.68	1.73	1.75	1.82	1.88	:
Croatia	0.96	0.97	1.05	0.87	0.76	0.81	0.9	:
FYROM	:	:	:	:	:	:	:	:
Turkey	0.53	0.48	0.52	0.59	0.58	0.72	:	:
Iceland	2.95	2.82	:	2.77	2.99	2.7	2.65	:
Liechtenstein	:	:	:	:	:	:	:	:
Norway	1.66	1.71	1.59	1.52	1.52	1.65	1.62	:
Switzerland	:	:	2.9	:	:	:	:	:

Source: Eurostat, Databases (2010)

The corresponding personnel measure does not have a special name. It covers total personnel working on R&D (in FTE) on national territory during a given year (Table 4).

Table 4. Research and development personnel, by sectors of performance (all sectors, % of the labour force)

	2001	2002	2003	2004	2005	2006	2007	2008
EU (27 countries)	0.91	0.92	0.92	0.93	0.94	0.97	1	1.03
EU (15 countries)	1.04	1.05	1.04	1.05	1.06	1.09	1.12	1.15
Euro area (16 countries)	1	1	1	1.01	1.01	1.05	1.08	1.12
Belgium	1.29	1.18	1.18	1.16	1.16	1.2	1.22	1.23
Bulgaria	0.44	0.45	0.47	0.47	0.48	0.48	0.49	0.48
Czech Republic	0.51	0.51	0.55	0.56	0.84	0.92	0.95	0.97
Denmark	1.39	1.49	1.45	1.47	1.5	1.54	1.61	1.63
Germany	1.21	1.21	1.19	1.18	1.15	1.17	1.21	1.23
Estonia	0.57	0.63	0.63	0.72	0.66	0.69	0.73	0.73
Ireland	0.73	0.73	0.76	0.8	0.82	0.82	0.82	0.87
Greece	0.66	:	0.67	:	0.69	0.72	0.72	:
Spain	0.7	0.72	0.78	0.81	0.84	0.88	0.91	0.94
France	1.28	1.29	1.26	1.29	1.27	1.32	1.33	:
Italy	0.65	0.69	0.67	0.67	0.72	0.78	0.84	0.94
Cyprus	0.21	0.25	0.27	0.29	0.31	0.33	0.32	0.33
Latvia	0.5	0.47	0.43	0.45	0.48	0.56	0.54	0.54
Lithuania	0.73	0.59	0.59	0.65	0.68	0.72	0.79	0.78
Luxembourg	:	:	2.06	2.18	2.16	2.14	2.18	2.23
Hungary	0.56	0.58	0.56	0.55	0.55	0.61	0.61	0.65
Malta	:	0.3	0.26	0.45	0.52	0.53	0.52	0.53
Netherlands	1.08	1.04	1.02	1.07	1.04	1.08	1.01	1
Austria	:	1	:	1.09	1.17	1.2	1.26	1.35
Poland	0.44	0.44	0.45	0.46	0.45	0.43	0.45	0.44
Portugal	0.43	0.45	0.47	0.47	0.46	0.55	0.63	0.87
Romania	0.29	0.31	0.34	0.34	0.34	0.31	0.29	0.31
Slovenia	0.88	0.89	0.71	0.71	0.89	0.96	1	1.11
Slovakia	0.55	0.52	0.51	0.54	0.54	0.57	0.58	0.58
Finland	2.05	2.11	2.2	2.25	2.19	2.2	2.1	2.1
Sweden	1.57	:	1.58	1.56	1.65	1.65	1.59	1.58
United Kingdom	1.03	1.05	1.07	1.07	1.08	1.1	1.14	1.15
Croatia	:	0.63	0.45	0.54	0.46	0.48	0.52	0.55
FYROM	:	:	:	:	:	:	:	:
Turkey	0.12	0.12	0.16	0.17	0.2	0.24	0.27	:
Iceland	:	:	1.83	:	1.97	1.98	1.66	1.71
Norway	1.15	1.16	1.23	1.26	1.28	1.3	1.36	1.38
Switzerland	:	:	:	:	:	:	:	:
Japan	1.32	1.28	1.32	1.35	1.39	1.4	:	:

Source: Eurostat, Databases (2010)

International comparisons are sometimes restricted to researchers (or university graduates) because it is considered that they are the true core of the R&D system (Table 5).

Table 5. Total researchers (FTE), by sectors of performance; All sectors

	2003	2004	2005	2006	2007	2008
EU (27 countries)	1243000	1300433	1367713	1417253	1448337	1504575
EU (15 countries)	1095868	1147385	1200908	1248549	1275363	1325842
Euro area (16 countries)	820278	859232	886375	928867	962712	1006299
Belgium	30917	32400	33146	34879	36318	36382
Bulgaria	9589	9827	10053	10336	11203	11384
Czech Republic	15809	16300	24169	26267	27878	29785
Denmark	24882	26167	28179	28846	30174	30945
Germany	268942	270215	272148	279822	290853	299000
Estonia	3017	3369	3331	3513	3690	3979
Ireland	10039	11010	11587	12184	12669	13709
Greece	15631	:	19593	19907	20817	:
Spain	92523	100994	109720	115798	122624	130986
France	192790	202377	202507	210591	215755	:
Italy	70332	72012	82489	88430	93000	96303
Cyprus	490	583	682	748	799	885
Latvia	3203	3324	3282	4024	4223	4370
Lithuania	6606	7356	7637	8036	8489	8458
Luxembourg	1949	2031	2227	2054	2201	2282
Hungary	15180	14904	15878	17547	17391	18504
Malta	276	436	479	521	494	524
Netherlands	37282	47225	46767	52039	49726	51052
Austria	:	25955	28148	29199	31676	34377
Poland	58595	60944	62162	59573	61395	61831
Portugal	20242	20684	21126	24651	28176	40563
Romania	20965	21257	22958	20506	18808	19394
Slovenia	3775	4030	5253	5857	6250	7032
Slovakia	9627	10718	10921	11776	12354	12587
Finland	:	41004	39582	40411	39000	40879
Sweden	48186	48784	55090	55729	47775	48220
United Kingdom	216690	228969	248599	254009	254599	261406
Croatia	5861	7140	5727	5778	6129	6697
FYROM	:	:	:	:	:	:
Turkey	32660	33876	39139	42663	49668	:
Iceland	1917	:	2155	2400	2208	2308
Norway	20989	21163	21653	23054	24769	:
Switzerland	:	25400	:	:	:	:
United States	1430000	1390000	1390000	1430000	:	:
Japan	675330	677206	704949	709691	709974	:

Source: Eurostat, Databases (2010)

As OECD (1994) documents mentioned national surveys which provide R&D data that are reasonably accurate and relevant to national users' needs may not be internationally comparable. This may simply hold because national definitions or classifications deviate from international norms. The situation is more complex when the national situation does not correspond to the international norms.

The use of research and technological data implied a lot of problems with collection and measurement. The problems of data quality and comparability are characteristic for the whole range of data on dynamic socio-economic activities. However, most of the research and technological indicators capture technological investment in small industries and in small firms only imperfectly. Usually only the manufacturing firms with more than 10,000 employees have established some research and technological laboratories, while industrial units with less than 1,000 employees usually do not have any particular research activities. Finally, the research and technological statistics concentrate mostly on the manufacturing sectors, while usually neglecting some service activities.

The collection of R&D data of regional statistics implied a lot of problems in comparison to data of national statistics. For the collection of regional statistics, we should take into account the local differences and related difficulties. R&D units can operate in more than one regions and we should allocate these activities between regions. Usually, regional statistics focused on the three first levels of NUTS (Nomenclature of Territorial Units for Statistics).

The reliability of R&D and innovation regional statistics is directly connected and depended on estimation-method and the application of statistical technique. Another important question on R&D and innovation regional statistics is the confidentiality and the collection-method of data-set that may cover the whole or the majority of the local-units. For the statistical methods focused at regional level, we can use either the ‘’local-units’’ (i.e. enterprises, office, manufacturing etc.) or the ‘’local-economic-units’’ (NACE codes, which is a division of national codes of European member states). Therefore, we can use the first method «top-to-the-bottom method» for the collection of aggregate R&D data (for the whole country) and after that on the distribution of these figures into a regional-level; the disadvantage of this method is that there is not a direct method for collection of data from the regions.

The second method «bottom-to-the-top method» for the collection of dissaggregate R&D data (for the whole regions) based on the direct-collection at regional-level and after that on the summation of these figures in order to obtain the aggregate-total R&D data (for the whole country); the advantage of this method is that there is a consistency in the summary of figures between regional and national level.

4. Modelling and Evidence from Research and Scientific Activities:

There is a huge literature suggesting and demonstrating that research and scientific indicators make an important contribution to the growth of the firm, industry and national levels. Most of these studies have investigated the relation between productivity, employment, growth and R&D.

4.1. The Input-Output framework

The structural decomposition analysis can be defined as a method of characterizing major shifts within an economy by means of comparative static changes. The basic methodology was introduced by Leontief for the structure of the US economy and has been extended in several ways.

Growth decomposition analysis uses input-output techniques because they capture the flows of goods and services between different industries. Input-output methods exploit the interlinkages effects and also search for the components of growth. In addition, input-output techniques allow us to calculate the contribution of *technical change* to output growth. The principal argument of the method of interindustry analysis is to show explicitly the interdependence of growth rates in different sectors of the economy. Usually, two different compositional indicators are used to analyze the extent of structural change, the annual growth rate of real output in each industry and the share of national real output accounted for each industry, (Denison 1962).

Input-output tables are available both in current and constant prices. We can consider the *basic material balance condition* for the gross output of a sector as given by:

$$X_i=W_i+F_i+E_i-M_i \qquad (\textit{material balance equation}) \qquad (1)$$

where: X_i=the gross output,

W_i=the intermediate demand for the output of sector i by sector j,

F_i=the domestic final demand for the output of sector i,

E_i=the export demand, and

M_i=the total imports classified in sector i.

The gross output of sector i is the sum of output to intermediate demand plus the domestic final demand plus the exports less the imports. In the matrix notation the *material balance condition* becomes:

$$X=AX+F+E-M=(I-A)^{-1}(F+E-M), \qquad (2)$$

where $(I-A)^{-1}$, the inverse of the coefficients matrix, captures the indirect as well as the direct flows of intermediate goods.

Holding one part of the material balance equation constant and varying the other components over time, the change in an industry's output can be decomposed into the following factors:

- technical change (corresponding to changes in the inverted I-A matrix);
- changes in final demand;
- changes in the structure of exports; and
- changes in the structure of imports

This equation provides, at aggregate level, a comprehensive picture of structural change for each country. It does not explain why the structure of an economy changed, but it describes how it came about and measures the relative importance of each factor on each industry's growth. Growth effects are analyzed in order to reveal how much output in each industry would have changed with the same growth rate for each element in the final demand. When growth rates vary between the final demand categories, the resulting growth rates for the industrial output will also vary. The positive or negative effects of structural change affect the final demand categories.

Technological change in the Input-Output framework

Technological change plays an important role in the expansion and decline of sectors. Technology intensity and real growth rates of output can be used to classify individual industries into different performance groups. These groups can then be used to describe the patterns of structural change and to make comparisons among various countries. The effects of technical change are analyzed in order to find out how much the use of primary inputs has changed, because of changes in the endogenous factors of the model. Furthermore, the effects of technical change on industrial output are analyzed, in order to reveal how much output in each industry has changed because input-output coefficients have altered.

A way of measuring changes in input-output coefficients is to compute the weighted average changes in the input-output coefficients of various sectors and to compare the matrices at two different points of time. For instance, we can use the following formula (3), in order to compute the weighted indices:

$$T_j = \frac{1}{\frac{1}{2}\Sigma(X_{ij}^2 + X_{ij}^1)} \Sigma\left[\frac{(A_{ij}^2 - A_{ij}^1)}{(A_{ij}^2 + A_{ij}^1)}(X_{ij}^2 + X_{ij}^1)\right] \quad (3)$$

where: A^2_{ij} is the elements of matrix of input-output coefficients for the second period,

A^1_{ij} is the elements of matrix of input-output coefficients for the first period,

X^2_{ij} is the matrix of interindustry transactions for second period at constant prices,

X^1_{ij} is the matrix of inter - industry transactions for first period at constant prices.

This index measures the overall input changes in each of the n production sectors due to technological changes, changes in the prices, and product mix (the so called *Rasmussen index* of structural change). The total change in sectoral output can be decomposed into sources by category of demand. The total change in output equals the sum of the changes in each sector and can also be decomposed either by sector or by category of demand. The relations, (with the two intermediate terms combined), can be shown as following:

$$DD_1 + EE_1 + IS_1 + IO_1 = \Delta X_1$$

$$DD_2 + EE_2 + IS_2 + IO_2 = \Delta X_2$$

$$. \quad . \quad . \quad . \quad . \quad .$$

$$DD_n + EE_n + IS_n + IO_n = \Delta X_n$$

$$\Sigma DD_i + \Sigma EE_i + \Sigma IS_i + \Sigma IO_i = \Sigma \Delta X_i = \Delta X \quad (4)$$

where: DD_i=domestic demand expansion in sector i,

EE_i=export expansion in sector i,

IS_i=import substitution of final and intermediate goods in sector i,

IO_i=input-output coefficients in sector i,

ΔX_i=change in the output of sector i.

Reading down the columns gives the sectoral composition of each demand category, while reading across the rows gives the decomposition of changes in sectoral demand by different demand categories. When making comparisons across countries and time periods, it is convenient to divide the entire table by □ □ X_i so that all components across sectors and demand categories sum to 100. Alternatively, it is sometimes convenient to divide the rows by □ X_i and then to look at the percentage contribution of each demand category to the change in sectoral output, (Denison 1962).

Table 6. Decomposition Formulas (*)

Sources of growth:	Variable	being	decomposed	
Domestic-final-demand expansion (FE)	Output ΔX	Val.Add. ΔV	Imports ΔM	Empl. ΔL
Export expansion(EE)	$B_0\hat{u}^f_0\Delta F$	$v_0B_0\hat{u}^f_0\Delta F$	$(m11 f_0+m^w_0A_0B_0\hat{u}^f_0)\Delta F$	$l_0B_0\hat{u}^f_0\Delta F$
Import-subst.of final goods (ISF)	$B_0\Delta E$	$v_0B_0\Delta E$	$m^w_0A_0B_0\Delta E$	$l_0B_0\Delta E$
Import- subst.of interm. goods(ISW)	$B_0\Delta\hat{u}^fF_1$	$v_0B_0\Delta\hat{u}^fF_1$	$(I-m^w_0A_0B_0)\Delta m^wW_1$	$l_0B_0\Delta\hat{u}^fF_1$
Technical change(IOA)	$B_0\Delta\hat{u}^wW_1$	$v_0B_0\Delta\hat{u}^wW_1$	$(I-m^w_0A_0B_0)\Delta m^wW_1$	$l_0B_0\Delta\hat{u}^wW_1$
Change in value-added-ratio (IOV)	$B_0\hat{u}^w_0\Delta AX_1$	$v_0B_0\hat{u}^w_0\Delta AX_1$	$(m^w_0+m^w_0A_0B_0\hat{u}^w_0)\Delta AX_1$	$l_0B_0\hat{u}^w_0\Delta AX_1$
Labour-productivity-growth (IOL)	-----	ΔvX_1	-----	-----
Labour-productivity-growth (IOL)	-----	-----	-----	ΔlX_1

Note: (*) the previous analysis can be extended to value added, employment, & imports.

At this stage, we can give an *alternative model*, which is known as the *deviation model* and measures changes in the relative shares of output. The deviation model starts from balanced growth, where it is assumed that all sectors grow at the same rate equal to the growth rate of total output.

4.2 The Catching Up Models

A higher level of innovation activities tend to have a higher level of value added per worker (or a higher GDP per head) and a higher level of innovation activities than others. Following the technological-gap arguments, it would be expected that the more technologically advanced countries would be the most economically advanced, in terms of a high level of innovation activities and in terms of GDP per capita (Table 7).

Table 7 GDP per capita in Purchasing Power Standards (PPS) (EU-27 = 100)

	2001	2002	2003	2004	2005	2006	2007	2008
EU (27 countries)	100	100	100	100	100	100	100	100
EU (25 countries)	104.8	104.6	104.4	104.2	104.1	103.9	103.7	103.4
EU (15 countries)	114.9	114.3	113.8	113.1	112.8	112.3	111.6	110.7
Euro area (16 countries)	112.1	111.3	110.6	109.4	109.6	109.3	109.2	108.5
Euro area (15 countries)	113.2	112.3	111.5	110.3	110.4	110.1	109.9	109.1
Belgium	123.7	125.3	123.3	121.2	119.8	117.7	115.7	115.2
Bulgaria	29.2	30.9	32.5	33.7	34.5	36.5	37.7	41.3
Czech Republic	70.2	70.4	73.4	75.1	75.9	77	80.1	80.4
Denmark	127.8	128.4	124.1	125.6	123.7	124.2	121.2	120.1
Germany	116.6	115.2	116.5	116.3	116.9	116.1	115.8	115.6
Estonia	46.4	50	54.5	57.4	61.6	65.2	68.8	67.4
Ireland	132.3	137.8	140.6	141.8	143.7	145.2	147.8	135.4
Greece	86.5	90.2	92.6	94	91.8	93	92.8	94.3
Spain	98.1	100.5	100.9	101	102	104.6	105	102.6
France	115.7	116	111.8	110	110.6	108.7	108.5	107.9
Italy	117.8	111.9	110.7	106.6	104.9	104.2	103.5	101.8
Cyprus	90.9	89.2	88.9	90.3	90.9	90.7	93.6	95.9
Latvia	38.7	41.2	43.3	45.6	48.6	51.6	55.7	57.3
Lithuania	41.5	44.1	49.1	50.5	52.9	55.3	59.3	61.9
Luxembourg	234.1	240.2	247.6	252.8	254.5	272.2	275.2	276.4
Hungary	58.9	61.6	62.8	63.4	63.2	63.2	62.6	64.4
Malta	77.9	79.5	78.3	77	77.9	76.8	76.4	76
Netherlands	133.7	133.4	129.3	129.2	130.8	131.2	132.2	134
Austria	125.1	126.2	126.8	126.8	124.5	124.6	123	123.5
Poland	47.6	48.3	48.9	50.6	51.4	51.9	54.4	56.4
Portugal	77.3	77	76.6	74.6	77	76.4	75.6	76
Romania	27.8	29.4	31.3	34.1	35	38.4	41.6	:
Slovenia	79.7	82.3	83.4	86.4	87.5	87.7	88.6	90.9
Slovakia	52.4	54.1	55.4	57	60.2	63.4	67.7	72.3
Finland	115.2	114.8	112.5	116.1	114.3	114.1	117.9	116.9
Sweden	122.6	122.2	124.1	126.4	121.8	123	125.3	122.3
United Kingdom	119.8	120.6	121.7	123.7	121.9	120.3	116.7	116.2
Croatia	50.3	52.3	54.3	55.8	56.6	57	60.2	62.7
FYROM	25.1	25.2	25.6	26.6	28.5	29.4	30.9	:
Turkey	37.4	36.2	35.9	39.5	42.4	44.4	44.6	45.6
Iceland	132.2	129.8	125.5	131.1	130.5	123.4	121.9	120.7
Liechtenstein	:	:	:	:	:	:	:	:
Norway	161.1	154.7	156.2	164.4	176.3	183.7	179.1	191.2
Switzerland	140.5	140.5	136.9	135.5	133.3	136.1	140.8	140.8
United States	156.5	154.2	156.3	157.3	159	158.1	155.6	154.6
Japan	113.6	111.9	112.2	113	112.9	112.7	112.2	:

Source: Eurostat, Databases (2010)

The level of technology in a country cannot be measured directly. A proxy measure can be used to give an overall picture of the set of techniques invented or diffused by the country of the international economic environment (Abramovitz 1986). For the productivity measure, we can use the real GDP per capita as an approximate measure. The most representative measures for *technological inputs and outputs* are the indicators of patent activities and the research expenditures (Table 7).

Table 8. European high-technology patents (per million inhabitants)

	2001	2002	2003	2004	2005	2006	2007
EU (27 countries)	23.751	22.118	19.353	21.32	20.994	18.975	7.776
Belgium	25.319	30.675	23.801	30.289	31.192	25.871	18.348
Bulgaria	0.36	0.19	0.351	0.281	0.838	0.518	:
Czech Republic	0.617	0.622	0.724	1.266	1.636	1.816	0.619
Denmark	42.021	41.108	43.659	43.61	41.793	32.647	9.51
Germany	47.2	44.55	38.268	42.062	39.703	36.276	19.994
Estonia	2.56	0.955	5.479	1.725	3.614	7.005	1.49
Ireland	20.796	16.511	12.367	13.087	14.156	15.595	2.882
Greece	1.093	1.619	1.835	1.395	1.461	1.105	0.604
Spain	3.69	3.488	3.027	3.275	4.046	4.128	1.305
France	30.099	29.291	28.955	29.516	30.068	28.049	13.063
Italy	6.854	8.446	8.257	8.669	9.607	7.134	3.412
Cyprus	6.207	2.367	4.125	:	0.614	0.431	1.708
Latvia	0.127	0.256	0.322	:	0.867	0.218	1.021
Lithuania	0.401	0.095	0.482	0.073	0.38	0.882	0.688
Luxembourg	17.654	8.152	8.722	22.903	15.892	34.279	7.35
Hungary	2.505	1.699	2.634	2.797	2.325	3.998	0.571
Malta	:	2.534	2.517	:	2.483	2.963	:
Netherlands	98.01	70.149	42.862	61.892	56.325	47.008	11.4
Austria	22.689	26.585	24.651	22.753	27.594	33.887	12.803
Poland	0.251	0.301	0.379	0.532	0.613	0.538	0.574
Portugal	0.819	0.466	0.932	0.585	3.245	2.221	2.222
Romania	0.178	0.115	0.115	0.117	0.285	0.261	0.178
Slovenia	2.894	6.038	3.173	1.002	2.243	2.521	6.466
Slovakia	0.889	1.277	0.573	0.619	0.665	1.412	0.71
Finland	125.039	120.557	108.459	128.246	120.06	96.724	14.872
Sweden	57.498	51.52	50.056	62.201	65.422	67.92	10.825
United Kingdom	28.212	25.384	22.231	22.483	21.441	18.899	4.775
Croatia	0.376	0.787	0.074	0.315	0.637	1.902	0.45
FYROM	:	:	:	0.739	:	:	:
Turkey	0.005	0.053	0.166	0.08	0.107	0.295	0.285
Iceland	23.892	32.697	45.065	11.77	17.372	11.004	:
Liechtenstein	83.681	54.586	59.062	29.16	173.41	23.779	28.435
Norway	15.828	17.767	13.903	15.913	16.625	13.424	2.173
Switzerland	63.835	54.555	41.893	56.146	53.774	44.322	21.707
Canada	18.846	19.551	20.257	27.955	31.006	26.408	10.748
United States	36.504	35.657	34.316	34.655	34.627	27.416	4.707
Japan	49.352	51.876	52.737	54.538	50.67	47.039	20.385

Source: Eurostat, Databases (2010)

The majority of empirical studies in the estimations between productivity growth and R&D follow a standard linear model; on this context we use a similar approach. The reason is that even though a more dynamic relationship exists, the data limitations (lackness of time series annual data on R&D activities for most countries) prevent the application of some complex models.

We can test the basic technological gap model (with and without these variables) reflecting the structural change, in order to decide to what degree these variables add something to the other explanatory variable of the model (Fageberg 1987). We can use the external patent applications (EXPA) and gross expenditures on research and development (GERD) as proxies for the growth of the national technological activities, GDP per capita (GDPCP) (in absolute values at constant prices) as a proxy for the total level of knowledge appropriated in the country (or *productivity*). Investment share (INV) has been chosen as an indicator of growth in the capacity for economic exploitation of innovation and diffusion (Table 8).

Table 9 Total investment as % of GDP

	2002	2003	2004	2005	2006	2007	2008	2009
EU (27 countries)	19.6	19.5	19.6	20	20.7	21.3	21.1	19.2
EU (25 countries)	19.6	19.4	19.6	19.9	20.6	21.2	20.9	19.1
EU (15 countries)	19.5	19.3	19.5	19.8	20.5	21	20.8	18.9
Belgium	19.1	18.8	19.8	20.7	21	21.7	22.6	21.3
Bulgaria	18.2	19.3	20.5	24.2	25.9	29.8	33.4	24.8
Czech Republic	27.5	26.7	25.8	24.9	24.7	25.2	23.9	22.7
Denmark	19.6	19.3	19.3	19.5	21.7	22.3	20.9	18.6
Germany	18.3	17.9	17.5	17.4	18.2	18.8	19	17.8
Estonia	29.7	31.6	30.9	32.1	34.9	34.5	29.3	21.9
Ireland	21.6	22.4	24.4	26.6	26.9	26	21.7	15.6
Greece	22.5	23.3	22.2	20.6	21.5	21.4	19.4	16.8
Spain	26.3	27.2	28	29.4	30.6	30.7	28.8	24.4
France	18.8	18.8	19.3	20	20.7	21.5	21.8	20.6
Italy	20.9	20.4	20.5	20.7	21.1	21.2	20.7	18.9
Cyprus	18.1	17.6	19	19.3	20.6	22	23.3	20.4
Latvia	23.8	24.4	27.5	30.6	32.6	33.7	29.4	21.3
Lithuania	20.3	21.1	22.3	22.8	25.2	28.3	25.2	17
Luxembourg	22.6	22.2	21.5	20.5	19.1	19.9	19.3	17.4
Hungary	23.1	22.3	22.5	23	21.7	21.2	20.9	20
Malta	16.3	19.6	19.2	20.2	20.8	20.3	16.3	14
Netherlands	20	19.5	18.8	18.9	19.7	20	20.4	18.9
Austria	21.7	22.4	22	21.7	21.6	21.8	21.8	20.8
Poland	18.7	18.2	18.1	18.2	19.7	21.6	22.1	21
Portugal	25	22.9	22.6	22.2	21.7	21.8	21.7	19
Romania	21.3	21.5	21.8	23.7	25.6	30.2	31.9	25.6
Slovenia	23.1	24	24.9	25.5	26.5	27.7	28.9	24
Slovakia	27.4	24.8	24	26.6	26.5	26.2	24.9	23.6
Finland	18.7	19	19.3	20.1	20	21.3	21.6	19.8
Sweden	17.4	16.8	17	17.9	18.7	19.6	20.1	17.3
United Kingdom	16.8	16.4	16.7	16.7	17.1	17.8	16.8	14.9
Croatia	21.2	25	25.5	24.6	26.1	26.2	27.6	25.5
FYROM	16.6	16.7	17.8	17	18.2	20.2	24.5	22.7
Turkey	16.7	17	20.3	21	22.3	21.4	19.9	16.8
Iceland	18.2	20	23.5	28.4	34	28.5	24.3	14.1
Liechtenstein	:	:	:	:	:	:	:	:
Norway	17.9	17.3	18	18.8	19.6	22.2	21.3	21.4
Switzerland	21.3	20.5	20.8	21.2	21.3	21.5	21.3	20.4

Source: Eurostat, Databases (2010)

The share of investment may also be seen as the outcome of a process in which institutional factors take part (since differences in the size of investment share may reflect differences in institutional system as well). For the structural change we used as an approximation changes in the shares of exports and agriculture in GDP, (Fageberg 1987).

We have tested the following version of the models:

GDP(or PROD)= f[GDPCP, EXPA (or GERD), INV],(basic model) (5)

GDP(or PROD)= f[GDPCP, EXPA (or GERD), INV, EXP] (6)

GDP= f[GDPCP, EXPA (or GERD), INV, TRD] (7)

The first model may be regarded as a pure *supply model*, where economic growth is supposed to be a function of the level of economic development GDPCP (GDP per capita with a negative expected sign), the growth of patenting activity (EXPA with a positive sign) and the investment share (INV with a positive sign).

4.3 An estimation of technical change: Technological progress and the production function

A production function is by definition a relationship between output and inputs. For a single country, say ith, the production function may be written as:

$$y_{it}=F_i(X_{i1t},X_{i2t},.......,X_{imt},t) \quad (8)$$

where: y_{it} is the quantity of output produced per producer unit and X_{ijt} is the quantity of the jth input employed per producer unit (j=1,2,....m) in the ith country for the period.

The concept of a production function plays an important role in both micro and macroeconomics. At the macro level it has been combined with the marginal productivity theory to explain the prices of the various factors of production and the extent to which these factors are utilised. The production function has been used as a tool for assessing what proportion of any increase in the output over time can be attributed first to increase in the inputs of factors in the production, second to the increasing returns to scale and third to *technical progress*.

Most studies on production function (Landau 1989) have been handled under one or more traditionally maintained hypothesis of *constant returns of scale*, *neutrality of technical progress* and *profit maximization* with competitive output and input markets. Therefore, the validity of each of these hypotheses affects the measurement of technical progress and the decomposition of economic growth into its sources.

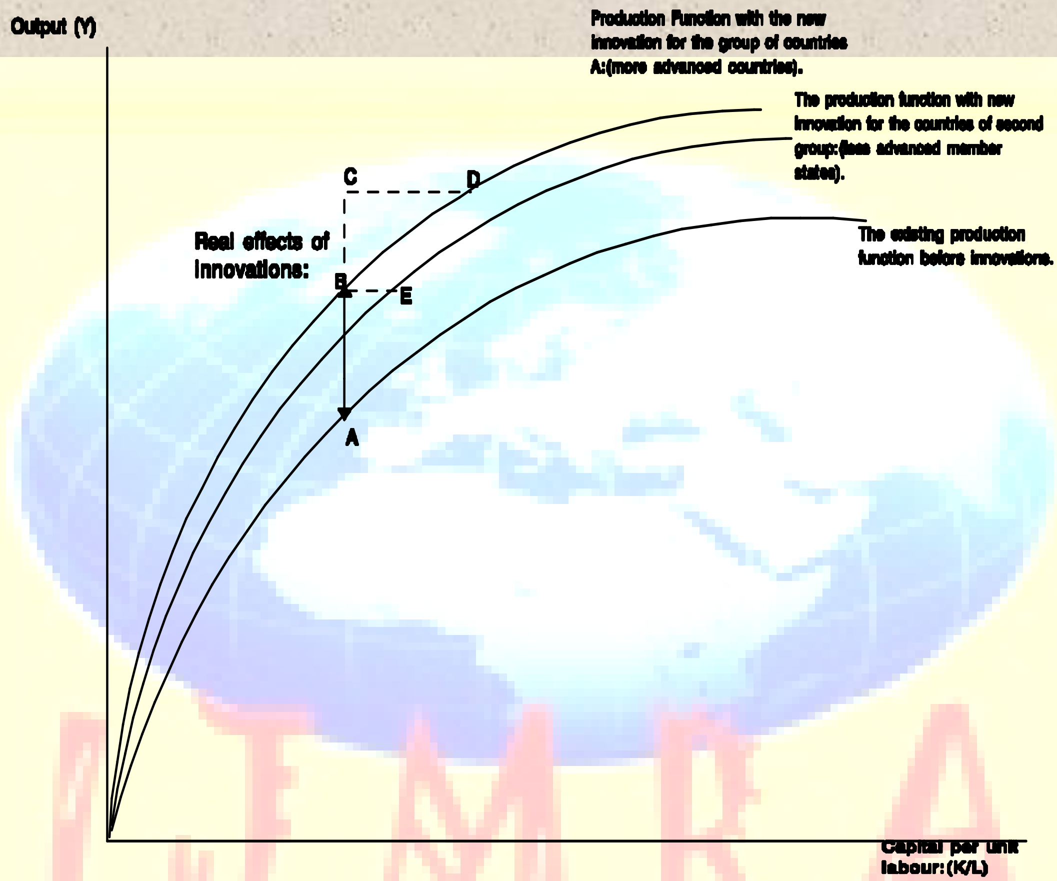

Figure 1. Effects of Innovations

Following the analysis of Landau (1989), we may assume that there is a production function that relates output to capital per unit of labour and we also assume first that the economy is at the point A (where labour force growth is static and investment is at an average level). When a new technology is introduced there is an upward shift of the production function. Of course, the shift of the production function will be different across different countries. This shift of the production function implies additional output per person and probably this can lead to extra savings and consequently to more capital per worker, which means that the economy will move along the production function. The above figure shows that the economy reaches the point E for less advanced countries and point D for more advanced countries. The real effects of innovation can now be measured by the distances AE and AD respectively.

The aggregate cost (or production) function is based on a cost function (or a production function), which is characterised by constant returns to scale:

$$C=F(P_K, P_L, Y, T) \tag{9}$$

where: P_K, P_L, Y, T indicate the price of capital input, labour input, the value added and time, (Christensen L.R., D.W.Jorgenson and Lau L.J. 1975).

The translog cost function can be written, (where ij=K,L):

$$\ln C(P_K, P_{L,} Y, T) = \alpha_0 + \alpha_y \ln y + \frac{1}{2}\alpha_{yy}(\ln y)^2 + \sum_{i=1}^{n}\alpha_i \ln P_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}\ln P_i \ln P_j$$

$$+ \sum_{i=1}^{n}\gamma_{ij}\ln P_i \ln y + \gamma_T T + \frac{1}{2}\gamma_{TT}T^2 + \sum_{i=1}^{n}\gamma_{iT}\ln P_i T + \sum_{i=1}^{n}\gamma_{yT}\ln y T \tag{10}$$

The parameters $\square_K$ and $\square_L$ can be interpreted as the average value shares of capital and labour inputs. The parameters $\square_T$ and $\square_Y$ indicate the average (negative) rate of technical change and the average share of output in total cost and the parameter $\square_T$ can be also interpreted as the average rate of productivity growth.

The parameters $\square_{KK}$, $\square_{KL}$, $\square_{LL}$ can be interpreted as constant share elasticities. These parameters describe the implications of patterns of substitution for the relative distribution of output between capital and labour. A positive share elasticity implies that the corresponding value share increases with an increase in quantity. A share elasticity equal to zero implies that the corresponding value share is independent of quantity. The bias estimates $\square_{KT}$ and $\square_{LT}$ describe the implications of patterns of productivity growth for the distribution of output. A positive bias implies that the corresponding value increases with time, while a negative bias implies that the value share decreases with time. Finally, a zero bias implies that the value share is independent of time. An alternative and equivalent interpretation of the biases is that they represent changes in the rate of productivity growth with respect to proportional changes in input quantities.

The parameter $\square_T$ can be interpreted as the average rate of productivity growth, while the parameters $\square_K$ and $\square_L$ can be interpreted as the average value shares of capital and labour inputs. The parameter $\square_Y$ has a positive value which indicates the average value share of output in the total cost. The parameter $\square_{YT}$ indicates how time affects the growth of output (*the rate of technical change or the acceleration rate*).

The parameter $\square_{KL}$ indicates the substitution patterns between the two factors (capital and labour); because we assumed a two factor cost function.

The parameter $\square_{YY}$ (the *flexibility cost*) indicates how the marginal cost will change with a change in the level of output; the marginal cost will increase as the output expands.

The parameters $\square_{KY}$, and $\square_{LY}$, indicate share elasticities with respect to the output (scale biases); in other words, they show how an input's share would be affected by a change in the level of output. The parameters $\square_{KT}$, and $\square_{LT}$ suggest the technical change biases and they represent a change of factor share with respect to time. The parameter $\square_{YT}$, measures the impact of technical change on the growth of output and this parameter indicates that technical change.

5. Conclusions:

This article attempts to identify the R&D activities and also to investigate the estimation methods, the techniques of scientific and technological activities and the 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 undertakes it.

Series of R&D statistics are only a summary of quantitative reflection of very complex patterns of activities and institutions. In the case of international comparisons, the size aspirations and institutional arrangements of the countries concerned should be taken into consideration. One way of constructing reliable indicators for international comparisons is to compare R&D inputs with a corresponding economic series, for example, by taking GERD as a percentage of the Gross Domestic Product. However, it is quite difficult to make detailed comparisons between R&D data and those of non-R&D series both because of the residual differences in methodology and because of defects in the non-R&D data.

UNESCO, OECD and EUROSTAT divisions organised the systematic collection, analysis publication and standardization of data concerning science and technological activities. The first experimental questionnaires were circulated to member states by UNESCO in 1966 and standardized periodical surveys were established in 1969.

The collection of R&D data of regional statistics implied a lot of problems in comparison to data of national statistics. For the collection of regional statistics, we should take into account the local differences and difficulties. In addition, we can use either the 'local-units' or the 'local-economic-units'. The first method «top-to-the-bottom method» focused on the collection of aggregate R&D data (at country level) and after that on the distribution of these figures into a regional-level; the disadvantage of this method is that there is not a direct collection of data from the regions or the second method «bottom-to-the-top method» for the collection of disaggregate R&D data (at regional level) based on the direct-collection at a regional-level and after that on the summation of these figures in order to obtain the aggregate-total R&D data (at country level).

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 in the estimation of technical change and productivity function. 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 newly introduced technologies.

In the literature there are various explanations for the slow-down in productivity growth for OECD countries. One source of the slow-down may be substantial changes in the industrial composition of output, employment, capital accumulation and resource utilization. The second source of the slow down in productivity growth may be that technological opportunities have declined; otherwise, new technologies have been developed but the application of new technologies to production has been less successful. Technological factors act in a long - run way and should not be expected to explain medium run variations in the growth of GDP and productivity.

Technological gap models represent two conflicting forces, innovation which tends to increase the productivity differences between countries and diffusion which tends to reduce them. In the Schumpeterian theory, growth differences are seen as the combined results of these forces. However, research on *why growth rates differ* has a long history which goes well beyond growth accounting exercises.

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