LESSONS AND EVIDENCE FROM PRODUCTIVITY AND REGIONAL GROWTH IN EUROPE

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Abstract:
This paper investigates the relationship between productivity and technological change. The question that we shall address in this paper, is whether the recent slow down in productivity can be explained by the slow-down of innovation activities. This paper measures the effects from productivity and technical change in regional growth for European member states. The paper concludes by summarizing some of the major findings of the discussion and pointing to some directions for future research activities.

Keywords: Innovation, technical change, productivity, economic growth.

1. Introduction

Since the observed serious declines in the rates of growth in productivity that occurred around 1973 in most OECD countries, an expansive research effort has sprung up to explain both these declines and the previous high productivity growth rates. Overviews of much of this work are provided by Maddison (1987), and Jorgenson (1987, 1988).

Many studies have suggested that there is a close correlation between technological development and productivity (see for example Abramovitz, 1986; Fagerberg, 1987, 1988, 1994), and economists have analysed different possible views of why productivity growth has declined. These alternative explanations can be grouped into the following categories:

- the capital factor, for instance investment may have been insufficient to sustain the level of productivity growth;
- the technology factor, for instance a decline in innovation might have affected productivity growth;
- the increased price of raw materials and energy;
- government regulations and demand policies that affect the productivity level;
- the skills and experience of the labour force may have deteriorated or workers may not work as hard as they used to;
- the products and services produced by the economy have become more diverse; and
- productivity levels differ greatly across industries.

The various factors which might influence the incidence of innovation and productivity are the following:

- the *technical applicability*;
- *profitability*;
- *finance*, (lack of financial resources might delay the diffusion of new processes);
- *size, structure and organisation*, (large companies may for a number of economic and technological reasons which behave differently from the SMEs;

- *management attitudes*, (which is the most difficult to assess or to quantify, but nevertheless they may be as important as economic factors in influencing the rate of adoption of new methods);
- *other factors*, such as research and development activities, access to information, the labour market availability of certain skills, licensing policy, the market situation and more precisely the growth of demand for the product as well as the competitive position with special regard to the import competition. All these illustrate the wide range of factors which could contribute to explain the differences in the speed of diffusion.

This paper attempts to measure the relationship between technology and productivity, or more precisely, to investigate the correlation between technological development and the decline in productivity growth. We shall empirically test the technological and catching-up models using data for the EU member states.

2. Technical Change, Productivity and Growth: Theory and Model Specification

Productivity growth is the basis of efficient economic growth. Economic growth has been defined as the process of a sustained increase in the production of goods and services with the aim of making available a progressively diversified basket of consumption goods to population Scarcity of resources, which includes physical, financial and human resources, has been recognised as a limiting factor on the process of economic growth. While output expansion based on increased use of resources is feasible, it is not sustainable.

Role of productivity growth in the process of economic growth became clear when in the 1950's it was found that accumulation of productive factors (capital and labour) could explain only a fraction of actual expansion of output. Empirical work on the American economy by Tinbergen (1942), Schmookler (1952), Fabricant (1954), Abramovitz (1956), Kendrick (1957), Solow (1957) and Denison (1962) showed that between 80 to 90 percent of observed increase in output per head could not be explained by increase in capital per head and was attributed to productivity growth. Further, Terleckyi (1974), Scherer (1982, 1987) and Griliches (1984) showed that technological advancement was a major source of productivity improvement for the American industry.

Productivity is a relationship between production and the means of production. Or, more formally a relation of proportionality between the output of a good or service and inputs which are used to generate that output. This relationship is articulated through the given technology of production.

Productivity growth is crucially affected by technological change. Their relationship is so close that the two terms are often used interchangeably. Productivity is a wider concept. Even though a crucial one, technological change is only one of the many factors which affect productivity growth. Other being social, cultural, educational, organisational and managerial factors. Better management of workers and machines and appropriate incentive structures can increase production and/or reduce costs. But these are different from technological change.

It is not easy or straightforward to disentangle the effects of technological change from social and cultural factors. One simple way to conceptualise the differences is in the following way suggested by Spence (1984). If changes concern primarily people then they may reasonably be considered as being *social* in nature. On the other hand, if they appear to be fundamentally about material products and related processes then they can be more easily viewed as *technological*.

Given input prices, one can view technological improvement as a downward shift of the cost function. Technology has two aspects, ‘embodied’ or ‘disembodied’. The former is identified with ‘hardware’ and consists of tools, machinery, equipment and vehicles, which together make up the category of capital goods. Disembodied technology is identified with ‘software’ and encompasses the knowledge and skills required for the use, maintenance, repairs, production, adaptation and innovation of capital goods. These are often called the ‘know-how and the know-why of processes and products’.

Technological change does not affect all factors equally. When it does, it is considered neutral technical change. Otherwise, it may have a specific factor using or factor saving bias. The terms technological change and technical change are used interchangeably in the literature under review, both being indicators of a shift in the production function. It would have been useful to reserve the latter term for indicating change in techniques or processes. The terms technological progress and technical progress are synonymous with technological change and technical change respectively, all change being considered as being for the better.

The aim of this section is to examine the nature of technological progress and productivity using the *translog production function.*

In particular, this section presents a theoretical background of technical progress and of the contributions of each of the sources of growth (namely: capital, labour and technical progress). One of the problems in estimating the rate of technical change and the elasticity of substitution is that of accurately specifying the production function as well as the type of technical progress. There is a big difference though, between the models adopted here and models of *induced* technical change. The sectoral cost functions have to be homogeneous of degree one, monotonic or non-decreasing and concave in input prices. This model contributes substantially and upgrade the methodologies adopted therein. It is possible to distinguish several different aspects of this procedure, for instance:

- The model was first proposed by Jorgenson D.W. and Fraumeni B.M. (1983). Their main innovation was that they estimated the rate of technical change along with income share equations as functions of relative input prices. The shares and the rate of technical change are derived from a translog production function.
- The procedure permits the decomposition into the estimated technical change of three components: *pure technology*, which is only the time element times a coefficient; *non-neutral*, shows how the time trend influences the usage of inputs; *scale augmenting* component, which suggests how time affects the economies of scale. The sum of those three give the growth of *multifactor productivity*.
- It relaxes the assumption of constant returns to scale by estimating the initial cost function along with factor shares and the rate of technological change, and so provides the evidence for the existence of *scale economies*.

The methodology is based on a two input (capital and labour) case dual translog cost function (Christensen, Jorgenson and Lau 1971, 1973), on the derived factor shares and on the rate of technical change for all twenty industrial sectors. All these variables are functions of relative prices and time. Implicitly, it is assumed that total cost and the input shares are translog functions of their corresponding prices and time. Technology is in fact endogenous in our sectoral models and is parametrically rather than residually estimated. Applying Jorgenson and Fraumeni's methodology we fitted the models so that they embrace all of these theoretical requirements. Since perfect competition is assumed, the input prices are exogenously determined. The translog cost function can be written

$$lnc^v(w_K, w_L, Y, T) = \alpha_0^v + \alpha_y^v lny^v + \frac{1}{2}\alpha_{yy}^v(lny^v)^2 + \sum_{i=1}^{n}\alpha_i^v lnw_i^v + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}^v lnw_i^v lnw_j^v + \sum_{i=1}^{n}\gamma_{iy}^v lnw_i^v lny^v$$

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

where C= total cost, W_i (i= K,L)=input prices (price of capital and labour), Y= value-added, and T= technical change index.

Since we are using the averages we have to transform the cost function, the share equations and the rate of technical change as, (for simplicity we can drop the superlative index which declares the number of sectors):

$$\overline{lnc}^{v}(\overline{w_K},\overline{w_L},\overline{Y},T) = \alpha_0^v + \alpha_y^v\ \overline{lny}^{v} + \frac{1}{2}\alpha_{yy}^v\ (\overline{lny}^{v})^2 + \sum_{i=1}^{n}\alpha_i^v\ \overline{lnw_i}^{v} + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}^v\ \overline{lnw_i}^{v}\ \overline{lnw_j}^{v}$$

$$+\sum_{i=1}^{n}\gamma_{iy}^v\ \overline{lnw_i}^{v}\ \overline{lny}^{v} + \gamma_T^v T + \frac{1}{2}\gamma_{TT}^v T^2 + \sum_{i=1}^{n}\gamma_{iT}^v\ \overline{lnw_i}^{v}\ T + \gamma_{yT}^v\ \overline{\ln y}^{v} T + \overline{e}_c^v \qquad \textbf{(2)}$$

where the share equation and the rate of technical change take the form:

$$\overline{S}_i^v(w_K,w_L,Y,T) = \alpha_i^v + \sum_{i=1}^{n}\gamma_{ij}^v\ \overline{lnw_j}^{v} + \gamma_{iy}^v\ \overline{lnY}^{v} + \gamma_{iT}^v\ T + \overline{e}_i^v \qquad \textbf{(3)}$$

$$-\overline{S}_T^v(w_k,w_L,Y,T) = \gamma_T^v + \gamma_{TT}^v\ T + \sum_{i=1}^{n}\gamma_{iT}^v\ \overline{lnw_i}^{v} + \gamma_{yT}^v\ \overline{lnY} + \overline{e}_T^v \qquad \textbf{(4)}$$

(where: v = 1,...,20 and i = K, L), are the average error terms. The share equations have the following form: S_K (share of capital)=(P_K*Q_K)/TC and S_L (share of labour)=(P_L*Q_L)/TC, where $P_{K,L}$L is the price of capital and the price of labour, $Q_{K,L}$ is the capital and labour and TC is the total cost.

The Allen-Uzava partial elasticities of substitution, σ_{ij}, and price elasticities of input demands, P_{ij}, are given by following equations.

$$\sigma_{ij} = (\gamma_{ii} + S_i^2 - S_i)/(S_i^2), \quad i = K, L\ i = j \qquad \textbf{(5)}$$

and $$\sigma_{ij} = (\gamma_{ij} + S_i S_J)/(S_i S_j), \quad i,j = K, L\ i \neq j$$

Where the own-partial elasticities of substitution, σ_{ii}, are expected to be negative. On the other hand, the cross-partial elasticities of substitution can be either positive, suggesting substitutability between inputs, or negative, suggesting input complementarity.

$$P_{ij} = \sigma_{ij} S_j,\ i = K, L\ i \neq j \qquad \textbf{(6)}$$

and $$P_{ii} = \sigma_{ii} S_i,\ i = K, L\ i = j$$

Several comments should be made concerning these substitution elasticity estimates. First, parameter estimates and fitted shares should replace the γ's and S's when computing estimates of the σ_{ij} and P_{ij}. This implies that in general the estimated elasticities will vary across observations. Second, since the parameter estimates and fitted shares have variances and covariances, the estimated substitution elasticities also have stochastic distributions. Third, the estimated translog cost function should be checked to ensure that it is monotonically increasing and strictly quasi-concave in input prices, as is required by theory. For monotonicity it is required that the fitted shares all be positive, and for strict quasi-concavity the (n x n) matrix of substitution elasticities must be negative semidefinite at each observation. Moreover, we may calculate the scale elasticities, (which is the percentages change of the total cost after the change one percentage in the output). As has been shown by Giora Hanoch (1975) there are computed as the inverse of costs with respect to output. More specifically, ***scale***=1/e_{cy} where e_{cy}= ∂lnc/∂lny and where for the translog function.

$$\overline{e}_{cy}^{v} = a_y + a_{yy}\ \overline{lnY}^{v} + \Sigma_i^n \gamma_{ij}\ \overline{lnP_i}^{v} + \gamma_{YT}\ \overline{T} \qquad \textbf{(7)}$$

A number of additional parameter restrictions can be imposed on the translog cost function, corresponding to further restrictions on the underlying technology model. For the translog cost function to be homothetic it is necessary and sufficient that $\gamma_{iy}=0 \; \forall \; i= 1,...,n$. Homogeneity of a constant degree in output occurs if, besides these homotheticity restrictions, we have $\gamma_{yy}= 0$. In this case the degree of homogeneity equals $1/\alpha_y$. Constant returns to scale of the dual production function occurs when, in addition to the above homotheticity and homogeneity restrictions, $\alpha_y=1$.

One potential problem with estimation of scale economies, however, is that the α_y and γ_{YY} parameters do not appear in the share equations, and so these parameters cannot be estimated by using only the share equation system. 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 --with endogenous lag variables-- (i.e. lag shares, lag prices of capital, labour and output). This method requires the usage of instrumental variables. We picked up the lagged variables of capital stock, price of capital, value added, price of output, number of employees and the price of labour. To interpret the estimates of these parameters it is useful to recall that if the production function is increasing in capital and labour inputs then the average value shares are non negative.

3. Recent trends & evidence of innovation activities & productivity puzzle

Schmookler (1966), Kendrick (1991), and Abramovitz (1986) have studied the interaction between technological change and productivity. In these studies, factor prices were used to weight the various inputs in order to obtain a measure of total input growth.

Table 1: Recent trends in productivity growth, 1980-99

	Trend growth in GDP per hour worked				Trend growth in multi-factor productivity			
	Total economy, percentage change at annual rate				Business sector, percentage change at annual rate			
	1980-90	1990-99	1990-95	1995-99	1980-90	1990-99	1990-95	1995-99
Canada	1.1	1.3	1.3	1.4	0.5	1.2	1.1	1.3
Mexico	..	-0.6	-1.0	-0.1	..	..	..	..
United States	1.3	1.6	1.3	2.0	0.9	1.1	1.0	1.2
Australia	1.2	2.0	1.8	2.2	0.5	1.4	1.4	1.5
Japan	3.2	2.5	2.6	2.2	2.1	1.2	1.3	0.9
Korea	6.3	5.1	5.3	4.7	..	..	..	..
New Zealand	..	0.7	0.5	0.9	0.7	0.9	1.0	0.7
Austria	..	..	..	2.9	..	..	..	..
Belgium	2.4	2.3	2.3	2.4	1.7	1.4	1.3	1.6
Czech	..	..	..	1.7	..	..	..	..
Denmark	1.7	1.8	1.9	1.6	0.9	1.5	1.5	1.5
Finland	2.8	2.9	3.0	2.8	2.3	3.3	3.0	3.6
France	2.7	1.8	1.8	1.6	1.8	1.0	0.9	1.1
Germany	2.3	2.0	2.2	1.8	1.5	1.1	1.1	1.1
Greece	1.3	1.4	0.9	2.0	..	..	..	..

Hungary	..	2.7	2.7	2.7	..	..	..	..
Iceland	..	1.5	1.3	1.6	..	1.3	1.2	1.4
Ireland	3.6	4.3	4.0	4.6	3.6	4.5	4.4	4.6
Italy	2.6	2.0	2.3	1.6	1.5	1.1	1.2	0.8
Luxembourg	..	5.1	5.5	4.6	..	..	..	..
Netherlands	2.9	1.8	1.9	1.7	2.3	1.7	1.9	1.5
Norway	2.6	2.6	3.1	2.0	1.2	1.7	2.1	1.2
Portugal	..	2.3	2.4	2.2	..	..	..	..
Spain	3.2	1.4	2.0	0.7	2.3	0.7	0.9	0.5
Sweden	1.2	1.7	1.8	1.6	0.7	1.3	1.3	1.3
Switzerland	..	0.8	0.6	1.2	..	..	..	..
United Kingdom	2.3	1.9	1.9	1.9	2.2	0.9	0.8	1.0

Source: OECD calculations, based on data from the *OECD Economic Outlook No. 68*. See Economics Department Working Paper No. 248.

The approach developed by Abramovitz (1986), Solow (1957) and Denison (1962) involves the decomposition of output growth into its various sources, which can be defined as the growth accounting and residual method. Growth accounting tries to explain changes in real product and total factor productivity based mainly on a comparison between the growth of inputs (capital and labour) and the growth of output. One part of actual growth cannot be explained and has been classified as 'unexplained total factor productivity growth' (or the so called residual).

In particular, following the decomposition analysis by Solow (1957), many alternative factors can explain the path of economic growth. According to Solow's findings, technology has been responsible for 90 per cent of the increase in labour productivity in the United States in the twentieth century.

Furthermore, technological gap theories (Abramovitz, 1986; Fagerberg, 1987, 1988, 1994) relate the technological level and innovation activities to the level of economic growth. According to these theories, countries where more innovation activities take place tend to have a higher level of value added per worker (or a higher per capita GDP).

Following the technological-gap argument, it would be expected that the more technologically advanced countries would also be the most economically advanced (in terms of innovation activities and per capita GDP). Technology-intensive industries play an increasingly important role in the international manufacturing trade of OECD countries. In the 1990s, OECD exports of high- and medium-high-technology industries grew at an annual rate of around 7%, and their shares in manufacturing exports reached 25% and 40%, respectively, in 1999.

Substantial differences in the shares of high- and medium-high-technology industries in manufacturing exports are found across the OECD area, ranging from over 75% in Japan, Ireland, and the United States to less than 20% in Greece, New Zealand and Iceland.

Catching-up theory (Abramovitz, 1986; Fagerberg, 1987) starts with the investigation of growth performance. The main idea is that large differences in productivity among countries tend to be due to unexpected events (for instance wars).

According to these studies, the only possible way for technologically weak countries to converge or catch up with the advanced countries is to copy their more productive technologies.

The outcome of the international innovation and diffusion process is uncertain; the process may generate a pattern where some countries follow diverging trends or one where countries converge towards a common trend. In this literature, economic development is analysed as a disequilibrium process characterised by two conflicting forces:

▪ innovation, which tends to increase economic and technological differences between countries, and
▪ diffusion (or imitation), which tends to reduce them. Technological gap theories are an application of Schumpeter' s dynamic theory.

Table 2 presents the annual average growth rate for the labor productivity growth by industry, for the period 1995-1998.

Table 2: Labor productivity growth by industry, 1995-98 annual average growth rate.

		United States			**Japan**			**European Union**		
	ISIC Rev. 3	Employment	Real value added	Labour productivity	Employment	Real value added	Labour productivity	Employment	Real value added	Labour productivity
All industries	01-95	2.1	4.6	2.4	0.3	1.5	1.2	1.0	2.4	1.4
Total non-agriculture business sector	10-67,71-74	2.5	5.9	3.3	-0.3	1.4	1.7	1.2	2.6	1.4
Mining and quarrying	10-14	0.7	3.7	3.1	-3.9	-0.9	3.1	-3.5	-1.5	2.1
Food, drink, tobacco	15-16	0.2	-5.4	-5.6	-1.3	-2.1	-0.8	0.3	0.0	-0.4
Textiles, clothing	17-19	-5.3	-3.9	1.6	-4.8	-3.8	1.0	-1.7	-1.4	0.4
Paper, printing	21-22	0.0	-0.4	-0.4	-1.7	-2.1	-0.4	0.1	1.5	1.3
Petroleum refining	23	-1.4	-0.4	1.1	-0.7	3.9	4.6	-1.9	0.9	2.8
Chemicals	24	0.1	2.6	2.5	-0.5	0.7	1.1	-0.9	1.3	2.3
Rubber, plastics	25	1.3	4.6	3.2	-2.1	-3.4	-1.4[3]	1.6	3.3	1.7
Non-metallic minerals	26	1.1	3.1	1.9	-1.9	-2.1	-0.2	-0.5	-0.1	0.4
Basic metals and metal products	27-28	1.2	2.5	1.4	-1.6	-2.7	-1.1	0.4	1.0	0.6
Machinery and equipment	29-33	1.8	14.5	12.4	-0.7	4.7	5.5	0.1	3.0	2.9
Transport equipment	34-35	2.2	2.5	0.4	-0.4	-1.9	-1.5	2.0	4.3	2.3

Wood and other manufacturing	20,36-37	1.3	0.5	-0.8	-2.1	0.1	2.2	-0.1	1.0	1.1
Electricity, gas and water supply	40-41	-2.0	-1.6	0.4	0.8	4.3	3.5	-2.6	2.1	4.8
Construction	45	4.5	4.9	0.4	-0.1	-2.0	-1.9	-0.6	-0.4	0.3
Services: Wholesale and retail trade, hotels, restaurants	50-55	1.6	8.5	6.8	0.3	1.1	0.8	1.4	2.4	1.0
Transport and storage	60-63	3.2	4.5	1.3	0.4	-3.4	-3.8	0.8	3.0	2.2
Post and telecommunications	64	2.4	4.5	2.1	0.4	17.7	17.3	-1.1	7.6	8.7
Finance and Insurance	65-67	2.6	7.5	4.8	-1.4	0.6	2.0	0.5	3.1	2.6
Business services	71-74	6.3	7.0	0.6	2.2	6.4	4.1	5.8	5.6	-0.2

Source: OECD, STAN and National Accounts databases.

Labour productivity levels relative to the total non-agriculture business sector, 1998, European Union. The ratio of value added to employment provides an indication of which industries yield relatively high value added per unit of labour input. Although total employment is not the best measure of labour input for this purpose (see box), a reasonably clear pattern emerges.

Labour productivity by industry can be measured in several ways. For the measurement of output, total production or value added are the typical yardsticks. If production (gross output) is used, productivity measures need to cover a combination of inputs, including intermediate inputs (such as materials and energy), labour and capital. If value added is used as the output measure, labour and capital suffice as indicators of factor inputs. The indicators shown here are determined by data availability and simply measure value added per person employed. Further adjustments to labour input, including adjustment for part-time work and hours worked per worker, can be made for certain OECD countries but international comparisons are not yet feasible.

For the labour productivity levels, 1998 value added at current prices was used. For the European Union, member countries' value added data were aggregated after applying 1998 US dollar GDP PPPs – industry-specific PPPs are preferable, but are not available for all sectors and countries.

For value-added volumes (used to estimate labour productivity growth), the European Union series were derived by aggregating member countries' value-added volumes after applying 1995 US dollar GDP PPPs, the reference year for the volume series being 1995. This is not an ideal practice since some countries, such as France and Sweden, now use annually reweighted chained (rather than fixed-weight) Laspeyres aggregation methods to derive their value-added volumes by industry. Volumes calculated in this manner are generally non-additive.

Table 3: Income and productivity levels, 1999. Percentage point differences in PPP-based GDP per capita with respect to the United States

	Gap	Productivity	Labour use (1)
Switzerland	-15	-9	-6
Norway	-17	8	-25
Canada	-21	-14	-6
Denmark	-21	-7	-14
Iceland	-22	-28	6
Netherlands	-22	9	-32
Australia	-24	-16	-8
Japan	-25	-26	1
Ireland	-25	-4	-21
Belgium	-27	10	-36
Austria	-27	-5	-22
Germany	-30	-6	-23
Italy	-32	6	-38
Sweden	-32	-16	-15
United Kingdom	-32	-13	-19
Finland	-33	-18	-15
France	-35	-3	-32
New Zealand	-45	-38	-7
Spain	-46	-24	-23
Portugal	-51	-47	-5
Korea	-53	-60	7
Greece	-55	-44	-12
Czech Republic	-60	-61	1
Hungary	-67	-55	-12
Mexico	-75	-69	-6

1.This reflects the joint effect of differences in the demographic structure of countries (the ratio of the working-age population to the total population), in employment rates and in average hours worked per person
Source: OECD, GDP and population from National Accounts database; working-age population, labor force and employment from Labor Force database; hours worked from OECD calculations, see S. Scarpetta, et al., Economics Department Working Paper No. 248, 2000

The labour productivity levels by industry are relative to the total non-agriculture business sector. This consists of all industries except agriculture, hunting, forestry and fishing (ISIC 01-05), real estate activities (ISIC 70) and community, social and personal services (ISIC 75-99; includes mainly non-market activities such as public administration, education and health).

Productivity growth in some services sectors may be low because estimates of real output are based on input measures (such as employment). Much effort is currently being undertaken in Member countries to improve the measurement of real output in the services sectors. Sectors that are considered technology- and/or knowledge-intensive are highlighted in the graphs.

Table 3 illustrates the income and the productivity levels for the period of 1999. The percentage point of differences for PPP, (Purchase Power Parity) is based on Gross Domestic Product per capita respecting the United States.

Table 4: Estimates of Multi-factor Productivity (MFP) growth rates, 1980-1998: average annual growth rates (based on trend series time-varying factor shares)

Countries	MFP growth rate without control for composition/quality changes in labour and capital 1980-1990	1990-1998	MFP growth rate with control for composition / quality changes in labour and capital 1980-1990	1990-1998
Australia	0.9	0.9	2.1	2.0
Belgium	1.4	-----	1.0	-----
Denmark	1.0	0.9	1.8	1.9
Finland	2.4	2.2	3.2	2.8
Greece	0.6	-----	0.3	-----
Ireland	3.9	3.8	3.9	3.6
Netherlands	2.2	2.2	1.7	1.7
New Zealand	0.7	0.6	1.1	1.2
Norway	1.1	0.9	2.1	1.9
Portugal	1.9	1.9	2.2	-----
Spain	2.2	-----	0.6	-----
Sweden	0.8	0.6	1.3	1.0
Switzerland	-----	-----	0.2	0.2

Source: O. E. C. D, Economic Outlook, 2000, Paris.

Productivity ratios relate a measure of output to one or several inputs to production. The most common productivity measure is labour productivity, which links output to labour input. It is a key economic indicator as it is closely associated with standards of living. Ideally, estimates of labour productivity growth should incorporate changes in hours worked.

Estimates of the increase in GDP per hour worked for OECD countries–adjusted for the business cycle – show that Korea, Ireland and Luxembourg had the highest rates of productivity growth in the 1990s. Switzerland, New Zealand, Spain and Mexico had the lowest. In countries such as Ireland, Australia, the United States, Greece and Germany, labour productivity growth in the second half of the 1990s was substantially higher than in the first half.

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. This measure is called multi-factor productivity (MFP). Growth in MFP is key to long-term economic growth, as it indicates rising efficiency in the use of all available resources. It is also a better reflection of technological progress than the increase in labour productivity, since the latter can also be achieved through greater use of capital in the production process and the dismissal of low-productivity workers.

Estimates of MFP growth are available for fewer countries than estimates of labour productivity growth, primarily because of the limited availability of data on capital stock. The estimates show that Ireland and Finland experienced the most rapid MFP growth over the 1990s. In countries such as Ireland, Finland, Belgium, Australia, Canada, the United States, France and the United Kingdom, MFP growth accelerated during the 1990s. In other countries, such as the Netherlands, Norway, Spain and Japan, MFP growth declined.

4. Conclusions

Technological progress has become virtually synonymous with long-term economic growth. This raises a basic question about the capacity of both industrial and newly industrialised countries to translate their seemingly greater technological capacity into productivity and economic growth. Usually, there are difficulties in estimating the relation between technology 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 quality changes in previously introduced technologies.

The countries of Europe have a long cultural and scientific tradition and the major scientific discoveries and developments in technology are products of European civilisation. There is a close relationship between innovation and productivity levels. However there are large technological disparities between the member states, which affects productivity performance, increases economic disparities and hinders economic integration.

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

The technological gap models represent two conflicting forces: innovation, which tends to increase productivity differences between countries; and diffusion, which tends to reduce them. In Schumpeterian theory, growth differences are seen as the combined result of these forces. We have applied an economic growth model based on Schumpeterian logic. This technological gap model provides a good explanation of the differences among various countries. The empirical estimates suggest that the convergence hypothesis applies for industrialised countries. Research on why growth rates differ has a long history that goes well beyond growth accounting exercises. The idea that poorer countries eventually catch up with richer ones was advanced as early as in the nineteenth century, to explain continental Europe's convergence with Britain. In the 1960s one of the most basic model was the Marx~Lewis model of abundant labour supplies, which explained the divergent growth experience of the Western European countries.

To achieve safe results it is necessary to conduct a cross-country, multi sectoral analysis of how technological activities affect the different sectors. According to our estimates there is a relationship between the level of economic growth and the growth of technological activities. Technological activities (best measured by patents) appear to contribute considerably to economic growth, unless this is a negative demand effect. Specifically, our results confirm that there is a close relationship between the level of economic growth (as measured by per capita GDP) and the level of technological development (as measured by the number of external patents). Our results indicate that both imitation and innovation activities have a significant effect on the growth of GDP and productivity. Countries that are technologically backward might be able to generate more rapid growth than even the advanced countries if they were given the opportunity to exploit the new technologies employed by the technological leaders.

The pace of the catching up depends on the diffusion of knowledge, the rate of structural change, the accumulation of capital and the expansion of demand. Those member states whose growth rates are lagging behind could catch up if they reduced the technological gap. An important aspect of this is that they should not rely only on technology imports and investment, but should also increase their innovation activities and improve their locally produced technologies (as happened in Korea and Singapore).

The catching-up hypothesis is related to economic and technological relations among countries. There are different opportunities for countries to pursue a development strategy that depends on resource and scale factors. In summary, we can say that the introduction of new technologies has influenced industrialisation and economic growth. Of course, for countries with poor technological apparatus the impact of new technologies is much smaller. Finally, it seems that the technological gap between the less and more advanced countries is still widening.

5. References

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