# Modeling the Technological Change and Innovation Activities for Estimation of Productivity Growth

**Abstract:**

Technological change and innovation activities contribute essentially to the regional dimension and productivity growth. The technological infrastructure and innovation capabilities affect not only the regional growth, but also the whole periphery and economy as well. In the last decades, OECD /introduced some measures and indexes, concerning the Research and Development Expenditures, patents etc., that measuring the innovation activities. However, there are a lot of problems and questions regarding the measurement of innovation activities at a regional level. This paper attempts to analyze the whole framework of innovation and technological activities and in particular to examine the methodological approaches, the appropriate measurement and also the statistical indices for estimation of productivity growth. On this context, it's also aiming to emphasize and to review the appropriate techniques, the most common methods and to analyze the particular methodological and statistical problems.

**Keywords:** Statistical and econometric measures, input-output, innovation activities, techniques and methods, research and development, productivity growth.

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## 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 keep or improve their competitiveness. By the statistical point of view it is not an easy task to identify when technological innovation activities take place as well as 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 the survey 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 for the definition of technological **innovation** suggested to firms surveyed by: "the set of knowledge, professional skills, procedures, capabilities, equipment, technical solutions required to manufacture goods or provide services". The **innovation in process** is "the adoption of technologically new methods in production or new methods to provide 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 non-technological 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

The – *Oslo Manual* (OECD, 1997a) defines technological product and process innovations as those implemented in technologically new products and processes and in 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 involves a series of scientific, technological, organisational, financial and commercial activities.

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 variables common used variables for S-R&T activities are:

– R&D expenditures

– R&D personnel

– Patents of New Technologies.

Table 2 illustrates some of the main type of variables in relation to the measurement of scientific and technological activities and also the Titles and Sources from which they derived. However, R&D statistics are not enough. 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:** Innovation and Not Innovation Activities

| | | | Innovation | | Not Innovation |
|---|---|---|---|---|---|
| | | | New to the World | New to the Firm | **Already in the Firm** |
| **Innovation** | Technologically New | Product | | | |
| | | Production Process | | | |
| | | Delivery Process | | | |
| | Significantly Technologically Improved | Product | | | |
| | | Production Process | | | |
| | | Delivery Process | | | |
| | | Organisation | | | |
| **Not Innovation** | No Significant Change. Change without novelty or other creative improvements | Product | | | |
| | | Production Process | | | |
| | | Delivery Process | | | |
| | | **Organisation** | | | |

**Table 2:** Type of Variables, Titles and Sources for the Measurement of Scientific and Technological 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.

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 improving substantially 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 3:** The three types of research in the 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, for the purpose | **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 ethic 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** |
| Ding 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, etc), in order to better comprehend historical phenomena (i.e. political, social, cultural development of a country, biography of an individual etc).** | **----** | **----** |

Source: UNESCO (1984) «Manual for Statistics on Scientific and Technological Activities».

**3. The Measurement for the 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. 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. 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.

As OECD documents mentioned the 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 be 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 the 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 the local differences and the 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).

**Table 4:** R&D intensity[1] & export specialisation[2] in high-technology industries 1999

| | **Export specialisation** | **R&D intensity** |
|---|---|---|
| Canada | 13,0 | **1,2** |
| United States | 38,3 | **3,0** |
| Japan (3) | 30,7 | **3,2** |
| Korea | 34,2 | **1,3** |
| Denmark (3) | 18,8 | **1,8** |
| Finland | 24,1 | **2,6** |
| France (3) | 23,1 | **2,2** |
| Germany | 18,5 | **2,7** |
| Ireland (4) | 46,0 | **1,1** |
| Italy | 10,6 | **0,8** |
| Netherlands (4) | 25,1 | **1,6** |
| Norway (4) | 10,7 | **1,2** |
| Spain (3) | 9,3 | **0,6** |
| Sweden (3) | 27,0 | **3,9** |
| **United Kingdom (3)** | **32,4** | **2,1** |

1. Manufacturing R&D expenditures/manufacturing production.
2. High-technology exports/manufacturing exports.
3. 1998.
4. 1997.

*Source:* OECD, STAN and ANBERD databases, May 2001.

The reliability of R&D and innovation regional statistics is directly connected and depending 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 be cover the whole or the majority of the local-units. For the statistical methods focused on a 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 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 a 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.

Table 4 illustrates the Research and Development intensity and also the export specialisation for the high-technology industries. Furthermore, Table 5 shows the annual average growth rate of exports in high- and medium-high-technology industries.

**Table 5:** Annual average growth rate of exports in high- and medium-high-technology industries, 1990-99

| | **High- and medium-high-technology** | **Total manufacturing** |
|---|---|---|
| Mexico | 29,4 | **26,4** |
| Ireland | 17,6 | **13,3** |
| Iceland | 17,2 | **3,7** |
| Turkey | 15,1 | **9,7** |
| Greece | 10,6 | **2,4** |
| New Zealand | 10,1 | **3,2** |
| Portugal | 9,8 | **4,7** |
| Spain | 9,5 | **8,2** |
| Australia | 9,1 | **5,4** |
| Canada | 9,1 | **8,0** |
| Finland | 8,6 | **5,0** |
| United States | 8,5 | **7,9** |
| Sweden | 6,9 | **4,7** |
| OECD | 6,5 | **5,4** |
| Belgium-Luxembourg | 6,2 | **4,4** |
| United Kingdom | 6,0 | **4,9** |
| France | 5,9 | **4,5** |
| Netherlands | 5,9 | **3,4** |
| Austria | 5,8 | **4,6** |
| EU | 5,7 | **4,4** |
| Norway | 5,4 | **2,6** |
| Denmark | 4,8 | **3,2** |
| Italy | 4,7 | **4,0** |
| Japan | 4,2 | **4,0** |
| Germany | 4,0 | **3,1** |
| **Switzerland** | **3,8** | **3,2** |

*Source:* OECD, STAN database, May 2001.

## 4. The Estimation and Modelling the Research and Scientific Activities

There is a huge literature suggesting and demonstrating that research and scientific indicators make an important contribution to the growth at 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 (1953) for the structure of the US economy and has been extended in several ways. Carter (1960) has incorporated some dynamic elements with a formal consideration of the role of investment in embodied technical change. Chenery, Syrquin and others (1963) added elements of trade into this framework.

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.

Input-output tables are available both in current and constant prices. Following Kubo et al. (1986), 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 an 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 measure the relative importance each factor in 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 category. When growth rates differ 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 1975 prices,

$X^1_{ij}$ is the matrix of interindustry transactions for first period at constant 1975 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:

$$\begin{array}{ccccccccc}
DD_1 & + & EE_1 & + & IS_1 & + & IO_1 & = & \Delta X_1 \\
DD_2 & + & EE_2 & + & IS_2 & + & IO_2 & = & \Delta X_2 \\
. & & . & & . & & . & & . \\
. & & . & & . & & . & & . \\
. & & . & & . & & . & & . \\
. & & . & & . & & . & & . \\
DD_n & + & EE_n & + & IS_n & + & IO_n & = & \Delta X_n \\
\hline
\Sigma DD_i & + & \Sigma EE_i & + & \Sigma IS_i & + & \Sigma IO_i & = & \Sigma \Delta X_i = \Delta X
\end{array}$$

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,

$\Delta X_i$=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 $\Sigma\Delta X_i$, so that all components across sectors and demand categories sum to 100. Alternatively, it is sometimes convenient to divide the rows by $\Delta X_i$ and then to look at the percentage contribution of each demand category to the change in sectoral output.

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.

**Table 6 :** Decomposition Formulas (*)

| *Sources of growth:* | *Variable* | *being* | *decomposed* | |
|---|---|---|---|---|
| Domestic-final-demand expansion (FE) | Output $\Delta X$ | Val.Add. $\Delta V$ | Imports $\Delta M$ | **Empl. $\Delta L$** |
| Export expansion(EE) | $B_0\hat{u}^f_0\Delta F$ | $v_0B_0\hat{u}^f_0\Delta F$ | $(m11f_0+m^w_0A_0B_0\hat{u}^f_0)\Delta F$ | **$l_0B_0\hat{u}^f_0\Delta F$** |
| 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) | ----- | $\Delta vX_1$ | ----- | **-----** |
| **Labour-productivity-growth (IOL)** | **-----** | **-----** | **-----** | **$\Delta lX_1$** |

*Source:OECD Document:"Structural change and Industrial performance", 1992.*

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

**Table 7:** Sources of output growth for selected countries: (percentage)

| | **D.D.E.** | **E.E.** | **I.S.** | **I.O.C.** | **Total:** |
|---|---|---|---|---|---|
| Greece: 1960-1980 | 78.43 | 28.37 | -4.91 | -3.71 | **100** |
| Greece: 1960-1970 | 98.67 | 14.50 | -7.55 | -5.63 | **100** |
| Greece: 1970-1980 | 60.26 | 38.07 | -0.29 | 1.95 | **100** |
| Japan: 1914-1935 | 73.8 | 26.7 | -0.5 | -0.1 | **100** |
| Japan: 1935-1955 | 90.8 | -13.8 | 15.6 | 7.4 | **100** |
| Japan: 1955-1960 | 87.9 | 8.0 | -4.1 | 8.3 | **100** |
| Japan: 1960-1965 | 90.8 | 15.1 | -2.1 | -3.8 | **100** |
| Japan: 1965-1970 | 82.6 | 14.9 | -3.2 | 5.7 | **100** |
| Korea: 1955-1963 | 74.5 | 10.0 | 21.4 | -6.0 | **100** |
| Korea: 1963-1970 | 81.8 | 21.9 | -1.8 | -1.9 | **100** |
| Korea: 1970-1973 | 51.9 | 55.7 | -3.2 | -4.4 | **100** |
| Taiwan: 1956-1961 | 54.3 | 23.9 | 15.1 | 6.7 | **100** |
| Taiwan: 1961-1966 | 61.3 | 37.6 | -1.1 | 2.2 | **100** |
| Taiwan: 1966-1971 | 52.7 | 49.5 | -0.2 | -2.0 | **100** |
| Israel: 1958-1965 | 76.7 | 25.6 | 3.1 | -5.4 | **100** |
| Israel: 1965-1972 | 69.1 | 42.0 | -18.9 | 7.9 | **100** |
| **Norway:1953-1961** | **60.7** | **40.4** | **-10.6** | **9.5** | **100** |
| **Norway:1961-1969** | **60.2** | **49.1** | **-13.3** | **4.0** | **100** |

Sources:The data for Greece comes from the results of the above analysis (in % units), while the data for other countries is from Shujiro Urata: "Economic

growth and structural change in the Soviet Economy 1952-1972" in chapter 19 of Maurizio Ciaschini: "Input-Output Tables".
Note: where, D.D.E.=Domestic Demand Expansion, E.E.=Export Expansion, I.S.=Import Substitution, I.O.C.=changes of Input-Output Coefficients.

The same industry can be driven by different factors in different countries. Since industrial production depends on different forces, for instance the existence of natural resources, human capital, trade policies, rates of economic growth, and innovation levels. Table 7 illustrates the sources of output growth for selected countries in order to draw some comparisons. Decomposition analysis shows that the sources of output growth varied from country to country. In most countries, domestic final demand was the primary force for output growth; domestic final demand was a significant factor in Japan, Korea, Norway and Israel. In addition, exports have contributed to growth. The effects of imports were negative for all countries.

The comparison of changes in output shares and differences in growth rates reveals the direction and the pace of structural change. Japan represents the most clear example of structural change. The high technology sectors increased rapidly and contributed significantly to manufacturing's share of total output. In Japan the low technology sector showed the second largest loss of output share of all countries examined.

Table 8 indicates the sources of growth in real output for various countries. This Table illustrates a typical example of decomposition of gross output for manufacturing in constant prices. Domestic Final Demand and Exports are the most important sources in the expansion of output growth.

**Table 8:** Sources of growth in real output of all industrial sectors (*)

| Country/Period (constant prices) | Annual aver. growth rate (%) | Domest. Final Demand Expans | Export Expans. | Domest. Final Demand Expans. | Imports Intermed goods | Input-output coef (tech. change) |
|---|---|---|---|---|---|---|
| France: 1972-1985 (1980) | 1.32 | 1.03 | 1.61 | -0.48 | -0.59 | **-0.25** |
| Germany:1978-1986 (1980) | 0.97 | 0.55 | 1.77 | -0.40 | -0.63 | **-0.32** |
| Greece:1960-1980 (1975) | 4.13 | 2.69 | 1.17 | -0.21 | -0.12 | **0.61** |
| Japan: 1970-1985 (1975) | 4.40 | 2.66 | 2.04 | 0.00 | -0.05 | **-0.26** |
| U.K.: 1968-1984 (1980) | 0.19 | 0.82 | 0.98 | -0.65 | -0.81 | **-0.15** |
| **USA: 1972-1985 (1982)** | **1.57** | **2.23** | **0.60** | **-0.40** | **-0.38** | **-0.48** |

*Source: OECD study of "Structural change & Industrial performance", 1992, Paris.*
Note (*) The values of Greece dervied as an avergae from the sectors of Industrial Intermediate goods, Industrial Manufacturing goods, Industrial Consumer goods

Table 9 summarises the sources of change in the real output shares of manufacturing (high, medium and low technology sectors) for various countries. Domestic final demand expansion contributed substantial to the low and medium technology industries, while technical change contributed positively for the high and medium technology industries and negatively for the low technology industries and for manufacturing sector.

**Table 9:** Sources of change in real output shares for manufacturing

| | *Total change output share(%)* | *Domest.Final DemandExpans.* | *Export Expans.* | *Imports of-final goods* | *Imports of-interm. goods* | *Techn. change (IOC)* |
|---|---|---|---|---|---|---|
| France: (1972-1985) | | | | | | |
| High Technology | 1.72 | 0.81 | 1.34 | -0.29 | -0.29 | **0.15** |
| Medium Technology | -0.52 | -0.46 | 1.63 | -0.76 | -0.95 | **0.02** |
| Low Technology | -5.18 | -2.35 | 1.52 | -1.29 | -1.68 | **-1.38** |
| Germany: (1978-1986) | | | | | | |
| High Technology | 0.87 | 0.31 | 0.94 | -0.26 | -0.25 | **0.13** |
| Medium Technology | 0.44 | -0.34 | 1.84 | -0.37 | -0.86 | **0.18** |
| Low Technology | -3.63 | -1.31 | 0.74 | -0.69 | -0.99 | **-1.38** |
| Japan: (1970-1985) | | | | | | |
| High Technology | 7.25 | 2.58 | 3.41 | 0.11 | 0.04 | **1.11** |
| Medium Technology | 1.02 | -2.29 | 3.00 | 0.01 | -0.12 | **0.43** |
| Low Technology | -6.92 | -4.34 | 0.38 | -0.11 | -0.29 | **-2.55** |
| Un.Kingdom (1968-84) | | | | | | |
| High Technology | 0.49 | 0.52 | 1.49 | -1.02 | -0.72 | **0.21** |
| Medium Technology | -4.09 | -0.40 | 0.65 | -1.84 | -2.66 | **0.16** |
| Low Technology | -7.97 | -2.88 | -0.44 | -1.32 | -1.96 | **-1.38** |
| **United States(1972-85)** | | | | | | |
| **High Technology** | **2.40** | **1.87** | **0.80** | **-0.34** | **-0.24** | **0.31** |
| **Medium Technology** | **-1.52** | **0.05** | **0.34** | **-0.77** | **-0.66** | **-0.47** |
| **Low Technology** | **-3.95** | **-1.05** | **0.42** | **-0.63** | **-0.78** | **-1.91** |

*Source: "Structural change and industrial performance:Growth decomposition in seven OECD economies" 1992, Paris, section 4.*

Table 10 indicates the Primary sources of change for fastest and slowest output growth industries.

**Table 10:**Primary sources of change for fastest and slowest output growth industries *

| (Fast/Slow) | Domes.Final Demand | Exports. Expans. | Imports Final products | Imports Interm.inputs | Technology |
|---|---|---|---|---|---|
| France (1972-1985) | 7/2 | 3/1 | 0/1 | 0/3 | **0/3** |
| Germany (1978-86) | 3/0 | 6/1 | 0/1 | 0/3 | **0/3** |
| Greece(**) (1960-80) | 9/0 | 9/0 | 2/7 | 4/5 | **5/4** |
| Japan (1970-1985) | 6/1 | 2/0 | 0/0 | 0/1 | **2/8** |
| Un.Kingd.(1968-84) | 5/1 | 3/0 | 0/3 | 0/3 | **2/3** |
| **U.S.A.(1972-1985)** | **10/1** | **0/0** | **0/4** | **0/0** | **0/5** |

Note: OECD, "Structural change and industrial performance:growth decomposition in seven OECD countries" 1992, Paris. (*) The first values in the nominator indicate the number of fastest growth sectors, while the values in the dominator indicate the number of slowest growth sectors for each source. (**) The values for Greece derived from the previous analysis.

### *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). 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. 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.

For the level of productivity, we can use as a proxy real GDP per capita (GDPCP). For the measurement of *national technological level*, we can also use some approximate measures; for instance, we can again use the traditional variables of *technological input* and *technological output* measures, (GERD and EXPA). 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. We will 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; 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.

We have tested the following version of the models:

GDP(or PROD)= f[GDPCP, EXPA (or GERD), INV],(basic model), **(1)**

GDP(or PROD)= f[GDPCP, EXPA (or GERD), INV, EXP], **(2)**

GDP= f[GDPCP, EXPA (or GERD), INV, TRD], **(3)**

**Table 11:** Relationship between productivity and innovation for EU member states, 1973~97

| |
|---|
| **Relation between productivity and patents:**<br>**GDPPC = 5547.23 + 529.695EXPA**<br>**t = (7.455) (4.544) $R^2$ = 0.28 (adj.df 0.22). DW = 2.05**<br>**Rho (autocorrelation coefficient) = -0.0962, t = -0.344. SEs and variance shown are heteroskedastic consistent estimates.** |
| **The logarithm models:**<br>**LGDPPC = 8.068 + 0.564LEXPA**<br>**t = (21.099) (2.336) $R^2$ = 0.23 (adj.df 0.16). DW = 1.69**<br>**Rho (autocorrelation coefficient) = 0.705, t = 0.223. SE's and variance shown are heteroskedastic consistent estimates.**<br>**LLGDPPC = 2.160 + 0.783LLEXPA**<br>**t = (128.747) (2.868) $R^2$ = 0.31 (adj. df 0.24). DW = 1.81**<br>**Rho (autocorrelation coefficient) = -0.032, t = -0.101. SEs and variance shown are heteroskedastic consistent estimates.** |
| **The relation between productivity and gross expenditures on research and development:**<br>**GDPPC = 9584.54 - 366.10GERD**<br>**t = (5.738) (-1.324) $R^2$ = 0.76 (adj. df 0.52). DW = 1.644**<br>**Rho (autocorrelation coefficient) = 0.131, t = 0.475. SEs and variance shown are heteroskedastic consistent estimates.** |
| **The logarithm models:**<br>**LGDPPC = 9.424 - 0.384LGERD**<br>**t = (25.721) (-1.529) $R^2$ = 0.091 (adj.df 0.02) DW = 1.24**<br>**Rho (autocorrelation coefficient) = 0.347, t = 1.352. SEs and variance shown are heteroskedastic consistent estimates.**<br>**LLGDPPC = 2.200 - 0.0647LLGERD**<br>**t = (141.439) (-1.586) $R^2$ = 0.087 (adj.df 0.017) DW = 1.177**<br>**Rho (autocorrelation coefficient) = 0.385, t = 1.525. SEs and variance shown are heteroskedastic consistent estimates.** |

Notes: GDPPC = GDP per capita average for the period 1973~1997, absolute values in constant (1985) prices (US$ 000) for per capita GDP. EXPA = average annual growth rates for the period 1973~1997 for external patent applications. GERD = average annual growth rates for the period for gross expenditure on research and development.

LGDP, LPROD, LEXPA, LGERD, LEXP, LINV, LTRD, LLGERD, LLGDPCP are the above variables in logarithmic and in loglogarithm form.

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). However, it can be argued that this model overlooks differences in overall growth rates between periods due to other factors and especially differences in economic policies. We can easily investigate the relationship between these two approximate measures using cross-section data on average growth rates in the period 1973~97 for the EU member states.

The correlation between productivity and patenting is much closer than between productivity and research expenditure. When conducting an econometric analysis of the technological gap models, it is important to include the most relevant variables. For the level of productivity, as a proxy we can use real GDP per capita (GDPPC). For the national technological level we can use some approximate measures, for instance we can again use the traditional variables of technological input and technological output (GERD and EXPA).

Following the model of Fagerberg (1987, 1988, 1994) we can test the basic technological gap model (with and without these variables), reflecting structural change, in order to determine the degree to which these variables have added something to the other explanatory variable of the model. We shall use external patent applications (EXPA) and gross expenditure on research and development (GERD) as proxies for the growth of national technological activities, and GDP per capita (GDPPC) (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 an improvement in the capacity for economic exploitation of innovation and diffusion; 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 the institutional system). Table 12 shows the model for EU member states, including as additional variables exports (as a share of GDP) and the terms of trade; this indicates that growth has been influenced by changes in the terms of trade (terms of trade shock). The export variable also has the expected sign and the results support the hypothesis of structural change as a source of economic growth. The second model takes account of structural changes using as a proxy the share of exports in GDP. The third model uses an additional variable that reflects changes in the macroeconomic conditions and suggests that growth rates are seriously affected by changes in the terms of trade. The models are tested for EU member states.

` The basic model is tested for the variables of GDP, GDP per capita, external patent applications and investment as a share of GDP. The explanatory power (or the overall goodness of fit of the estimated regression models) is not very high, but this is not surprising for cross-sectional data. However there is a problem with interdependence between the variables. For this reason we shall focus on the relationship between productivity and innovation. Most of the variables have the expected signs.

**Table 12:** The basic model tested for the EU member states, 1973~1997

| |
|---|
| **The basic model including patents:**<br>**GDP = 2.824 - 0.002GDPPC + 0.10EXPA + 0.027INV**<br>**t = (1.53) (-3.30) (2.30) (0.32) $R^2$ = 0.52 (adj. df 0.39). DW = 1.52**<br>**Rho (autocorrelation coefficient) = 0.385, t = 1.475. SEs and variance shown are heteroskedastic consistent estimates.**<br>**The logarithm model:**<br>**LGDP = 1.499 - 0.384LGDPPC + 0.155LEXPA + 0.806LINV**<br>**t = (0.593) (-2.569) (0.930) (1.340) $R^2$ = 0.56 (adj. df 0.42). DW = 1.36**<br>**Rho (autocorrelation coefficient) = 0.297, t = 0.985. SEs and variance shown are heteroskedastic consistent estimates.** |
| **The basic model including patents:**<br>**PROD = 0.453 - 0.00015GDPPC - 0.0198EXPA + 0.174INV**<br>**t = (-0.386) (-3.979) (-0.245) (3.012) $R^2$ = 0.64 (adj. df 0.54). DW = 1.49**<br>**Rho (autocorrelation coefficient) = 0.301. SEs and variance shown are heteroskedastic consistent estimates.**<br>**The logarithmic model:**<br>**LPROD = -0.566 - 0.384LGDPPC - 0.131LEXPA + 1.558LINV**<br>**t = (-0.220) (-2.519) (-0.770) (2.541) $R^2$ = 0.75 (adj. df 0.66). DW = 1.38**<br>**Rho (autocorrelation coefficient) = 0.241, t = 0.786. SEs and variance shown are heteroskedastic consistent estimates.** |
| **The basic model including the gross expenditures on research and development:**<br>**GDP = 1.775 - 0.00129GDPPC + 0.0142GERD + 0.0646INV**<br>**t = (0.92) (-1.86) (0.21) (0.75) $R^2$ = 0.40 (adj. df 0.24). DW = 2.30**<br>**Rho (autocorrelation coefficient) = -0.153, t=-0.539. SEs and variance shown are heteroskedastic consistent estimates.**<br>**The logarithm model:**<br>**LGDP = 0.619 - 0.275LGDPPC + 0.00625LGERD + 0.837LINV**<br>**t = (0.246) (-2.098) (0.0396) (1.408) $R^2$ = 0.47 (adj. df 0.33). DW = 2.38**<br>**Rho (autocor.coefficient) = -0.228, t = -0.815. SEs and variance shown are heteroskedastic consistent estimates.** |
| **The basic model including the gross expenditures on research and development:**<br>**PROD = 0.349 - 0.00018GDPPC - 0.0716GERD + 0.168INV**<br>**t = (0.231) (-3.413) (0.933) (2.677) $R^2$ = 0.66 (adj. df 0.57). DW= 1.43**<br>**Rho (autocorrelation coefficient)=0.301. SEs and variance shown are heteroskedastic consistent estimates.**<br>**The logarithmic model:**<br>**LPROD = -0.404 - 0.421LGDPPC - 0.0345LGERD + 1.568LINV**<br>**t = (-0.130) (-2.585) (-0.176) (2.126) $R^2$ = 0.61 (adj. df 0.50) DW=1.79**<br>**Rho (autocorrelation coefficient) = -0.0131, t = -0.0402. SEs and variance shown are heteroskedastic consistent estimates.** |

Notes: GDP = annual average growth rates for real gross domestic product. PROD = annual average growth rates for product (defined as labour product GDP per person employed). GDPPC = average absolute values in constant (1985) prices (US$ 000) for GDP per capita. EXPA = annual average growth rates for external patent applications. GERD = annual average growth rates for gross expenditures on research and development. EXP = annual average growth rates for exports as a share of GDP. INV = annual average growth rates for investment as a share of GDP. TRD = annual average growth rates for the terms of trade. LGDP, LPROD, LEXPA, LGERD, LEXP, LINV and LTRD are the above variables in a logarithmic form.

The introduction of the terms of trade variable into the basic model led to a negative sign for the innovation variables (GERD and EXPA); this indicates that the economic slowdown after 1973 can be better explained by a terms of trade shock. However, some of the results are not statistically significant and the explanatory power is not very high.

In both cases we used the same approach, first testing the basic model and then introducing the terms of trade and export variables. It is worth noting that for the technologically advanced member states the estimated coefficients display the expected signs except for exports (EXPA) and gross expenditure on R&D (GERD). The results do not support the hypothesis of structural changes as independent causal factors of economic growth. These results can be seen as supporting the view that the influence of a change in outward orientation on growth depends on the international macroeconomic conditions (since random shocks and crises and slow growth in world demand in the 1970s restrained the growth of outward-oriented countries).

### *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:

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

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.

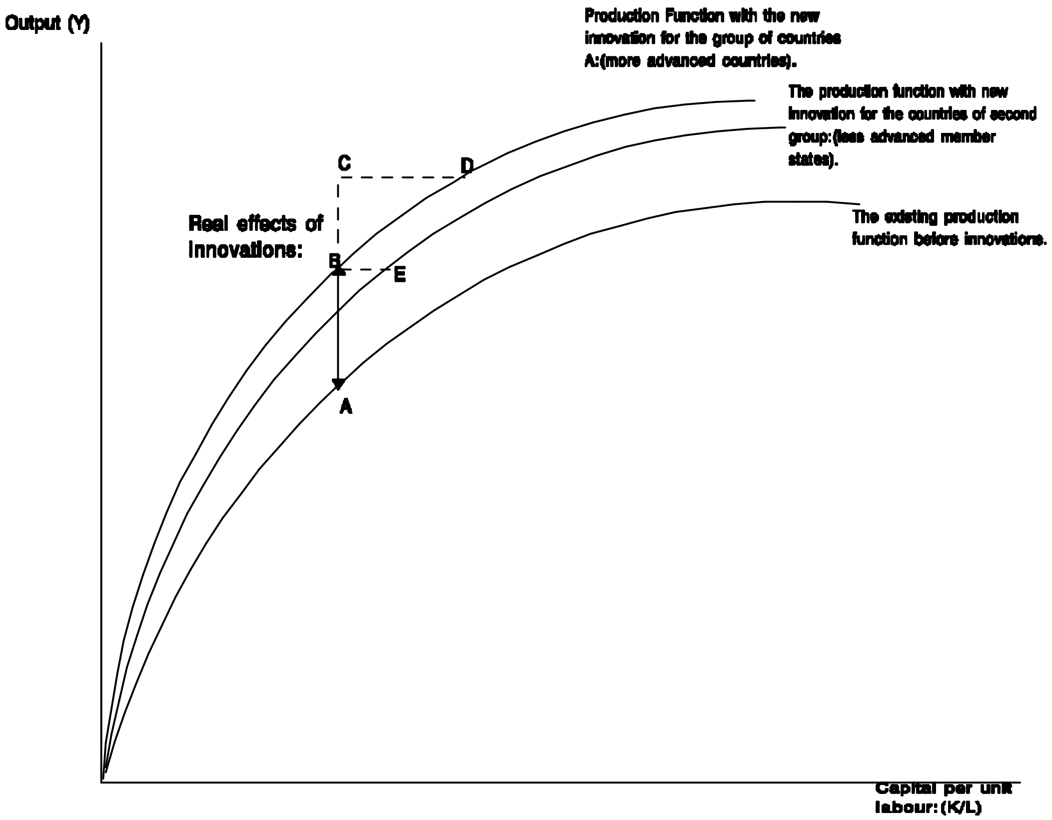
In a cross section study, technology can be regarded as given in each country, but this is clearly not in the case when we consider a single country over a period of time. The country's production function will shift as new and more efficient techniques are adopted. A major problem with time series data is to distinguish between increases in output resulting from movements along the production function (for instance, from increased inputs) and increases in output which occur because of shifts in the production function resulting from the technical progress. The problem of simultaneous equation bias is present with time-series data as with cross sectional data. However, there is a more serious problem with time series data that of the technical progress or innovation over time.[4]

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 of the production function (Solow 1957, Griliches 1967) have been handled under one or more traditionally maintained hypothesis of *constant returns of*

[4]With cross sectional data the identification problem can arise if product and factor prices show any marked tendency to change at similar rates over time, as this may leave price ratios constant. See Thomas R.L., (1993).

*scale*, *neutrality of technical progress* and *profit maximization* with competitive output and input markets. Therefore, the validity or otherwise of each of these hypotheses affects the measurement of technical progress and the decomposition of economic growth into its sources.




Following the analysis of Landau, we can assume that there is a production function that relates output to capital per unit of labour and also 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 moves along the production function. Figure 2, 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:

$$C=F(P_K, P_L, Y, T) \qquad \textbf{(1)}$$

where: $P_K$, $P_L$, Y, T indicate the price of capital input, labour input, the value added and time.

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

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

$$+\sum_{i=1}^{n}\gamma_{ij}\ln P_i \ln y+\gamma_T T+\frac{1}{2}\gamma_{TT}T^2+\sum_{i=1}^{n}\gamma_{iT}\ln P_i T+\sum_{i=1}^{n}\gamma_{yT}\ln yT\,, \qquad \textbf{(6)}$$

We use aggregate data and assuming that input prices are endogenous, in order to estimate the *translog share equation system* and to avoid the simultaneous equation problems, we employ three stage least squares with an instrumental variable estimator provided that appropriate instruments are available. The aggregate data we use are available for forty years 1950-1990, as reported from IMF. Output is measured as value added. Labour is measured as the number of employees and capital is measured as the capital stock. As the price of capital we use the long-term interest rate and as the price of labour wages and salaries. To estimate the above model of the average cost functions along with the share of one input and the rate of technical change, we adopted the three stage least squares (using instrumental variables with endogenous lag variables, such as lag shares, lag prices of capital, labour and output and some exogenous variables, such as export and import prices and consumer prices).

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

The parameters $\gamma_{KK}$, $\gamma_{KL}$, $\gamma_{LL}$ 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 $\gamma_{KT}$ and $\gamma_{LT}$ 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 $\gamma_T$ can be interpreted as the average rate of productivity growth, while the parameters $\gamma_K$ and $\gamma_L$ can be interpreted as the average value shares of capital and labour inputs.

The results of multivariate regression appear in Tables 14 and 15 where the numbers in brackets are t-statistics. The countries included are France, Germany, Italy, Netherlands and United Kingdom (the first category of more advanced member states) and Greece, Ireland and Spain (the second category of less advanced member states).

The parameter $\alpha_Y$ has a positive value which indicates the average value share of output in the total cost (except for Britain and Ireland). The parameter $\gamma_{YT}$ indicates how time affects the growth of output (*the rate of technical change or the acceleration rate*); this parameter has negative values for both Ireland and the United Kingdom.

The parameter $\gamma_{KL}$ indicates the substitution patterns between the two factors (capital and labour); because we assumed a two factor cost function, we do not expect capital and labour to be complements. In this sense, capital and labour are substitutes as the parameter $\gamma_{KL}$ is negative; actually, the parameter $\gamma_{KL}$ is negative for all countries, (except the case of France where it is positive but not statistically significant).

The parameter $\alpha_{YY}$ (the *flexibility cost*) indicates how the marginal cost will change with a change in the level of output; for three countries (England, Germany and Ireland) the marginal cost will increase as the output expands.

The parameters $\gamma_{KY}$, and $\gamma_{LY}$, 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 $\gamma_{KT}$, and $\gamma_{LT}$ suggest the technical change biases and they represent a change of factor share with respect to time. The parameter $\gamma_{YT}$, measures the impact of technical change on the growth of output and this parameter indicates that the technical change in England and Ireland decreases aggregate the output.

**Table 14:** Parameter estimations time series of translog-cost function for selected countries (1950-1990)

| | $\alpha_0$ | $\alpha_Y$ | $\alpha_{YY}$ | $\alpha_K$ | $\alpha_L$ | $\gamma_T$ | $\gamma_{KK}$ | $\gamma_{LL}$ | $\gamma_{TT}$ | $\gamma_{YT}$ | $\gamma_{KY}$ | $\gamma_{KL}$ | $\gamma_{KT}$ | $\gamma_{LY}$ | $\gamma_{LT}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Engl. | 193 | -575 | 152 | -0.16 | 1.163 | 13.40 | 0.214 | 0.214 | 0.083 | -3.54 | 0.123 | -0.21 | 0.026 | -0.12 | (-0.2) |
| | (3.44) | (-3.4) | (3.41) | (-0.4) | (3.41) | (3.33) | (24) | (24) | (3.23) | (-3.3) | (1.31) | (-24) | (1.02) | (-1.3) | (-1.0) |
| Fran. | -223 | 134.8 | -39.7 | 2.548 | -1.54 | -5.26 | -0.02 | -0.02 | -0.05 | 1.552 | -0.55 | 0.02 | 0.01 | 0.55 | -0.01 |
| | (-1.8) | (1.89) | (-1.9) | (23.8) | (-14) | (-1.9) | (-0.7) | (-0.7) | (-2.3) | (2.0) | (-20) | (0.7) | (17) | (20) | (-17) |
| Gree. | -37.8 | 26.81 | -8.06 | -0.74 | 1.741 | -1.33 | 0.213 | 0.213 | -0.09 | 0.357 | 0.280 | -0.21 | -0.01 | -0.28 | 0.014 |
| | (-2.3) | (2.5) | (-2.4) | (-16) | (37.8) | (-2.7) | (26.9) | (26.9) | (-1.7) | (2.4) | (18.8) | (-26) | (-1.0) | (-18) | (1.0) |
| Germ | 1.71 | 0.763 | 0.194 | -0.24 | 1.249 | -0.37 | 0.168 | 0.168 | -0.03 | 0.071 | 0.160 | -0.16 | 0.002 | -0.16 | -0.02 |
| | (0.6) | (0.5) | (0.4) | (-1.4) | (7.11) | (-0.6) | (13) | (13) | (-0.4) | (0.4) | (3.5) | (-13) | (0.19) | (-3.5) | (-0.4) |
| Italy: | -33.0 | 22.31 | -6.45 | -0.66 | 1.661 | -1.03 | 0.226 | 0.226 | -0.09 | 0.287 | 0.248 | -0.20 | 0.003 | -0.24 | -0.03 |
| | (-0.6) | (0.7) | (-0.6) | (-7.5) | (18.9) | (-0.7) | (20.8) | (20.8) | (-0.6) | (0.7) | (6.89) | (-20) | (1.1) | (-6.8) | (-1.1) |
| Irel. | 85.27 | -46.1 | 13.32 | -4.3 | 5.33 | 1.10 | 0.229 | 0.229 | 0.010 | -0.34 | 1.155 | -0.22 | -0.01 | -1.15 | 0.013 |
| | (0.7) | (-0.6) | (0.64) | (-13) | (17) | (0.44) | (14.6) | (14.6) | (0.37) | (-0.4) | (13.1) | (-14) | (-4.6) | (-13) | (4.6) |
| Nethr | -104 | 61.5 | -17.1 | 0.219 | 0.780 | -2.02 | 0.203 | 0.203 | -0.01 | 0.558 | -0.01 | -0.20 | 0.09 | 0.013 | -0.09 |
| | (-2.0) | (2.0) | (-1.9) | (1.26) | (4.51) | (-1.9) | (10) | (10) | (-1.5) | (1.85) | (-0.2) | (-10) | (4.4) | (0.2) | (-4.4) |
| Spain | -21.2 | 16.8 | -5.4 | 0.502 | 0.497 | -0.85 | 0.086 | 0.086 | -0.01 | 0.284 | -0.06 | -0.08 | 0.08 | 0.06 | -0.08 |
| | (-2.9) | (3.6) | (-3.8) | (7.9) | (7.8) | (-4.2) | (5.9) | (5.9) | (-4.2) | (4.4) | (-4.5) | (-5.9) | (10) | (4.5) | (-10) |

Note: The numbers in the brackets are t-statistics.

**Table 15:** Substitution, price elasticities and technical change (1959-1990)

| | $\sigma_{LL}$ | $\sigma_{KK}$ | $\sigma_{KL}$ | $P_{LL}$ | $P_{KK}$ | $P_{LK}$ | $P_{KL}$ | c/l | TCH1 | TCH2 | TCH3 | MFP | Scale |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| England: | -0.122 | -0.103 | 0.109 | -0.048 | -0.047 | 0.048 | 0.047 | c.s | 15.204 | 0.0027 | -15.21 | -0.0095 | 0.584 |
| France: | -1.500 | -0.68 | 1.001 | -0.596 | -0.403 | 0.596 | 0.403 | c.u | -6.449 | 0.0375 | 6.405 | -0.0587 | 0.233 |
| Greece: | -0.016 | -0.074 | 0.054 | -0.021 | -0.033 | 0.021 | 0.033 | c.s | -1.538 | -0.002 | 1.416 | -0.124 | 0.403 |
| Germany: | -0.417 | -0.209 | 0.283 | -0.165 | -0.117 | 0.165 | 0.117 | c.s | -0.385 | 0.0003 | 0.297 | -0.086 | 0.321 |
| Italy: | -0.059 | -0.059 | 0.057 | -0.028 | -0.028 | 0.028 | 0.028 | c.s | -1.243 | 0.0004 | 1.169 | -0.074 | 0.405 |
| Ireland: | -0.052 | -0.044 | 0.047 | -0.024 | -0.022 | 0.024 | 0.022 | c.s | 1.3318 | -0.021 | -1.40 | -0.096 | 0.608 |
| Netherl.: | -0.195 | -0.160 | 0.172 | -0.090 | -0.082 | 0.090 | 0.082 | c.s | -2.360 | 0.0074 | 2.328 | -0.024 | 2.903 |
| Spain: | -0.563 | -0.758 | 0.651 | -0.301 | -0.349 | 0.301 | 0.349 | c.s | -1.119 | 0.0059 | 1.163 | 0.0503 | 0.317 |

Note: $\sigma_{LL}$, $\sigma_{KK}$, $\sigma_{KL}$= substitution elasticities, $P_{LL}$, $P_{KK}$, $P_{KL}$=price elasticities, TCH1, TCH2, TCH3=technical change, MFP, Scale=multifactor productivity and scale, respectively. The proxy overall growth of technical change is examined by ST. Finally, c/l=capital-labour saving (where c.u. is the capital-using (or labour saving)); according to David and Van De Klundert, (1965) technical progress is capital-saving if and only if the elasticity of substitution between capital and labour is less than unity in absolute value.

Table 15 illustrates the estimates of substitution and price elasticities. The elasticity of substitution ($\sigma_{KL}$) for the production function is equal to:

$$\sigma_{ij}=(\gamma_{ij}+S_iS_j)/S_iS_j.$$

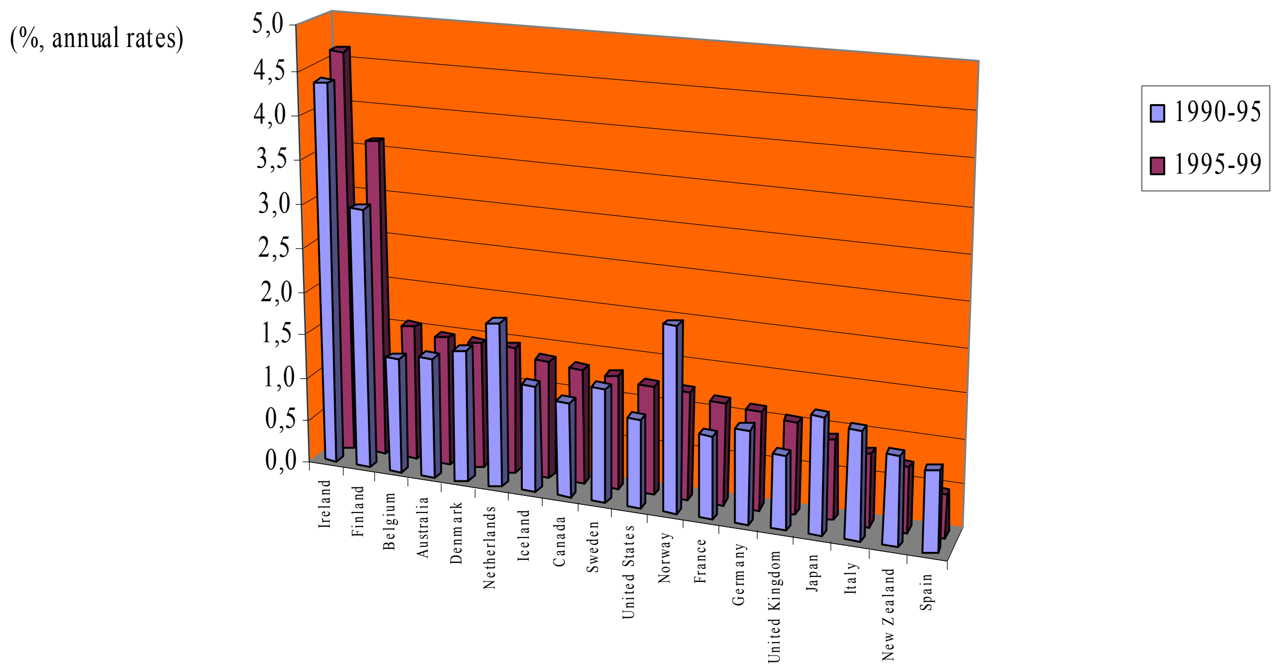
If $\sigma_{KL}$ is greater than zero then inputs are substitutes for this country; otherwise if $\sigma_{KL}$ is less than zero then they are complements. The price elasticities can be defined as:

$$P_{ij}=(\gamma_{ij}+S_iS_j)/S_i.$$

*Multifactor productivity MFP* (or the rate of technical change) is decomposed into three parts, pure technology, non- neutral technology and scale augmenting technology. The *multifactor productivity* is negative for all countries (except Spain) which means technological change reduces total costs.

An initial investigation of the aggregate function allows for the possibility that the growth of conventional inputs may be *non-neutral* in the sense that the marginal productivity of those inputs does not increase at the same rate through time. An interesting question is to see whether the technical progress is *capital or labour augmenting* and furthermore if it is *capital (or labour) saving* in the sense that the demand for capital (labour) relative to the labour (capital) at a given quantity of output, is reduced as a result of the technical progress.

**Figure 1: Multifactor Productivity Growth, Business Sector, (1990-1999)**




The *neutrality of technical change* implies that the *rate of technical progress* is independent of capital and labour. The *non neutrality of technical progress* implies that the *rate of technical progress* at time t will vary depending on the quantities of capital and labour inputs at time t and to that extent may be regarded as endogenous. According to our estimates, we can divide technical change into *neutral technical change* and *non neutral technical change* (where time affects capital and labour inputs). Neutral technical change is indicated by TCH1 for the various countries. Non neutral technical change is indicated by TCH2.

Figure 1 shows the multifactor productivity growth for the Business Sector, for the period 1990-1999. Labour productivity is a partial measure of productivity; it relates output to only one input in the production process, albeit an important one. More complete measures of productivity at the economy-wide level relate output growth to the combined use of labour and capital inputs.

**Table 13:** Trends in multi-factor productivity growth,[1,2] 1990-95 and 1995-99

| | 1990-95 | 1995-99 |
|---|---|---|
| **Ireland** | **4,4** | **4,6** |
| **Finland** | **3,0** | **3,6** |
| **Belgium** | **1,3** | **1,6** |
| **Australia** | **1,4** | **1,5** |
| **Denmark** | **1,5** | **1,5** |
| **Netherlands** | **1,9** | **1,5** |
| **Iceland** | **1,2** | **1,4** |
| **Canada** | **1,1** | **1,3** |
| **Sweden** | **1,3** | **1,3** |
| **United States** | **1,0** | **1,2** |
| **Norway** | **2,1** | **1,2** |
| **France** | **0,9** | **1,1** |
| **Germany** | **1,1** | **1,1** |
| **United Kingdom** | **0,8** | **1,0** |
| **Japan** | **1,3** | **0,9** |
| **Italy** | **1,2** | **0,8** |
| **New Zealand** | **1,0** | **0,7** |
| **Spain** | **0,9** | **0,5** |

1. Adjusted for hours worked, based on trend series and time-varying factor shares.
2. 2. Series end in 1997 for Austria, Belgium, Italy and New Zealand; 1998 for Australia, Denmark, France, Ireland, Japan, Netherlands and United Kingdom. Data for Germany start in 1991.
3. *Source:* OECD calculations, based on data from the OECD *Economic Outlook No. 68*. See S. Scarpetta et al., Economics Department Working Paper No. 248, 2000 for details; May 2001.

**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 performs 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, its 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 establised 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 the local differences and the 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 (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 collection of data from the regions or the second method «bottom-to-the-top method» for the collection dissaggregate R&D data (for the whole regions) 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 (for the whole country).

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 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.

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 reprsent 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. Research on *why growth rates differ* has a long history which goes well beyond growth accounting exercises.

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