AN INTER COMPARSION STUDY OF LABOUR PRODUCTIVITY IN THE EUROPEAN UNION AND THE UNITED STATES, 1979-2001

KORRES, George M.*
CHIONIS, Dionysios P.
TSAMADIAS, Constantine

Abstract:
This paper examines the possible macroeconomic consequences of changes in trend of productivity growth for European countries. Overall the results suggest that a rise in trend factor productivity will lead to higher levels of production and real income, however employment adjustment will depend on the extent to which the long-run equilibrium of an economy is affected. In this paper we present an international comparison of growth trends in the OECD countries, with a special attention to developments in labor productivity, allowing for human capital accumulation, and multifactor productivity (MFP). The main conclusions are that some «traditional» factors lay behind the disparities in growth patterns across the European countries.

JEL classification: C50, J0, J24
Keywords: Economic growth, productivity, technical change.

1. Introduction

Since the mid 1990s the average growth rates of real GDP, labor productivity and total factor productivity in the European Union have

* Dr. George M. Korres is Assistant Professor, University of the Aegean, Department of Geography, University of Hill, Mitilene: 81100, Lesbos, Greece. e-mail: gkorres@hol.gr; Dr. Dionysios P. Chionis is Associate Professor, Universite Democrite De Thrace, University Campus, Komotini: 69100, Komotini, Greece, e-mail: dchionis@ierd.duth.gr; Constantinos Tsamadias is Assistant Professor with Harokopio University of Athens, Dept. of Home Economics and Ecology. 70, El. Venizelou str., Athens 17671, Greece e-mail: gsaeoffice@gsae.edu.gr

fallen behind those in the United States. What makes this remarkable is that this is the first time since world war II that these performance measures have shown lower growth rates for the EU for several years in a row. The recent economic slowdown in the US and the EU has not changed this development. As a result the labor productivity gap in the EU relative to the US has widened by 2 percentage points, from 96 per cent of the US level in 1995 to 94 per cent in 2000, and by another 2 percentage points to 92 of the US level in 2002. At the same time there is considerable diversity both in terms of growth performance as well as comparative levels between European countries. Comparative growth rates of labor productivity between 1995 and 2002 differ between -0.3 per cent (for Spain) and 5.0 per cent (for Ireland). And there is a variation of plus 1 7 percentage points (for Belgium) and minus 38 per cent (for Portugal) around the average EU labor productivity level relative to the US in 2002.

Economic theory is relatively clear about the positive long-term consequences of the introduction of new technologies which lead to increased factor productivity. Provided that the supply of production factors is not adversely influenced, higher productivity can be expected to raise potential output, and, if labor and product markets are sufficiently flexible, aggregate demand should adjust to this increased supply potential in the long-run. Empirical macro-economic models provide a useful framework for examining some of these issues and the possible short and medium-term consequences of productivity changes, especially the dynamic links between productivity, technical change and output. This paper attempts to analyze and to estimate the productivity levels of European members states at a national level using aggregate data from OECD. Furthermore, we attempt to examine the relationship between productivity and regional disparities in Europe.

2. The main types of productivity measures

There are many different productivity measures. The choice between them depends on the purpose of productivity measurement and, in many instances, on the availability of data. Broadly, productivity measures can be classified as single factor productivity measures (relating a measure of output to a single measure of input) or multifactor productivity measures (relating a measure of output to a bundle of inputs). Another distinction, of particular relevance at the industry or firm level is between productivity measures that relate some measure of gross output to one or several inputs and those which use a value-added concept to capture movements of output.

Table 1**:** Overview of main productivity measures

10.5	Type of input measure			
	Labor	Capital	Capital and labor	Capital, labor and intermediate)
Gross output	(a). Labor productivity (based on gross output)	(c). Capital productivity (based on gross output)	(e). Capital-labor MFP (based on gross output)	(f). KLEMS multifactor productivity
Value added	(b). Labor productivity (based on value added)	(d). Capital productivity (based on value added)	(g). Capital-labor MFP (based on value added)	-----
	Single factor productivity measures: (a), (b), (c), (d).		Multifactor productivity (MFP) measures: (e), (f), (g).	

Note: Intermediate goods includes: energy, materials and services. Other approaches consider intermediate factors of production more complementary than substitutive for primary inputs (labor and capital) and thus they are considered outside the production function as in the three regimes growth approach suggested by Guisan(1980) and (2004).

Table 1 uses these criteria to enumerate the main productivity measures. The list is incomplete insofar as single productivity measures can also be defined over intermediate inputs and labor-capital multifactor productivity can, in principle, be evaluated on the basis of gross output. However, in the interest of simplicity, Table 1 was restricted to the most frequently used productivity measures.

These are measures of labor and capital productivity, and multifactor productivity measures (MFP), either in the form of capital-labor MFP, based on a value-added concept of output, or in the form of capital-labor-energy-materials MFP (KLEMS), based on a concept of gross output. Total factor productivity is defined as the change in output after taking account of growth in physical capital and changes in the quantity and quality of labor input. These measures are not independent of each other. For example, it is possible to identify various driving forces behind labor productivity growth, one of which is the rate of MFP change.

3. Modeling the theoretical framework of productivity, technical change and regional growth

The economic theory of productivity measurement goes back to the work of Jan Tinbergen and Robert Solow (1957). They formulated productivity measures in a production function context and linked them to the analysis of economic growth. The field has developed considerably since, in particular following major contributions by Dale Jorgenson, Zvi Griliches and Erwin Diewert. Today, the production theoretical approach to productivity measurement offers a consistent and well-founded approach that integrates the theory of the firm, index number theory and national accounts.

We can also adopt the index number approach in a production theoretic framework. This «growth accounting» technique examines how much of an observed rate of change of an industry's output can be explained by the rate of change of combined inputs. Thus, the growth accounting approach evaluates multifactor productivity (MFP) growth residually. To construct an index of an industry's output, different types of outputs have to be weighted with their share in total output. To construct an index of combined inputs, the rates of change of different inputs (labor, capital, intermediate inputs) have to be weighted appropriately.

The econometric approach to productivity measurement is only based on observations of volume outputs and inputs. Furthermore, it is possible to investigate forms of technical change other than the

Hicks-neutral formulation implied by the index number based approach; and there is no a *priori* requirement to assume constant returns to scale of production functions. The literature about the econometric approach is large, and examples of integrated, general models can be found in Morrison (1986) or Nadiri and Prucha (2001). Hulten (2001) points out that there is no reason why the econometric and the index number approach should be viewed as competitors. Econometric methods are used to further explain the productivity residual, thereby reducing the ignorance about the «measure of our ignorance».

3.1. The Growth Accounting Approach: Growth accounting and most other approaches to measuring productivity are firmly rooted in a standard neo-classical equilibrium concept. Equilibrium conditions are very important because they help to guide measurement of parameters that would otherwise be difficult to identify. An obvious example is the use of cost shares instead of output elasticities - the former are observable, the latter are not, but theory shows that, in competitive equilibrium, one must equal the other. Although its usefulness is generally recognized, it has been argued that an equilibrium approach sits uneasily with the notion of innovation and productivity growth. Evolutionary economists, for instance, Dosi 1988; Nelson and Winter 1982; Nelson 1981, in the tradition of Schumpeter, argue that innovation and technical change occur as a consequence of information asymmetries and market imperfections. In a quite fundamental sense, innovations and information asymmetries are one and the same phenomenon. Indeed, such asymmetries can scarcely be termed market imperfections when they are necessary conditions for any technical change to occur in a market economy. The point made by evolutionary economists is that equilibrium concepts may be the wrong tools to approach the measurement of productivity change, because if there truly was equilibrium, there would be no incentive to search, research and innovate, and there would be no productivity growth.

3.2 The Index Number Approach: Accounting is not explaining the underlying causes of growth. Growth accounting and productivity measurement identifies the relative importance of different proximate sources of growth. At the same time, it has to be complemented by institutional, historical and case studies if one wants to explore the underlying causes of growth, innovation and productivity change. Because the technology parameter cannot be observed directly, MFP growth is derived as the difference between the rate of growth of a Divisia index of output and a Divisia index of inputs, as shown below. The Divisia index of inputs is made up of the logarithmic rates of change of primary and intermediate inputs, weighted with their respective share (s_X, s_M) in overall outlays for inputs:

Percentage (%)change of gross-output based MFP =

$$= \frac{\partial \ln H}{\partial t} = \frac{\partial \ln A}{\partial t} = \frac{d \ln Q}{dt} - s_X \frac{d \ln X}{\partial t} - s_M \frac{d \ln M}{\partial t}$$

Alternatively, one could define a *value-added function*. *A* value-added function presents the maximum amount of current-price value added that can be produced, given a set of primary inputs and given prices of intermediate inputs and output. Such a value-added function is an equivalent ("dual") representation of the technology described by a production function. For the present purpose, call the value-added function $G = G(A(t),X,P_M,P)$. Dependence of the value-added function on intermediate input prices P_M and on gross-output prices P signals that producers adjust the level of intermediate inputs when relative prices change. Just as the measure of technical change for the production function was defined as the shift of that function over time, productivity change could be defined as a shift of the value-added function, *i.e.* as the relative increase in value added that is associated with technical change. Parallel to the earlier statement regarding the production function, this can be formulated as $\frac{\partial \ln G}{\partial t}$.

Again, this change cannot be directly observed but it can be shown that it corresponds to the difference between the growth rate of the Divisia volume index of value added (called *VA)* and the growth rate of the Divisia index of primary inputs:

Percentage (%) change of value-added based MFP =

$$= \frac{\partial \ln G}{\partial t} = \frac{d \ln VA}{dt} - \frac{d \ln X}{dt}.$$

3.3. The Approach of Cost Function: A cost function shows the minimum input cost of producing a certain level of output, given a set of input prices. Under relatively weak regularity conditions, cost functions can be derived foregone to provide the amount of savings needed to permit capital accumulation. In practice, this would imply the use of a private consumption deflator in the perpetual inventory method. The effect is to relegate all advances in knowledge (embodied and disembodied) explicitly to the productivity residual. See also Durand (1996) on this point from production functions, and vice versa - there is duality. To illustrate this point, one expresses a simple cost function C as $C = B\ Q - c(w_1, w_2,...,w_N)$, where C is total cost that varies as a function of the level of output, Q, of unit costs c (themselves dependent on input prices w_i) and of a parameter B. This parameter plays a role similar to the productivity parameter A in the production function $Q = A\text{-}F(X_1,X_2,...X_N)$. It can indeed be shown that $\frac{d\ln A}{dt} = -\frac{d\ln B}{dt}$.
Thus, the MFP productivity residual can be measured either as the residual growth rate of output not explained by the growth rate of inputs or as the residual growth rate of average costs not explained by change in input prices:

$$\frac{d\ln C}{dt} - \frac{d\ln Q}{dt} = \sum_i s_i \frac{d\ln w_i}{dt} - \frac{d\ln A}{dt}.$$

This expression states that the rate of growth of average costs equals the rate of growth of aggregate input prices, reduced by advances in multifactor productivity. A slightly different formulation is that productivity growth equals the diminution in total costs that is neither explained by a fall in output nor by substitution of inputs that have become relatively more expensive for those whose relative price has fallen.

This formulation of MFP in terms of average costs lends a richer interpretation to technological change. It is intuitively plausible that total and average costs can be reduced by many means including technological innovations in an engineering sense but also by organizational innovations, learning-by-doing, and managerial efforts. The cost approach also shows how average cost can decline as a consequence of embodied technological change only: suppose that one of the inputs exhibits falling prices (user costs) relative to other inputs as a consequence of (embodied) technical change. Most likely, a substitution process will take place where computer services replace other factors of production.

3.4. Modeling a Flexible Functional Form: A different and simpler approach has been recently proposed in de la Fuente (1995) and Bernard and Jones (1996), in which a model with decreasing returns to capital is augmented with exogenous differences in the countries' ability to adopt new technology. Our model differs from de la Fuente's in two major respects. First, as in Shell (1966), the flow of new technology in each period is proportional to the amount of resources endogenously allocated to innovation. Second, the impact of any given technology gap on technology growth in a follower country is proportional to its propensity to innovate (or imitate). In this respect, our formulation is closer to the one used in Benhabib and Spiegel (1994) to assess the impact of the stock of human capital on the diffusion of technology. As for Bernard and Jones (1996), the main differences are that in our model the growth rate of the leader economy is endogenous, and that we make specific statements on what determines a country's ability to adopt new technology. The starting point of this model is the *translog function* (Christensen, Jorgenson). The objective is to characterize the distribution of the value of output between capital and labor inputs and changes in this distribution over the time. To do this we must describe capital and labor inputs in terms of the value shares. The aggregate cost (or production) function is based on a cost function (or a production function), which is characterised by constant returns to scale:

$$C=F(P_K, P_L, Y, T)$$

where: P_K, P_L, Y, T indicate the price of capital input, labor input, the value added and time. If the cost function C is increasing then the value shares are nonegative. To be able to check these restrictions for particular values of capital and labor prices and time, we can compute the value shares and verify that they have the right sign. Similarly, the share elasticities can be expressed in terms of the second order partial derivatives of the cost function with respect to capital and labor prices. The translog cost function can be written, (where ij=K,L):

$$lnC(P_K, P_L, Y, T) = a_0 + a_y lny + \frac{1}{2} a_{yy}(lny)^2 + \sum_{i=1}^{n} a_i lnP_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} g_{ij} lnP_i lnP_j + \sum_{i=1}^{n} g_{iy} lnP_i lny$$

$$g_T T + \frac{1}{2} g_{TT} T^2 + \sum_{i=1}^{n} g_{iT} lnP_i T + g_{yT} \ln yT$$

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. Output is measured as value added. Labor 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 labor wages and salaries.

The σ_{LL}, σ_{KK} have to be negative because of the *demand law* for inputs (as actually they are negative in the following results). That implies downward slopping demand curves for the inputs. If σ_{KL} (the substitution elasticity between K and L) is positive then K and L are complements (otherwise they are substitutes). Finally, we can dirive *technical change* into neutral (related only to time) and non neutral (related to the time path inputs of capital and labor respectively: γ_{KT} and γ_{LT}). The parameters α_K and α_L can be interpreted as the average value shares of capital and labor inputs. The parameters γ_T and α_Y indicate the average (negative) rate of technical change and the average share of output in total cost and the parameter γ_T can be also interpreted as the average rate of productivity growth.

4. An empirical estimation of productivity, technical change and growth

Once productivity measures are conceptualised on the basis of economic theory, there are several ways to go about their empirical implementation. From a broad methodological viewpoint, parametric approaches can be distinguished from non-parametric ones. In the first case, econometric techniques are applied to estimate parameters of a production function and so obtain direct measures of productivity growth. In the second case, properties of a production function and results from the economic theory of production are used to identify empirical measures that provide a satisfactory approximation to the unknown «true» and economically defined index number. The growth accounting approach to productivity measurement is a prominent example for non-parametric techniques.

All estimations are based on national data derived form OECD'data dank. 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. Output can be represented as a function of two inputs and the time as an indicator of the level of technology. Substitution possibilities among intermediate inputs and primary factor input can be incorporated explicitly. Output is measured as value added. Labor 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). Table 2 shows the aggregate developments of output, employment and productivity growth in the US, EU and Japan, as well as the growth rates for individual EU countries.

Comparing the EU with Japan and the US, the table 2 shows that during the 1980s, real GDP growth was fastest at 4.0 per cent per year on average in Japan, followed by 3.2 per cent in the US. Growth was slowest in the EU at only 2.4 per cent. During the early 1990s GDP growth slowed in all three regions, but both the US and the EU saw a substantial recovery during the second half of the 1990s. However, the recovery was much faster in the US than in the EU. In contrast, the EU realized a substantial expansion in labor input but productivity growth slowed down to a rate that was substantially lower than that achieved during the 1980s.

Table 2: Recent trends in productivity growth, 1980-1999
(percentage change at annual rate)

	Trend growth in GDP per hour worked		Trend growth in multi-factor productivity	
	1980-90	1990-99	1980-90	1995-99
Canada	1,1	1,3	0,5	1,3
Mexico	..	-0,6	..	..
United States	1,3	1,6	0,9	1,2
Australia	1,2	2,0	0,5	1,5
Japan	3,2	2,5	2,1	0,9
Korea	6,3	5,1	..	..
New Zealand	..	0,7	0,7	0,7
Austria	..	..	..	..
Belgium	2,4	2,3	1,7	1,6
Czech Republic	..	..	..	..
Denmark	1,7	1,8	0,9	1,5
Finland	2,8	2,9	2,3	3,6
France	2,7	1,8	1,8	1,1
Germany	2,3	2,0	1,5	1,1
Greece	1,3	1,4	..	..
Hungary	..	2,7	..	..
Iceland	..	1,5	..	1,4
Ireland	3,6	4,3	3,6	4,6
Italy	2,6	2,0	1,5	0,8
Luxembourg	..	5,1	..	..
Netherlands	2,9	1,8	2,3	1,5
Norway	2,6	2,6	1,2	1,2
Portugal	..	2,3	..	..
Spain	3,2	1,4	2,3	0,5
Sweden	1,2	1,7	0,7	1,3
Switzerland	..	0,8	..	..
United Kingdom	2,3	1,9	2,2	1,0

Source: Calculations based on data from the OECD Economic Outlook.

These growth rates can also be seen in conjunction with estimates of the distance between countries in levels of GDP, labor productivity and employment rates. Starting from a higher level in 1980, and continuing through to the early 1990s, the EU GDP level fell below that of the US in the second half of the 1990s. Moreover the labor productivity gap between the EU and the US also widened at this time. This has been the first time since World War II that the productivity level in the EU did not converge to the US level for a sustained period. Hence despite relatively high labor productivity levels, in contrast, the Japanese economy entered a period of very slow growth, a decline in labor input, and a cost-reducing productivity growth track.

Some European countries, per capita income levels are lower due to lower labor intensity levels in the EU. In contrast to the US position, however, there is as yet less evidence that this productivity slowdown is of a structural nature. Firstly, it should be noted that the productivity growth rates experienced in recent years in the EU are no less than those in the US in the 1980s and so recent experience may largely be driven by the end of catch-up growth, before any benefits from the new technology were manifest. Many EU countries are still in the midst of an adjustment process towards a new arrangement of their economies, with less emphasis on capital intensive manufacturing, and a greater emphasis on technology use and diffusion in services. Secondly, there is still a much greater potential in terms of underutilized resources to be employed in the EU. This latter view is consistent with the notion that the EU is merely lagging the US in the adoption of new technology and that the EU will see the benefits within the next decade. These developments did not entirely pass the EU by, but their impact on speeding up growth has been less than in the US for various reasons. Firstly, some EU countries, for instance Germany, developed institutional and innovation systems focused on technology diffusion, which have been very effective during the catch-up phase. Others, in particular France and the UK, have aimed to compete head-on with US high technology industries.

As the most advanced European countries were approaching the US productivity level, the benefits of technology borrowing got gradually exhausted. The joint process of European economic integration and more intensive global capital flows (including foreign direct investment) required these countries to find new ways to increase efficiency and develop new markets domestically and internationally. At the same time, lower income countries in the EU, for instance Finland, Ireland, and to a lesser extent Spain and Portugal) have continued to benefit from their catch-up potential, but the realization of that potential has been very much dependent on their specific initial conditions. It is also interesting to examine the contributions of various member states to the overall EU growth by multiplying each country's respective growth rates by its share in EU employment.

It can be seen from Table 3 that the major contributors to EU labor productivity growth in the 1980s are Germany, France, the UK and Italy.

Table 3**:** Contributions of member states to EU-15 annual labor productivity growth 1979-2001

	1979-1990	1990-1995	1995-2001
Belgium	0.08	0.09	0.03
Denmark	0.04	0.05	0.02
Germany	0.59	0.68	0.22
Greece	0.01	0.02	0.05
Spain	0.18	0.15	0.22
France	0.40	0.27	0.22
Ireland	0.02	0.04	0.10
Italy	0.27	0.36	0.18
Luxembourg	0.01	0.01	0.01
Netherlands	0.14	0.13	0.11
Austria	0.07	0.09	0.04
Portugal	0.02	0.02	0.04
Finland	0.05	-0.01	0.04
Sweden	0.06	0.03	0.06
UK	0.31	0.38	0.39
EU-15	2.26	2.31	1.72

Source: Data derived from OECD.

By the end of the 1990s, the slowdown can be seen to be chiefly the result of the decline in all of these large nations, excepting the U.K. Many of the smaller EU-15 nations have seen modest reductions over this period, and a number of the Southern European nations have seen slight increases. But the fortunes of Germany and Italy in particular have had a large impact on the EU growth slowdown. The EU is considerably less competitive than the US in the manufacture of high technology equipment. In many traditional manufacturing industries, however, the EU is now competitive relative to the US, reflecting both greater wage moderation in the late 1990s, less pronounced declines in labor productivity levels and a relatively favorable exchange rate between the EU currencies and the US dollar during the late 1990s.

Table 4 illustrates the labor productivity in EU manufacturing industries. But comparisons with the US are less relevant here, since both the EU and US are likely to have high unit labor costs relative to their main competitors in developing countries. Japan is the country with the highest labor productivity slowdown across the two periods, losing ground to both the EU and the US.

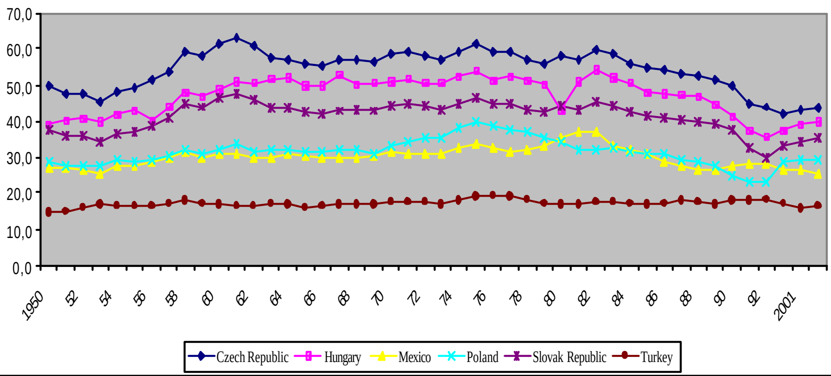
Average labor productivity growth decreased from a rate of 3.02% in the period 1992-1995 to a negative - 0.5% in 1996-2001. The service sector experiences the most severe deceleration with growth rates going from 3.97% to -1.09%. These trends are not surprising given the economic difficulties the Japanese economy had to face since the late 1980s. In fact, labor productivity growth at the aggregate economy level has been decreasing since 1985.

Table 4**:** Labor productivity in EU-14 manufacturing industries relative to the US (US=100)

	ISIC rev 3	1979-81	1994-96	1999-01
Food, drink & tobacco	15-16	64.5	79.7	100.6
Textiles	17	103.4	99.1	100.8
Wearing apparel	18	66.1	67.7	61.0
Leather	19	95.2	88.0	89.9
Wood products	20	63.0	86.8	101.3
Pulp and paper products	21	76.8	104.9	120.0
Printing & publishing	22	67.0	120.3	134.5
Chemicals	24	54.7	70.5	78.4
Rubber & plastics	25	180.2	145.8	127.0
Non-metal mineral products	26	121.2	142.6	148.8
Basic metals	27	65.1	109.1	107.8
Fabricated metal	28	108.9	108.5	111.4
Machinery	29	66.5	97.4	110.8
Computers	30	133.3	89.8	71.9
Insulated wire	313	87.3	93.7	77.6
Other electrical machinery	31-313	79.7	91.3	112.1
Semiconductors	321	47.8	31.8	41.6
Telecommunication eq.	322	71.9	63.9	65.7
Radio and television receivers	323	44.0	62.8	63.1
Scientific instruments	331	114.4	106.9	103.2
Other instruments	33-331	42.8	49.2	47.3
Motor vehicles	34	30.0	44.9	43.7
Ships and boats	351	59.2	95.8	88.7
Aircraft and spacecraft	353	46.7	71.1	71.8
Railroad and other transport	352+359	68.8	76.4	80.4
Furniture, miscellaneous goods	36-37	110.5	100.8	94.4
Total manufacturing	15-37	84.6	88.0	80.3

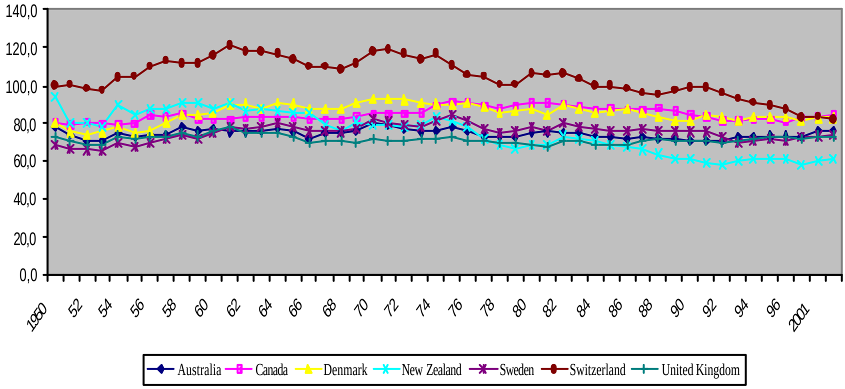
Sources and data derived from OECD.

Figure 1: Panel-(a): Low rates of catch-up (<1,2 % annually). Catch-up & convergence in OECD income levels, 1950-2002, (USA=100). Source: OECD, STAN & National Accounts, (2003).



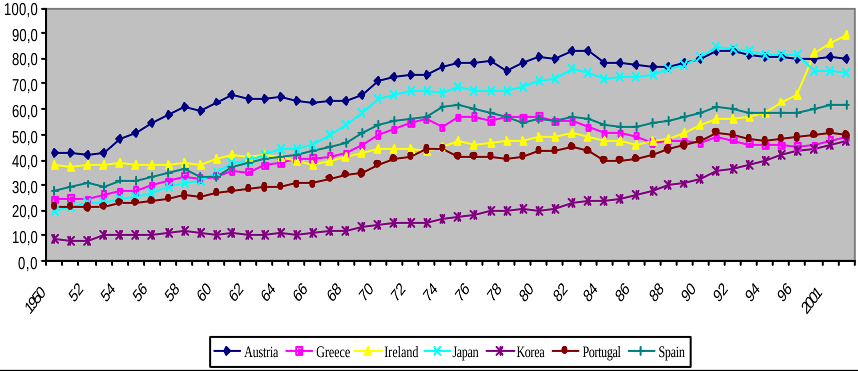
MFP is commonly defined as the portion of output growth left after accounting for growth in capital and labor, where both capital and labor are expressed in quality-adjusted terms. This measure captures disembodied technological and organizational improvements that increase output for given amount of inputs. Dale Jorgenson, in particular, argues that this is the only identifiable component of technological progress. The other procedures to calculate MFP that use different measures for the capital aggregate, for instance capital stock at acquisition prices, are likely also to pick up changes in the composition and quality of the capital stock due to other reasons than technological change. Other researchers have recently focused on the identification of the «embodied» part of technological progress. Greenwood (1999) and Hercowitz (1998) have suggested a way to tackle the «embodiment» controversy by adding an additional source of information (and in fact mixing the primal and dual approach). On the one hand they suggest the estimation of the disembodied component as the residual of a production function.

Figure 1: panel--(b): Rapid catch-up. Catch-up & convergence in OECD income levels, 1950-2002, (USA=100). Source: OECD, STAN & National Accounts, 2003.



Low starting point, low rates of catch-up In the European area, cross-country differences in GDP per capita and labor productivity have eroded considerably since the 1950s. Over the 1950s and 1960s, income levels of European countries except the United Kingdom that was catching up with those of the United States. In the 1970s, this phenomenon was less widespread and the rate of catch-up had fallen, Korea being the main exception. In the 1980s, there was even less catch-up, as GDP per capita grew more slowly than in the United States in 19 OECD countries.

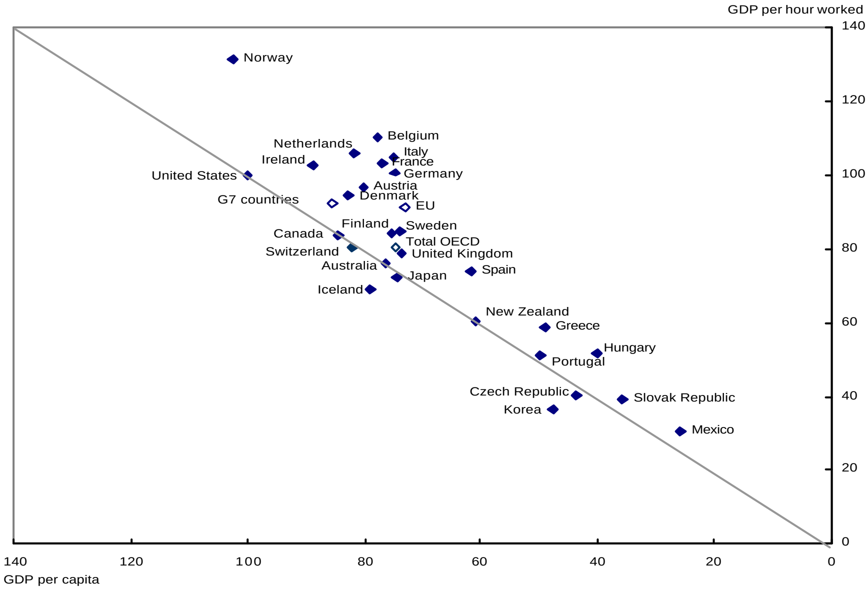
Figure 1: Panel-(b): Rapid-catch-up, (>1,2 % annually). Catch-up & convergence in OECD income levels, 1950-2002, (USA=100). Source: OECD, STAN & National Accounts, 2002.



The same was true for 20 OECD countries in the 1990s. Japan and Korea had the highest rates of catch-up over the 1950-99 period, with GDP per capita growing more rapidly, by 2.7% and 3.2%, respectively, than in the United States. Most of Western Europe had much lower rates of catch-up, typically below 1% a year. Countries such as Australia, New Zealand, the United Kingdom and Canada were already at relatively high income levels in 1950 and have since done little catching up with the United States. Switzerland had a marked decline in relative income levels.

From the estimation of a flexible functional form, namely the translog function, we can summarise that the σ_{LL}, σ_{KK} have to be negative because of the *demand law* for inputs (as actually they are negative in the following results). That implies downward slopping demand curves for the inputs. If σ_{KL} (the substitution elasticity between K and L) is positive then K and L are complements (otherwise they are substitutes). Finally, we can dirive *technical change* into neutral (related only to time) and non neutral (related to the time path inputs of capital and labor respectively: γ_{KT} and γ_{LT}).

Figure 2**:** GDP per capita and GDP per hour worked , (USA=100), 2002.



Using the translog cost function, we can estimate the appropriate parameters indicating the average value shares of capital and labour inputs. In addition, we can estimate the parameters showing the average rate of technical change, the average share of output in total cost, and also the average rate of productivity growth. Finally, we can estimate the constant share elasticities describing the implications of patterns of substitution for the relative distribution of output between capital and labour. The bias estimates describing the implications of patterns of productivity growth for the distribution of output. 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.

Summarizing the main econometric results for a selected number of member states using a flexible functional form, namely the translog cost function, we can conclude the following points:

- The results of multivariate regression include the countries of 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 estimate parameter, indicating the average value share of output in the total cost, has a positive value which for all member states, except for Britain and Ireland. There is an estimation of the parameter of *the rate of technical change or the acceleration rate,* indicating how time affects the growth of output, appearing a negative value for both Ireland and the United Kingdom.
- We assumed a two factor cost function, indicating the substitution patterns between the two factors (capital and labour), whereas, capital and labour are substitute except the case of France where it is positive but not statistically significant.
- The parameter of *flexibility cost* indicating that the marginal cost will change with a change in the level of output, whereas for three countries, namely England, Germany and Ireland, indicate that the marginal cost will increase as the output expands.
- The share of capital (or in other words, it show how an input's share would be affected by a change in the level of output) showing that increases with an increase in output for Britain, Germany, Greece, Italy and Ireland, while in the other countries namely France, Netherlands and Spain, it decreases. Exactly the opposite estimated for labour input and for the share of labour.
- Looking for the impact of technical change on the growth of output, the estimated parameter suggests that the technical change is biased and they represent a change of factor share with respect to time. This parameter indicates that the technical change in England and Ireland decreases aggregate the output.
- Finally, we can estimate the *multifactor productivity MFP,* or the rate of technical change, that 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.

More complete measures of productivity at the economy-wide level relate output growth to the combined use of labor and capital inputs. This measure is called multi-factor productivity (MFP). Growth in MFP is a 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 labor 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 labor 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.

5. Implications and Conclusions

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. The countries that are technologically backward have a potentiality to generate more rapid growth even greater than that of the advanced countries, if they are able to exploit the new technologies which have already employed by the technological leaders.

Furthermore, conclusions cannot be easily drawn from simple summary measures of the extent or the rate of compositional structural change, without having some additional information regarding the direction of change, the path followed from the previous industrial structure and associated and institutional factors. Therefore, we have applied and implemented a new method for the measurement of technical progress and the economic growth; this is based on the *translog function*, (using time series data for selected member states). Our estimates indicate that technical progress is capital augmenting for Greece, Germany, Italy, Ireland, Netherlands and Spain, (where the elasticity of substitution between capital and labor has been found to be less than unity); the opposite result holds for France.

The differences in productivity between European Union and the USA are lower than the differences in rates of Employment, what means that European policies should have into account that the increase in productivity should not be accompanied of decreases in employment rates. The USA has higher productivity levels, higher wages and higher rates of employment. This is a very important question which at some extent is related with the lower levels of fiscal pressure on income and wages in the USA in comparison with Europe.

Finally, this paper argues that the European slowdown in growth is a reflection of an adjustment process towards a new industrial structure, which has developed more slowly in the EU than in the US. Rapid diffusion of new technology will facilitate the adjustment process in the future. However, an institutional environment that slows down change may hold up the structural adjustment process in Europe and inhibit the reallocation of resources to their most productive uses.

- Labor productivity is a useful measure: it relates to the single most important factor of production, is intuitively appealing and relatively easy to measure. Also, labor productivity is a key determinant of living standards, measured as per capita income, and from this perspective is of significant policy relevance. However, it only partially reflects the productivity of labor in terms of the personal capacities of workers or the intensity of their efforts. Labor productivity reflects how efficiently labor is combined with other factors of production, how many of these other inputs are available per worker and how rapidly embodied and disembodied technical change proceed. This makes labor productivity a good starting point for the analysis of some of these factors. One way of carrying out further analysis is to turn to multifactor productivity (MFP) measures.
- Multifactor productivity measurement helps disentangle the direct growth contributions of labor, capital, intermediate inputs and technology. This is an important tool for reviewing past growth patterns and for assessing the potential for future economic growth.

- However, one has to be aware that *not all technical change translates into MFP growth.* An important distinction concerns the difference between embodied and disembodied technological change. The former represents advances in the design and quality of new vintages of capital and intermediate inputs and its effects are attributed to the respective factor as long as the factor is remunerated accordingly.
- Further, in empirical studies, measured *MFP growth is not necessarily caused by technological change:* other non-technology factors will also be picked up by the residual.

6. References

Aghion, P. and P. Howitt (1998), *Endogenous Growth Theory*, Cambridge, Mass.: The MIT Press.

Ark, Bart van (1996), «Issues in Measurement and International Comparison of Productivity».

Baily, Martin (1993), «Competition, Regulation, and Efficiency in Service Industries», *Brookings Papers on Economic Activity*, pp. 71-159.

Bally, M.N., E.J. Bartelsman and J. Haltiwanger (1996), «Downsizing and Productivity Growth: Myth or Reality?», *Small Business Economics*, Vol. 8, August, pp. 259-278.

Barro, R.J. (1998), «Notes on Growth Accounting», *NBER Working Paper* No. 6654, Cambridge, MA.

Baumol, William J., Sue Anne Batey Blackman, and Edward N. Wolff (1992), *Productivity and American Leadership: The Long View*, MIT Press.

Berndt, Ernst R. and Melvyn A. Fuss (1986), «Productivity Measurement with Adjustments for Variations in Capacity Utilisation and Other Forms of Temporary Equilibria», *Journal of Econometrics* 33.

Caves, Douglas W., Laurits R. Christensen, and W. Erwin Diewert (1982), «The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity», *Econometrica*, pp. 1393-1413.

Commission of the European Communities, OECD, IMF, United Nations, World Bank (1993), *System of National Accounts 1993,* Brussels/Luxembourg, New York, Paris, Washington, DC.

Denison, Edward F. (1985), *Trends in American Economic Growth 1929-82,* The Brookings Institution, Washington, DC.

Denison, Edward F. (1989), *Estimates of Productivity Change by Industry: An Evaluation and an Alternative,* The Brookings Institution, Washington, DC.

Diamond, P.A. (1965), «Technical Change and the Measurement of Capital and Output», *Review of Economic Studies,* Vol. 32, pp. 289-99.

Diewert, Erwin W. (1976), «Exact and Superlative Index Numbers», *Journal of Econometrics*, pp.115-45.

Diewert, Erwin W. (1980), «Aggregation Problems in the Measurement of Capital», in Diewert, Erwin W. (1983), «The Theory of Output Price Index and the Measurement of Real Output Change», in Erwin W. Diewert and Claude Montmarquette (eds.), *Price Level Measurement,* Statistics Canada.

Diewert, Erwin W. (1987a), «Index Numbers», in J. Eatwell, M. Milgate and P. Newman (eds.), *The New Palgrave: A Dictionary of Economics.*

Diewert, Erwin W. (1987b): «Cost Functions», in J. Eatwell, M. Milgate and P. Newman (eds.), *The New Palgrave: A Dictionary of Economics.*

Diewert, Erwin W. (2000), *The Challenge of Total Factor Productivity Measurement,* International Productivity Monitor.

Diewert, Erwin W. and Catherine J. Morrison (1986), «Adjusting Output and Productivity Indexes for Changes in the Terms of Trade», *The Economic Journal 96,* pp. 659-679.

Domar, Evsey (1961), «On the Measurement of Technological Change», *Economic Journal* 71.

Dosi, Giovanni (1988), «Sources, Procedures and Micro-economic Effects of Innovation», *Journal of Economic Literature* 36.

Durand, René (1994), «An Alternative to Double Deflation for Measuring Real Industry Value Added», *Review of Income and Wealth,* Vol. 40.

Fisher, M. Franklin and Karl Shell (1998), *Economic Analysis of Production Price Indexes,* Cambridge University Press.

Gersbach, Hans and Bart van Ark (1994), *Microfoundations of International Productivity Comparisons,* Research Memorandum, Institute of Economic Research, University of Groningen.

Greenwood, J. and B. Jovanovic (1999), «Accounting for Growth», in: C. Hulten (ed.), *Studies in Income and Wealth: New Directions in Productivity Analysis,* Chicago: University of Chicago Press for NBER.

Griliches, Z. (1963), «The Source of Measured Productivity Growth: US Agriculture, 1940-1960», *Journal of Political Economy,* Vol. 71, pp. 331-46.

Griliches, Z. (1987), «Productivity: Measurement Problems», in J. Eatwell, M. Milgate and P. Newman (eds), *The New Palgrave: A Dictionary of Economics,* NY: Stockson Press.

Griliches, Zvi (1996), «The Discovery of the Residual: A Historical Note», *Journal of Economic Literature,* Vol. XXXIV.

Guisan, M. Carmen & Cancelo, M. Teresa & Diaz, M. Rosario (1998) «Evaluation of the effects of European regional policy in the diminution of regional disparities». Working Paper no. 29 of the Series *Economic Development*, available on line.

Guisan, M.C. and Aguayo, E. (2004) «Comparative Studies of European Countries: Employment, population and regional development in Western and Central Europe: Econometric Models and Challenges of EU Enlargement», *Applied Econometrics and International Development*, Volume 4, Issue 2, April-June, pp. 129-142.

Harberger, Arnold C. (1998), «A Vision of the Growth Process», *American Economic Review*, March.

Hill, Peter (1988), «Recent Developments in Index Number Theory and Practice», *Economic Studies No. 10*, OECD, Paris.

Hulten, Charles R. (1973), «Divisia Index Numbers», *Econometrica* 41.

Hulten, Charles R.(1978), «Growth Accounting with Intermediate Inputs», *Review of Economic Studies* 45.

Hulten, Charles R. (2001), «Total Factor Productivity: A Short Biography», in Hulten, Dean and Harper (eds.).

Hulten, Charles R., Edwin R. Dean and Michael J. Harper (eds.) (2001), *New Developments in Productivity Analysis*, University of Chicago Press for the National Bureau of Economic Research.

Hulten, Charles R. and Frank C. Wykoff (1980), «Economic Depreciation and the Taxation of Structures in United States Manufacturing Industries: An Empirical Analysis», in Dan Usher (ed.), *The Measurement of Capital*, University of Chicago Press.

Jorgenson, D.W. (1966), «The Embodiment Hypothesis», *Journal of Political Economy;* Vol. 74, No. 1,pp. 1-17.

Jorgenson, D.W. and Z. Griliches (1967), «The Explanation of Productivity Change», *Review of Economic Studies, V*ol. 34, No. 3.

Jorgenson, Dale (1995a), *Productivity Volume 1: Postwar U.S. Economic Growth*, MIT Press.

Jorgenson, Dale (1995b), *Productivity Volume 2: International Comparisons of Economic Growth*, MIT Press.

Jovanovic, B. and Y. Nyarko (1996), «Learning by Doing & Choice of Technology», *Econometrica*, Vol. 64, pp. 299-310.

Korres G (1998): "Productivity and technical change on EEC countries", The Cyprus Journal of Science and Technology, Vol. 1, Number 4.

Korres G (2002): "Technical Change, Diffusion and Innovation in a Context of a Growth Model", in "Globalisation and Economic Growth: A Critical Evaluation", John Smithin, Christos Paraskevopoulos, Theodore Georgakopoulos (eds.), APF (Athenian Policy Forum), Toronto/Canada, pp. 111-122.

Malmquist, Sten (1953), «Index Numbers and Indifference Surfaces», *Trabajos de Estatistica* 4, pp. 209-242.

Morrison, C.J. (1999), *Cost Structure and the Measurement of Economic Performance*, Norwell, MA: Kluwer Ac.
Nadiri, Ishaq and Ingmar Prucha (2001), «Dynamic Factor Demand Models and Productivity Analysis», in Hulten, Dean and Harper (eds.).

Nelson, Richard (1981), «Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures», *Journal of Economic Literature*.

Nelson, R.R., and S.G. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge, MA: The Belknap Press of Harvard University Press.

OECD (1991), *Technology and Productivity: The Challenge for Economic Policy*, Paris.

OECD (1996), *Industry Productivity: International Comparison and Measurement Issues*, OECD, Paris.

OECD (1995) «Technical Progress, Factor Productivity and Macroeconomic Performance in the Medium Term», by Claude Giorno, Pete Richardson and Wim Suyker, Economics Department Working Papers, No: 157, Paris, 1995.

OECD (2001), *OECD Measuring Productivity: Measurement of Aggregate and Industry – Level Productivity Growth*, OECD Manual, Paris.

Rodriguez, X.A. and Exposito, P. (2004): «Models of Productivity in European Union, the USA and Japan», *Applied Econometrics and International Development*, Vol.4-4 October-December, pp.

Romer, P.M. (1990), «Endogenous Technological Change», *Journal of Political Economy* Vol. 98, Supplement, pp. 71-102.

Shepard, R.W. (1953), *Cost and Production Functions*, Princeton University Press.

Solow, R.M. (1957), «Technical Change and the Aggregate Production Function», *Review of Economics and Statistics*, Vol. 39, pp. 312-20.