Abstract

The telecommunication industry appears one of the driving force of the new economy, which is characterized by the diffusion of, information and communication technologies and their applications. So, the analysis of the productivity evolution in the telecommunication industry, for different countries, is the first step to understand the productive patterns of the national economies. In particular, this paper focuses on the evolution of productivity in the telecommunication industry for 11 OECD European countries over the period 1979-1998. First it reviews the measures of productivity employed in the framework of the neoclassical growth models to capture the relationship between current and future cross-country output differences. In particular, it analyzes labour and total factor productivity. Then it tests the existence of convergence in the two productive measures among the 11 OECD countries by means of the cross-section technique.

Keywords: Labour Productivity, Total Factor Productivity, Data Envelopment Analysis, Convergence

Introduction

Over the past twenty years the telecommunication industry has been characterized by a deep process of transformation. The determinants of this process are strictly connected to the
dynamic forces operative in an economy; technical progress and institutional arrangements. In particular, the technical progress has steadily increased the quality and the amount of the telecommunication services offered to consumer; while the institutional arrangements has driven enterprise from a monopolistic position to a more competitive one (actually telecommunication services in the European union are fully liberalized). Thus this is a good time to look back and asses the movements of productivity in the telecommunication industry during the past twenty years. So, the main objective of this paper is to analyze the evolution of productivity in the telecommunications industry. We consider both labour and total factor productivity in order to identify the differential effects of capital accumulation and technological change on the evolution of productivity. In particular, Total Factor Productivity has been analyzed by mean of the Malmquist productivity index, which allows to decompose the productivity change in efficiency change and technical change. The index has been obtained by mean of the Data Envelopment Analysis and the software program developed by Coelli (1996)\(^1\)

The paper is organized as follows. Section 1 describes the data used for the analysis. Section 2 examines the labour and total factor productivity evolution for 11 OECD countries over the period 1979-1998. Section 3 tests the existence of convergence in labour and total factor productivity by mean of the cross section technique. Finally section 4 concludes and discusses further developments.

1. Data and Variables

The main sources of data used in this analysis are the World Telecommunication Industry (WTI) data base of International Telecommunication Union (2000) and the Purchasing Power Parity (PPP) and Real Expenditure Statistics of Organisation for Economic Cooperation and Development OECD (1999). The WTI database contains data on communication statistics covering telephone network size and dimension, mobile services, quality of services, traffic, staff, tariffs, revenue and investment for 209 countries. The OECD statistics measures PPA for 29 countries and 65 expenditure categories using the Elteto Koves and Slüze (EKS) index

\(^1\) The DEAP software written by Tim Coelli can be downloaded from [www.enu.edu.au/econometrics/cepa.htm](http://www.enu.edu.au/econometrics/cepa.htm).
number. In particular, PPP for the communication sector has been employed in the empirical analysis. However, this paper uses data of telecommunication industry for Belgium, Canada, Denmark, Finland, France, Italy, Japan, Netherlands, United Kingdom, United States and Sweden from 1987 to 1998. The remaining 18 countries have not been included for the presence of gaps in data over the observed period.

Output Data
As far as output is concerned it is possible to evaluate it in physical terms (e.g. number of subscriber, total national traffic, etc.) or to take total turnover.

An evaluation of the physical output has two main problems: first the WTI data base suffers of data missing, second the industry does produce multiple form of outputs.

Revenues in the WTI data base consist of telecommunications service earning during the financial year under review. Revenue not include monies received in respect of revenue earned during previous financial years, neither does it include monies received by way of loans from government, or other external investors, nor monies received from repayable’ subscribers’ contribution or deposit.

However, in order to eliminate differences in revenue due to the exchange rate fluctuations the variable, expressed at 1996 price for each country, have been deflated by the PPP for communications. In other terms revenues of the telecommunication industry expressed in common currency using PPP’s for communication reflect only differences in the volume of services provided.

Input Data
Two inputs have been considered: labour and capital.

The best way to measure the labour volume is represented by total hours worked. Unfortunately this variable is not collected in WTI data base. In its absence, labour volume has been proxied by the total full-time staff. In particular WTI variable, total full time staff, consider people employed by telecommunication network operators in the country for the provision of public telecommunication services.

Dealing with the capital input the choice has been to employ a physical measure: the number of main lines in operation. A main line is a telephone line connecting the subscriber’s terminal equipment to the public switched network and which has dedicated port in the telephone exchange equipment.
A summary of the values of the output and the inputs is reported in the next Table 1. Three features of the data stand out. The telecommunication industry countries involved varied from very small (Finland) to large (United States). Telecommunication industry have steadily increased the volume of service produced. The third feature of the data is that on average telecommunication industry have substituted out of labour.

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Table 1. Telecommunication Industry data for 11 OECD, 1979-1998.

2. Production Function

2.1 The efficient frontier

The computation of the productive efficiency represent one of the most important topics in analyzing performance of firms, industry sector and the whole economy. Whatever is the level of the economic analysis the computation of the productive efficiency derives directly from the notion of production function. The production function indicates the maximum
production level which can be obtained by different combinations of the production factors for a given technology. In its turn the production function in literature has been estimated both by mean of parametric technique, via regression analysis, and by mean of non parametric technique, via Data Envelopment Analysis (DEA). The former reflects “average” or “central tendency” behavior of the observations while the latter deals with best performance and evaluates all performances by deviation from the frontier line. To guide imagination in comparing the two above techniques consider figure 2 which represent, for explanatory reason, a constant production function for a single input (x) single output (y) case.

DEA identifies point like c for future examination or to serve as benchmark to use in seeking improvements. The efficient frontier touches at least one point and all points are therefore on or below this line. In fact, the name Data Envelopment Analysis come from this property because in mathematical term, such a frontier is said to “envelope” these points. The statistical approach, on the other hand averages c along with the other observations, including
as a basis for suggesting where improvements might be sought. So the two approaches can also result in different approaches to improvement. One of the advantage of the non parametric technique, based on linear programming, is that the a priori specification of the functional form is not required. In other terms, with linear programming, the efficiency of a productive unit will be established in comparison with the optimum, which is the situation of the “ideal” productive unit (in our example the “ideal” productive unit is represented by the projection of the points, below the efficient frontier, on the frontier itself) providing the maximum output with the least of input. Analogously it can be consider the dual problem, that is identify the “ideal” productive unit providing the most of output with the minimum input.

In the literature can be found different DEA model with respect to the type of envelopment surface and orientation. There are three types of envelopment surfaces associated with the assumption concerning returns-to-scale: Constant Returns to Scale (CRS), Variable Returns to Scale (VRS) and Non Increasing Return to Scale (NIRS). The CRS model assumes that there is a proportional growth between inputs and outputs. The VRS and the NIRS assume that the scale of operation affects the results.

Figure 2. CRS, VRS and NIRS Efficient Frontier.
In figure 2 are drawn the three types of frontier for the five productive unit which produce one output, $y$, with one input, $x$. Once that the frontier has been built the input efficient measure, in the sense used by Farrell (1957), is represented by the maximum reduction in inputs, given the outputs, which allows to reach the efficient frontier.

More formally, let us consider a set of $I$ productive unit. Each productive unit $i (i=1,2,..., I)$ produce $M$ output, $y_m (m=1,2,..., M)$, employing $N$ inputs, $x_n (n=1,2,..., N)$. So, if $Y$ denote the vector of output values and, $X$ denotes the vector of inputs value then the mathematical expression of the CRS, model with input orientation is given by the following dual linear programs called the envelopment form (see Coelli, 1996 and Lovell 1983 for mathematical details about the DEA models):

$$\begin{align*}
\min_{\alpha, \lambda} & \quad \theta \\
\text{s.t.:} & \quad -y_i + Y\lambda \geq 0, \quad i=1,...,n \\
& \quad \theta x_i - X\lambda \geq 0, \quad \lambda \geq 0
\end{align*}$$

The value of obtained from the solution of relations (1) gives the Overall Technical Efficiency, $O_i$, of unit $i$. Note that linear programming problem must be solved $I$ times in each period $t$, once for each productive unit in the sample. A value of less than one of $O_i$ indicates overall technical inefficiency for productive unit $i$. The VRS and the NIRS models are obtained imposing $1 = \sum_{i}^{I} \bar{e}_i$ and $1 \leq \sum_{i}^{I} \bar{e}_i$ in the minimization problem (1) respectively.

By mean of the CRS and VRS models it is possible to decompose the Overall Technical Efficiency into its component, Scale Efficiency $S_i$ and Pure Technical Efficiency $P_i$. In particular for each unit $i$ the efficiency measure can be written as follow:

$$O_i = S_i \times P_i \quad i = 1,...,I$$

(2)
In other terms an overall technical inefficiency, $O_i < 1$, for a productive unit can be caused by an inefficient input output configuration, $P_i < 1$, and as well as the size of the operation $S_i < 1$. Finally comparing the VRS results with the NIRS ones it can be individuate for each productive unit the type of returns to scale: increasing returns to scale (irs), constant return to scale (crs) and decreasing return to scale (drs).

2.2 Measuring the change of Total Factor Productivity

Once obtained the measure of efficiency for each productive unit in each period it is possible to compute the Malmquist (1953) productivity index. The Malmquist productivity index allows changes in productivity to be broken down into changes in efficiency and technical change. Moreover, it can be estimated using DEA. Letting, in this framework, the analytical mathematical formulation apart (see Coelli, 1996 among others) the Total Factor Productivity TFP change for each productive unit can be written as follow:

$$M_t^i = OC_t^i \times TC_t^i$$

Where $OC_t^i$ measures the Overall Technical Change and $TC_t^i$ measures the Technological Change between $t$ and $t+1$. A value of $OC_t^i$ greater than one indicates an efficiency improvement and a value of $TC_t^i$ higher than unity indicates technical progress. Moreover, from relation (2), the Malmquist index can be further decomposed taking into account the Scale Efficiency Change, $SC_t^i$, and Pure Technical Efficiency Change, $PC_t^i$: 
\[ M_i^t = SC_i^t \times PC_i^t \times TC_i^t \quad i = 1, \ldots, I; \quad t = 1, \ldots, T \] (4)

Values of the \( M_i^t \), \( PC_i^t \), \( SC_i^t \) or \( TC_i^t \) greater than one indicate efficiency improvement or technological progress, while, on the contrary, values less than one indicate efficiency decline or technological regress.

Thus, if for productive unit \( i \) between period \( t \) and \( t+1 \) technological change has not occurred, no movement of CRS efficient frontier (\( TC_i^t = 1 \)), the variation of the TFP measured by the Malmquist index is due to the change of technical efficiency of the productive unit, \( OC_i^t \), which in its turn can be caused by scale, \( SC_i^t \), and/or pure technical, \( PC_i^t \), movements.

On the contrary if the productive unit between period \( t \) and \( t+1 \) has not change its own technical efficiency, \( OC_i^t = 1 \), the variation of TFP can be explained only by the movement of the CRS frontier. Clearly, in the most of cases, the variation of TFP is caused by both efficiency and frontier movements.

3. Empirical Result

3.1 Measuring Total Factor Productivity

Figures 4 and 5 show the evolution over time of TFP, and its components, of the 11 OECD telecommunication industry as a whole measured by means of the geometric mean of Malmquist index for each country.
Observing figure 3 it is easy to note that the TFP at overall level is steadily increased over the considered period since, in each year, the value of the Malmquist index is greater than
one. On average growth rate of TFP in the telecommunication industry has been 8.1% at year, for the 11 OECD countries. The value is remarkable if compared, for the same countries, to the average growth rate of total industry, 1.2%, and of manufacturing industry, 2%, in the period 1980-1997. However, two periods have been characterized by rapid growth of TFP: 1987-89 and 1996-98. In both periods the increase of productivity can be explained by the rapid diffusion of the mobile services. In fact, for the 11 OECD countries the number of cellular mobile subscribers has increased, on average, of 35% in the first period and of 53% in the second one. Looking at the break down of the TFP into Overall Technological Efficiency Change (OC) and Technical Change (TC) it can be notice as the technological change has been the more important. In particular, the TC has caused an improvement of 7% against 1.1% of OC. The pattern of the variable OC, greater than one in almost of period, indicates that on average, inputs employed in the telecommunication industry could been reduced by a slight amount 1.1%=(1-1.011)x100%. Moreover, see figure 4, Pure Technical Efficiency Change, PC, has greater impact than Scale Efficiency Change on Overall Technical Efficiency. On average PC and SC contribute at explanation of OC by 0.7% and 0.3% respectively. Thus, these result suggest as the source of inefficiency for the telecommunication industry on average has done at the input output configuration rather than at the size of the operation.

3.1 Measuring Labour Productivity

Once obtained the measure of the Total Factor Productivity the next step has been to compute the Labour Productivity (LP) for each country dividing the volume measure by the

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full telecommunication staff. The geometric mean of the labour productivity is shown in table 2.

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Table 2. Annual Average Productivity Growth Rates, 1980-1998

The labour productivity varies from 15.30% in Italy to 7.10% in Netherlands. Moreover, analyzing the above table, it is possible to individuate two clusters of countries respect to the average labour productivity rates. The first one is composed by those countries which present significant level in their average productivity growth rates: Finland, Italy, United Kingdom, Sweden. The second one is composed by countries characterized by a moderate level of average productivity growth rate: Belgium Canada Denmark, France, United States, Netherlands.

The values of the average TFP growth rate are greater than the average labour growth rate in all countries, showing a low dispersion level among the countries. This suggests a continuing role for capital accumulation in labour productivity changes. A valuable difference in the two average growth rates for the first group of countries (Finland, Italy, United Kingdom and Sweden) proposes a process of jobless growth in the telecommunications industry.
3.3 Catching-up and Convergence

In the empirical literature on international productivity convergence, the catching-up hypothesis has been considered as one of the most important factor of the convergence process (Abramowitz, 1982). According to the above hypothesis, industries should experience higher growth rates when they initially locate far below the production frontier. In another term the catching-up hypothesis implies a negative relationship between initial efficiency/productivity levels and subsequent productivity growth rates. However, as noted by Lichtenberg (1994), most of those traditional test establish necessary, but not sufficient condition for convergence. In fact, employing the analysis productivity rate dispersion it is not possible to determine if the levels of productivity converge in the long run. So in order to investigate the convergence more deeply we have to compute the level of productivity for the TFP. While for the LP level there are not computational problems in determining the per-period level for the TFP level we have had to estimate the initial level since the parametric technique that we have employed produce the growth rate alone. So to estimate the initial level of TFP we assume the existence of constant return to scale and consequently we measure it by mean of a Cobb Douglas production function:

\[
\ln TFP_{i,1979} = \alpha_{i,1979} \ln \left( \frac{Q_{i,1979}}{L_{i,1979}} \right) + (1 - \alpha_{i,1979}) \ln \left( \frac{Q_{i,1979}}{K_{i,1979}} \right) \quad i=1,...,I;
\]

where \( Q_{i,1979}/L_{i,1979} \) is the Labour Productivity, \( Q_{i,1979}/K_{i,1979} \) is the Capital Productivity and \( \alpha_{i,1979} \) is the labour share for each country in 1979\(^3\). Thus the value of TFP obtained for 1979 should be considered a lover bound of the real growth in the TFP measure (Nadiri and Shankeman, 1981; Denny and Waverman, 1981; Kiss and Lefebvre 1987).

Figures 5 and 6 outline the logs of LP and TFP by country respectively. In particular, from figure 5 it is easy to note that the labour productivity has progressively increase for all countries. In particular, comparing labour productivity logs levels between Netherlands, the most productive country, and Finland, the least productive one, the spread in 1979 was equal to 1.25. Otherwise, the same value between Italy, the new productivity leader, and Finland in

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\(^3\) The labour share computed by OCSE in the Intersectoral Database for communication industry in 1979 have been employed
1998 was 1.40. So, even if the county with the highest and lowest level are different after nineteen years the gap is unchanged.
The TFP presents (see Figure 6) a similar pattern. Italy has been the country that over the period considered has shown the highest level of growth both in labour and total factor productivity.

At this point we analyzed the dispersion both for the total factor and the labour productivity.

Figure 7. Standard deviation of Log (Labour Productivity)

Figure 8. Standard deviation of Log (TFP)
The dispersion in the productivity level is shown in figures 7 and 8, which plot the coefficient of variation of labour and total factor productivity, respectively. Cross-section dispersion for LP and TFP show different patterns. In particular, LP dispersion values decreased from 0.45 to 0.29 over the period 1979-1992, while increased from 0.29 to 0.40 in 1998.

The growth of the dispersion values started in 1992 could be explained by the rise of the mobile communications market in the European region. In 1992, the mobile penetration rate (number of subscribers per 1000 inhabitants) has been 13.77 in Italy and 25.98 in United Kingdom. In 1997, in the same countries the mobile penetration rates were respectively of 204.07 and 150.20. In 1997, in the same countries the mobile penetration rates were respectively of 204.07 and 150.20. In the same year, Finland and Sweden achieved a mobile penetration rate of 420.16 and 358.18 against a ratio of 98.55 and 99.56 respectively for Germany and France. However, the reduction of the standard deviation reflects the fact that the productivity levels of the countries are getting closer together over the time.

On the contrary the TFP shows an increase in cross-country dispersion over the considered period. These result suggest that productivity differences in the TFP of the telecommunication industry might be permanent rather than transitory.

The final step in our work has been to assess the existence of convergence in the productive measures among the 11 OECD countries. Following Bernard and Jones (1996) we consider a model of productivity catch-up. In this connection, we assume whatever is the measure of productivity, \( P_i \), considered at time \( t \) in country \( i \), that the rate of productivity involves according to:

\[
\ln P_{i,t} = \gamma_i - \lambda \ln \left( \frac{P_{i,t}}{P_{i,t-1}} \right) + \ln P_{t-1,1} + \ln \epsilon_{i,t} \quad i=1,\ldots,I \quad (6)
\]

Where \( \gamma_i \) is the asymptotic rate of productivity growth in country \( i \), \( \lambda \) is the speed of catch-up, \( \frac{P_{i,t}}{P_{i,t-1}} \) is the ratio between the level of productivity of country \( i \) and country \( I \), the most productive country, and \( \epsilon_{i,t} \) represents an industry productive shock. Solving the difference equation (6) (see Bernard and Jones, 1996) it is possible to obtain the following function:

\[
P_{i,t}^* = \alpha + \beta \ln P_{i,0}^* + \epsilon \quad i=1,\ldots,I; \quad (7)
\]
with, $p^*_i$, being the average growth rate relative to country $j$ between time 0 and time $T$, $P^*_i$, is the ratio of productivity level in country $i$ to the level in country $j$ at time 0 and $\varepsilon$ is a stochastic error term normally distributed. In this framework a negative and significant coefficient $\beta$ confirms the existence of productivity convergence among countries. This simple way to analyze the productivity evolution among countries is powerful, since it overcomes the specification problems on the production function.

Since 1979 Netherlands has achieved the highest levels in the two productivity measures. we have regressed the average growth rates, obtained in Table 2, on the relative level of productivity of each country in the same year. Table 3 shows the regression results of the labour and total factor productivity.

<table>
<thead>
<tr>
<th></th>
<th>$\beta$</th>
<th>$T$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP</td>
<td>-0.0038</td>
<td>-2.371</td>
<td>0.41</td>
</tr>
<tr>
<td>TFP</td>
<td>-0.0039</td>
<td>-1.395</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Table 3. Convergence Regression

The regressions have poor capacity to explain cross-country growth rates. In fact, the simple regression explains 41% of cross-country variation for labour productivity and only 20% of cross-country variation of TFP. Moreover while for LP we have obtained a significant negative estimate of $\beta$, for the TFP we have refused the null hypothesis of catch up among the 11 OECD countries at the 5% level. This result can be explained in the “new growth theory” where the long-run average productivity growth rate of countries that are not converging will be different.

4. Conclusions

The paper analyzes the evolution of labour and total factor productivity for 11 OECD countries over the period 1979-1998 in the telecommunication industry. The analysis has been conducted employing an non parametric techniques, based on linear programming, called Data Envelopment Analysis (DEA) which allows to measure the Malmquist Total Factor Productivity index. In this framework we have found that countries have been characterized
by different average growth rates both in labour and total factor productivity. In particular Finland, Italy, United Kingdom and Sweden have shown the highest levels of the average labour productivity growth rate. This tendency could be explained by the rapid diffusion in those countries of the new technologies related to the mobile communications services and to the transmission of data, voices and images. However we have pointed out that the above process has been not followed by job growth. In other terms over the period 1979-1998 there was, especially for the most productive countries, a jobless growth.

Looking at the break down of the TFP into Overall Technological Efficiency Change and Technical Change it has been shown as the technological change has been the more important cause of TFP growth. In particular, the Technical Change has caused an improvement of 7% against 1.1% of the Overall Technological Efficiency. Finally, the cross sectional technique has highlighted the presence of weak convergence process only for the Labour Productivity.

REFERENCES


