IMPACT OF REGULATORY CHANGES ON PRODUCTIVITY GROWTH IN TELECOMMUNICATIONS INDUSTRY OF OECD COUNTRIES

A Heteroskedastic Error Components Model with Unbalanced Panel Data

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ABSTRACT

Telecommunications industry has gone through remarkable changes in the last two decades. The first big change was a revolutionary transformation of technology that introduced and popularized new products and services. The second major change was regulatory reforms, which forced the monopolistic/oligopolistic market structure to give way to competition. These changes were particularly marked in OECD countries, especially among the European members. The move towards European Economic Union provided a big stimulus for regulatory reforms. In 1991, 6 out of 24 OECD countries had some sort of competition in the mainline telecommunications. By the end of 1998, 23 out of 29 members achieved full competition, and almost all countries had more than two mobile communication operators. These changes had a significant impact on productivity growth.

This paper, using a 9-year long unbalanced panel data, examines the impact of these changes on Total Factor Productivity (TFP) growth; and quantifies the impact of regulatory reforms on TFP growth. An index of competition is incorporated in a multi-output flexible cost function to measure TFP growth in the presence of a quasi-fixed factor (capital). TFP growth is then decomposed into its constituent components.

Because of the unbalanced nature of the panel, and diversity of these countries in size and resources, a test failed to reject heteroskedastic variances. In the presence of heteroskedasticity in the cost function, application of the standard Seemingly Unrelated Regression (SUR) or iterative SUR gives inefficient parameter estimates. To correct for this, a random effect error components model is used. This is an extension of the standard error components model. First, a generalized error components model is used with firm-specific variances. Second, the generalized error components model is applied to a simultaneous equation system, where firm-specific variances are also introduced in the factor share equations. Then the system of equations is estimated using the ITSUR method.

The model is estimated using data from OECD Telecommunications Outlook (1999). Twenty-five countries are included in this analysis. Results show that during the study period, the selected OECD countries achieved a 48% overall TFP growth. Two main contributors to this growth are technological change, which contributed to about 57% of total TPF growth, and the impact of quasi-fixed factor, which contributed to approximately one-third of TFP growth. For all countries, the impact of regulatory reforms on technological change, hence on TFP growth, is found to be positive.

I. Introduction

The telecommunications industry has gone through remarkable changes in the last decade. Apart from sweeping technological changes, which introduced and popularized new products and services, many regulatory reforms were introduced. The main purpose of deregulation was to move away from a monopolistic/oligopolistic market structure to a competitive one. These changes were particularly marked in the OECD (Organization of Economic Cooperation and Development) countries. A move towards an Economic Union among the European members provided a further boost to regulatory reforms. Facing a large growth in demand and the pressure of cost reduction, the need for abolition of monopoly power was strongly felt in the telecommunications industry. Until the late 80's, the telecommunications industry in most OECD countries was a public-owned monopoly. In 1991, 6 out of 24 OECD countries had some sort of competition in the mainline telecommunications; and by the end of 1998, 23 out of 29 members achieved full competition; and almost all countries have more than two mobile communication operators.[1] Favorable impact of deregulation on Total Factor Productivity (TFP), both selection effect and competitive effect, have been discussed at great length in economics literature. The effects are believe to be pervasive in the telecommunications sector.[2]

This paper analyzes different aspects of productivity growth in selected OECD countries, at a time of growing economic opportunities, fast technological change and reduction of monopolistic control. The objective is to analyze the effect on different elements of TFP growth among OECD member countries, as a result of their privatization and liberalization policies during 1990s. An index of competition is used to capture the cost reduction effect of deregulation. An unbalanced panel data on 25 OECD countries is used to measure TFP growth. Because of unbalanced nature of the panel and diversity of the countries in respect of size and resources a heteroskedasticity corrected error components model is estimated. Results show that during the study period the selected OECD countries achieved a 48% overall TFP growth. Two major contributor to this TFP growth are Technological Change (TC), which accounted for 57% of total growth; and the impact of quasi fixed factors, which contributed to approximately one-third of TFP growth. For all countries the impact of regulatory changes on TFP growth was found to be positive.

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[1] These 6 countries are - Czech Republic, Greece, Hungary, Poland, Portugal, and Turkey. However, these countries have made commitments to open their markets by specified dates.

[2] see Kaserman et al. (1993), Levy and Spiller (1994), and Donald and Sappington (1997) for some recent reviews.

The rest of the paper is organized as follows. Section II discusses the changes in economic and competitive environment in the OECD countries. The econometric model is specified in Section III. Estimation procedure is elaborated in Section IV; Section V presents a brief discussion on the data used. The results are discussed in Section VI; and Section VII presents the conclusions of the study.

II. Privatization, Competition, and Modernization in OECD Countries

Most OECD countries had government-owned monopoly in the telecommunications sector prior to the late 1980s. The countries had large disparities not only in infrastructure investment and economic efficiency, but also in income and economic opportunities, which determine the demand for telecommunications services. In 1975, the main telephone line penetration rate (number of main lines per 100 population) was 24 in United Kingdom, 13 in France and 9 in Portugal [Waverman and Sirel (1997)]. Similarly, there were large differences in telecommunication revenue and investment per capita. In 1990, the level of telecommunication investment as a percentage of Gross Fixed Capital Formation (GFCF) was pretty high in some countries, e.g., Germany (3.6%), Italy (3.9%), Spain (4.6%), Portugal (3.7%), Korea (3.5%), and Australia (3.5%). But countries like Norway, Turkey, Belgium, Iceland, and Greece it was below 2%.[3] Between 1988 and 1997, telecommunication investment has almost doubled in OECD countries - from $88 billion to $152 billion, with mobile investments accounting for 26% of total investment [OECD (1999)].[4] The main drivers of increasing investment are mobile communications and network upgrades due to internet demand or greater investment in local access markets [OECD (1999)]. But prices were very much out of touch with costs.[5] The opening of markets led to a growing recognition, by the European Commission, that high cost and inefficiency in the telecommunications sector have been a major hindrance for industrial development; and rapid deregulation can help resolve this problem.

In Europe, UK was the first to take the bold step towards liberalization of the telecom industry in 1984. Competition was introduced in the telecom equipment sector in 1988, following a directive issued by the Commission. Countries like Sweden, Netherland, Finland, and Denmark soon followed the path. But counties like Germany, France, Spain,

[3] The overall GFCF for OECD in the same period was 2.5%.

[4] One of the important characteristics of investment in IT infrastructure is its network externality. Studies show that there exists a significant positive causal link between IT infrastructure investment and productivity growth of OECD countries. (see Röller and Waverman (2001), and Leff (1984))

[5] A large part of this was in the form of charging higher prices for domestic long-distance and international calls to subsidize the local phone service.

Italy, Belgium, Portugal, and Norway followed a cautious approach with a combination of limited privatization and limited competition.[6] The process gathered momentum in 1990s. The 1991 guidelines on competition in the telecommunications sector set the broad rules of the game. Rules for licensing, interconnection, spectrum allocation procedures and funding for the provision of universal phone service were specified, with a phased-in approach towards full-fledged competition, starting in the new millennium. Although the pace of liberalization has not been even, and a lot remains to be done, the ball has definitely started rolling. Most European countries have a high degree of competition today, compared to the beginning of '90s. Among non-European members, Japan and USA made significant progress in this area since late 1980s, which was further enhanced with the growth of cellular mobile market. In 1998, only 6 out of 29 OECD countries had monopoly ownership of Public Switched Telecommunication Network (PSTN) [OECD (1999)].[7]

The British telecommunications market is by far Europe's leader in privatization and liberalization. The process started in early 1980s, with a move from monopoly to duopoly. Competition intensified in the 1990s. By mid-1990's, Britain had a high degree of competition in local and long-distance telephone markets (both domestic and international), in data communications and leased lines, mobile communications and the equipment sector. This was also true for some other OECD countries - Sweden, Japan, New Zealand, and USA.[8] Most other OECD countries have already achieved a medium level of competition in both wired and wireless phone services by 1995. Besides liberalization, several other factors have played a part in accelerating growth in telecommunication markets, including liberalization of markets and network growth. Opening of countries like Poland, Czech Republic, and Hungary improved performance of their PTOs dramatically, which is clearly linked to their overall transition to the market economy. Some other countries, e.g., Turkey, Korea, and Greece, lagged behind in terms of deregulation, but still experienced a significant growth in network size.

A major impact of liberalization was felt in the cellular mobile communication market. Prior to 1992, all OECD countries had monopolies in the provision of cellular mobile communications, with the exception of six countries, which had duopolies. Since 1992, all

[6] for details see Waverman and Sirel (1997)

[7] Some of these countries (e.g., Netherlands, Czech Republic, Greece, and Poland), have already enacted new telecommunications legislations to boost competition in this sector. See Waverman and Sirel (1997) for further details on recent liberalization in European telecommunications.

[8] See Spiller and Cardilli (1997) for a good review of recent state of deregulation and evolution of competition in Australia and New Zealand.

OECD countries, except three, introduced greater competition in mobile communication, with up to six infrastructure providers competing in some areas. Between 1992 and 1998, the number of cellular users increased from 15 million to 170 million; and mobile communications now represents 20% of telecommunication market. Taken together the new revenue streams and stimulated traditional services provided by liberalization the share of telecommunication sector in GDP increased from 2.1% in 1990 to 2.7% in 1997.

Another significant development is opening of local markets in the early 1990s. Once again, opening of local markets started in the UK with the end of the duopoly. Between 1992 and 1997, new entrants added 3 million new lines in UK to provide competitive local services.[9] In the USA, the process gained momentum since the late 1990s. Opening of local markets is a slow process in the USA, and it will take quite some time to achieve full competition in local telecom market. In the local telephone market in the USA, rate of return regulation was typically accompanied by granting a monopoly franchise and imposing rules that require local companies to provide services to all customers in a service territory who request it. In addition, the pattern of price regulations typically included cross-subsidies. This led to a price structure which did not reflect cost differentials or demand elasticities.[10] In recent years, long distance carriers are selectively allowed to compete with local exchange carrier companies in some states. And some local carriers are allowed to provide end-to-end services. It is too early to determine the overall revenue impact of competition in a mature local market. Consumers are certainly going to benefit; apart from greater choices and improved services, prices are certainly going to go down. In UK, between 1992 and 1997, minutes of local call traffic increased by 7.7% per annum, but revenue from local calls increased by only 0.7% per annum.

One of the main benefits of greater competition has been innovation in the mobile pricing which turned mobile communication into a mass market. The primary beneficial effect of liberalization is price reduction - for both residential and business users. Between 1990 and 1998 the cost of a basket of services in OECD countries fell by 11%; for residential consumers the fall was in the order of 7%. The rate of decline was high for usage charges, which were very high in the initial years. Price reduction was very high for some countries; e.g., prices dropped by 47% in France between 1996 and 1997. Despite a sharp

[9] This advances in telecommunication infrastructure and technologies encouraged by UK government polices on telecommunications and its investment have wide-reaching consequences for not only the telecommunications industry/sector but also the British economy as a whole (see Correa (2003) for details).

[10] see Harris and Kraft (1997). For a detailed economic description of the industry see Laffont and Tirole (2000).

decline in prices, revenue increased considerably in this period. Between 1987 and 1992 the compound annual growth rate (CAGR), at constant US$, of public telecommunication revenue was 4.5%; and for the period 1992 to 1997 the same number (CAGR) jumped to 7.4% [OECD (1999)]. New pricing structures was pioneered by Internet Service Providers (ISPs). Innovations in internet-related pricing and expansion of network technologies have given these countries faster and cheaper access to information, which have a very important influence on overall TFP growth and technological change [Creti (2001)].

III. Econometric Model Specification

Traditional TFP growth measures, based on Divisia Index, assumes that producers are in long-run equilibrium, with constant returns to scale (CRS), operating under perfectly competitive output and factor markets. This measure may give biased results if any one of these conditions is violated. Moreover, the traditional measure does not allow for the existence of regulatory controls. The model presented here relaxes these assumptions and allows for regulatory controls.

We assume that the objective of telecommunications units (PTOs) in OECD countries is to minimize cost, subject to a given technology and exogenously determined outputs. So the optimization problem for a country's telecommunications industry can be expressed as

$$\text{(1)} \qquad \text{Min: } C = W'X\,, \quad \text{subject to} \quad F(Y, X, t) = 0\,,$$

where C is total cost, $W = [w_1, \ldots, w_N]$ is a $(N \times 1)$ vector of hiring prices of variable inputs $\in R_+^N$, $Y = [y_1, \ldots, y_M]$ is a $(M \times 1)$ vector of final outputs $\in R_+^M$, $X = [x_1, \ldots, x_N] \in R_+^N$, and t is the time trend variable - representing disembodied technological change. Since the telecommunications industry in OECD is wholly or partially regulated; output can be treated as exogenous. Under certain regularity conditions, the solution to the above optimization problem can be written in terms of a dual cost function as

$$\text{(2)} \qquad C = C(W, Y, t)\,.$$

Traditionally, Total Factor Productivity Growth (TFPG) is defined as the difference between the rate of output growth and the rate of growth of all inputs. We deviate from the traditional measure; and following Denny *et. al.,* (1981) TFP growth is defined as[11]

$$(3) \qquad T\dot{F}P \equiv \dot{Y} - \dot{X} = -\dot{C}_t + \dot{Y}\Big\{1 - \sum_m E^C_{y_m}\Big\}.$$

Here a '.' over a variable indicates its growth rate (not its time derivative), $\dot{C}_t = \partial \ln C/\partial t$, $E^C_{y_m} = \frac{\partial \ln C}{\partial \ln y_m}$, where m indexes output, and

$$(4) \qquad \dot{Y} = \sum_m \frac{E^C_{y_m} \dot{y}_m}{\sum_m E^C_{y_m}} .$$

Since returns to scale, RTS, is defined as

$$(5) \qquad RTS = \Big[\sum_m E^C_{y_m}\Big]^{-1} ,$$

the above formula (3) decomposes TFP growth rate into two components: technical change $(-\dot{C}_t)$ and a scale effect $\big\{\dot{Y}\big(1 - \sum_m E^C_{y_m}\big)\big\}$. Thus, $T\dot{F}P = -\dot{C}_t$, only when a unitary RTS is observed.

In the above formulation, the effects of quasi-fixed factors have not been considered. Unlike traditional approach, the cost function used in this study is derived from a short-term cost function, which allows for inadequate adjustments in quasi-fixed inputs to changes in output, variable input prices and technology. In the presence of a quasi-fixed factor, the dual representation of the production possibility frontier can be expressed as[12]

$$(6) \qquad G = C(W, Y, Z, t) + R'Z ,$$

where G is total cost, $Z = (z_1, \ldots, z_Q)$ is a (Q) vector $\in R^Q_+$ of quasi-fixed inputs, and $R = (r_1, \ldots, r_Q) \in R^Q_+$ is a the hiring prices of quasi-fixed factors. Totally differentiating equation (6) with respect to t and rearranging terms, the rate of change in total cost, adjusted for quasi-fixed factors, can be expressed as

$$(7) \qquad \dot{G} = \sum_j S_j \dot{w}_j + \sum_q S_{z_q} \dot{r}_q + \sum_q E^G_{z_q} \dot{z}_q + \sum_m E^G_{y_m} \dot{y}_m + \dot{G}_t ,$$

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[11] In deriving the $T\dot{F}P$ formula in (3), the cost elasticities with respect to output have been used as weights to obtain the growth rate of aggregate output $(\dot{Y})$ in (4). An alternative to this approach is to use the revenue shares as weights. These two measures are identical if a marginal cost pricing rule is used. Since the most telecommunication units in OECD countries are regulated, marginal cost pricing rule may not be consistent with profit maximization. We, therefore, used the cost elasticities as weights in the TFP growth measure. See Denny *et. al.* (1981) for details.

[12] See Nadiri and Schankerman (1981) and Schankerman and Nadiri (1984) for role of quasi-fixed factor adjustment in cost function and TFP growth measurement.

where $S_j = w_j x_j / G$ is the share of the jth variable input in total cost, $S_{z_q} = r_q z_q / G$ is a similar cost-share for the qth quasi-fixed input, $E^G_{z_q} = \partial \ln G / \partial \ln z_q$ is the elasticity of total cost with respect to z_q, $\dot{G}_t = \partial \ln G / \partial t$, and $E^G_{y_m} = \partial \ln G / \partial \ln y_m$. Since $G = W'X + R'Z$, we can also write

$$\dot{G} = \sum_j S_j \dot{w}_j + \sum_j S_j \dot{x}_j + \sum_q S_{z_q} \dot{z}_q + \sum_q S_{z_q} \dot{r}_q \,. \tag{8}$$

In the presence of quasi-fixed inputs, the TFP growth rate can be defined as

$$T\dot{F}PZ = \dot{Y} - \dot{X} - \dot{Z} \,, \tag{9}$$

where $\dot{X} = \sum_j S_j \dot{x}_j$, $\dot{Z} = \sum_q S_{z_q} \dot{z}_q$, and

$$\dot{Y} = \sum_m \frac{E^G_{y_m} \dot{y}_m}{\sum_m E^G_{y_m}} \,. \tag{10}$$

Substituting equations (7) and (8) in (9), we get[13]

$$T\dot{F}PZ = -\dot{G}_t + \Big\{1 - \sum_m E^G_{y_m}\Big\}\dot{Y} - \sum_q E^G_{z_q} \dot{z}_q \;\equiv TC + SCLC + QFAC \,, \tag{11}$$

where $TC = -\dot{G}_t$; $SCLC = \Big\{1 - \sum_m E^G_{y_m}\Big\}\dot{Y}$; and $QFAC = -\sum_q E^G_{z_q} \dot{z}_q$.

The above expression shows that the TFP growth rate in the presence of quasi-fixed inputs ($T\dot{F}PZ$) is composed of three effects. The first term, TC, represents the contribution of disembodied technological change in TFP growth. Other things remaining unchanged, a cost reduction due to technical change has a favorable effect on TFP growth. The second term, $SCLC$, captures the contribution of scale economies. In the presence of increasing returns to scale ($RTS > 1$), output expansion ($\dot{Y} > 0$) augments TFP growth; in the case of decreasing returns it adversely affects productivity growth. The last term, $QFAC$, represents the effect sluggish adjustments in quasi-fixed factor (capital) on TFP growth. If there is a perfect adjustment of Z at every instant, then the effect of a further adjustment in the quasi-fixed input on variable cost would be zero, i.e., $E^G_{z_q} = 0$. In such cases, no adjustment term is required in the TFP growth expression.

Since telecommunication includes an array of services (e.g., voice telephone, data transfer, internet network), an econometric model using multiple outputs and multiple inputs is developed below. Over the past two decades, telecommunication industry in

[13] See Flaig and Steiner (1993) for a similar derivation in a single output case.

OECD countries has undergone major regulatory changes. Some counties experienced a fast transition from monopoly to competitive market, while other countries took a cautious approach. Moreover, these regulatory changes did not impact all areas of telecom industry in the same way. In some countries local service was less impacted compared to long distance and data transfer system. In other countries, wireless sector experienced more competition than local and long distance. One important objective of this paper is to measure the impact of regulatory changes on $TFPG$. Regulatory changes in various services are introduced in the cost function in terms of a competition index - τ, which is defined later in details in the data section. For estimation, the cost function in (2) is approximated in terms of a multi-input multi-output Translog cost function as

$$
\begin{aligned}
\ln C_{it_i} = \alpha_o &+ \sum_n \alpha_n \ln w_{int_i} + \sum_m \alpha_m \ln y_{imt_i} + \sum_j \alpha_j \ln \tau_{ijt_i} + \sum_q \alpha_q \ln z_{iqt_i} + \alpha_t t_{it_i} \\
&+ \frac{1}{2}\Big\{ \sum_n \sum_q \beta_{ns} \ln w_{int_i} \ln w_{ist_i} + \sum_m \sum_p \beta_{mp} \ln y_{imt_i} \ln y_{ipt_i} \\
&+ \sum_j \sum_l \beta_{jl} \ln \tau_{ijt_i} \ln \tau_{ilt_i} + \sum_q \sum_d \beta_{dq} \ln z_{iqt_i} \ln z_{idt_i} + \beta_{tt} t_i^2 \Big\} \\
&+ \sum_n \sum_m \gamma_{nm} \ln w_{int_i} \ln y_{imt_i} + \sum_n \sum_j \gamma_{nj} \ln w_{int_i} \ln \tau_{ijt_i} \\
&+ \sum_n \sum_q \gamma_{nq} \ln w_{int_i} \ln z_{iqt} + \sum_n \gamma_{nt} \ln w_{int_i} t_{it} + \sum_m \sum_j \gamma_{mj} \ln y_{imt_i} \ln \tau_{ijt_i} \\
&+ \sum_m \sum_q \gamma_{mq} \ln y_{imt_i} \ln z_{iqt_i} + \sum_m \gamma_{mt} \ln y_{imt_i} t_i + \sum_j \sum_q \gamma_{jq} \ln \tau_{ijt_i} \ln z_{iqt_i} \\
&+ \sum_j \gamma_{jt} \ln \tau_{ijt_i} t_i + \sum_q \gamma_{qt} \ln z_{iqt_i} t_i + \epsilon_{it_i} \,,
\end{aligned} \tag{12.1}
$$

where i indexes country ($i = 1, \ldots, I$) and t indexes year ($t = 1, \ldots, T$). Subscripts n and q represent N variable inputs; m and p index M outputs; j and l represent J regulatory environment factors; d and q represent Q quasi-fixed inputs; and ϵ_{it} is the error term. Symmetry restrictions, i.e., $\beta_{sn} = \beta_{ns}$, $\beta_{mp} = \beta_{pm}$, $\beta_{jl} = \beta_{lj}$, and $\beta_{dq} = \beta_{qd}$ are imposed on (12.1). Since the cost function is homogeneous of degree one in input prices, the following restrictions are also imposed on the parameters

$$
\sum_n \alpha_n = 1\,; \ \sum_n \gamma_{nm} = 0, \ \ \forall\, m\,; \ \sum_j \gamma_{nj} = 0, \ \ \forall\, j\,; \ \sum_n \gamma_{nq} = 0\,; \text{ and } \sum_n \gamma_{nt} = 0\,.
$$

The error term ϵ_{it_i} is specified as

$$
\epsilon_{it_i} = \mu_i + \nu_{it_i}\,, \tag{13.1}
$$

where μ_i is the country specific component, and ν_{it_i} is the white noise component varying across country and over time.

Using Shephard's Lemma, the cost-share equations for the nth variable input can be written as

(12.2)

$$S_{int_i} = \alpha_n + \sum_n \beta_{ns} \ln w_{int_i} + \sum_m \gamma_{nm} \ln y_{imt_i} + \sum_q \gamma_{nj} \ln z_{ijt_i} + \sum_j \gamma_{nj} \ln \tau_{ijt_i} + \gamma_{nt} t_i + \eta_{int_i} ,$$

where $S_{int_i} = ((w_{int_i} x_{int_i})/C_{it_i})$, is the cost-share of the nth variable input, and x_{int_i} the amount of nth variable input used by country i at time t. Finally, η_{int_i} is the classical error term appended to the nth share equation, which alike (13.1) is specified as

$$\eta_{int_i} = \theta_{in} + \xi_{int_i} . \qquad (13.2)$$

where θ_i is country specific component and ξ_{it_i} captures white noise.

Using the Envelop theorem, we derived the equilibrium condition for the quasi-fixed input, Z. In equilibrium, the rental rate (r) of a quasi-fixed factor is equal to the expected marginal benefit obtained from that factor, which is measured by the magnitude of reduction in variable cost due to that factor. In terms of our cost function in (12.1) it can be expressed for the qth quasi-fixed factor as

(12.3)

$$-S_{iqt_i} = \alpha_q + \sum_q \beta_{dq} \ln z_{iqt_i} + \sum_n \gamma_{nq} \ln w_{int_i} + \sum_m \gamma_{mq} \ln y_{imt_i} + \sum_j \gamma_{jq} \ln \tau_{ijt_i} + \gamma_{qt} t_i + \zeta_{iqt_i} ,$$

where S_{iqt_i} is the share of physical capital, Z, in total cost; and ζ_{iqt_i} is the classical error term appended to the capital share equation, which is specified as

$$\zeta_{iqt_i} = \kappa_{iq} + \vartheta_{iqt_i} , \qquad (13.3)$$

where κ_{iq} captures country specific effects in the qth capital share equation and ϑ_{iqt_i} captures white noise, which varies across time and country.

From the Translog cost function (12.1), the rate of technological change, TC, is given by

$$TC_i = -\left[\alpha_t + \beta_{tt} t_i + \sum_n \gamma_{nt} \ln w_{int_i} + \sum_m \gamma_{mt} \ln y_{imt_i} + \sum_j \gamma_{jt} \ln \tau_{ijt_i} + \sum_q \gamma_{qt} \ln z_{iqt_i}\right]. \qquad (14)$$

The rate of technical change (TC) can be further decomposed into five sources, viz.,

$$\text{PTC} = -\left[\alpha_t + \beta_{tt} t_i\right] , \qquad (14.1)$$

(14.2) $$\text{NTC} = -\Big[\sum_{n} \gamma_{nt} \ln w_{int_i}\Big] \, ,$$

(14.3) $$\text{STC} = -\Big[\sum_{m} \gamma_{mt} \ln y_{imt_i}\Big] \, ,$$

(14.4) $$\text{RTC} = -\Big[\sum_{j} \gamma_{jt} \ln \tau_{ijt_i}\Big] \, , \quad \text{and}$$

(14.5) $$\text{KTC} = -\Big[\gamma_{zt} \ln z_{it_i}\Big] \, ,$$

where PTC is pure technological change, NTC is non-neutral technological change, STC is scale-augmenting technological change, RTC is deregulation-augmented technological change, and KTC is quasi-fixed factor augmented technological change. This decomposition highlights the effect of different arguments of the cost function in bringing about its shift over time. The PTC component measures the effect of the state of production technology. Since time is taken as an indicator of knowledge, PTC is measured solely by the time-trend variable, t_i. The effect of input prices on the rate of shift of the cost function is captured by NTC. The third component, STC, represents the part of the shift that can be attributed to the level of output. The effect of deregulation/competition on TC is captured by RTC. Finally, the effect of capital on the shift in cost function is measured by the last component KTC.

IV. Estimation Procedure

Parameters of the model presented in Section III can be estimated from the cost function alone. To improve efficiency of parameter estimates, cost share equations are estimated along with the cost function. The error term of cost function (ϵ_{it_i}) is heteroskedastic because of the heterogeneous nature of the PSTN operating in different countries with varying levels of economic development with widely differing population size and resources. Heterogeneity in a country's cost structure is captured by the country-specific intercepts defined in (13), which can be treated either as fixed or as random. In this study these are considered to be as random variables, because a Houseman specification test failed to reject the hypothesis that η_i, θ_i, and κ_i are random.

Since we have unbalanced panel data, and countries are diverse in size, it is unlikely that the model would pass a test of homoskedastic variances. Even logarithmic specifications postulating percentage variation across cross-sectional units are likely to be hetroskedastic, because observations for lower output firms are likely to evoke larger variances [Mazodier and Trognon (1978), Baltagi and Griffin (1988)]. Moreover, the estimation of a Seemingly Unrelated Regression model (SUR) with an unbalanced panel dataset gives rise to some estimation problems [Schmidt (1977)]. For different time periods there are different numbers of units (i.e., countries drop out without replacement), which change the ordering of observations. Since it dictates the structure of the variance-covariance matrix, the ordering is important in error component models [Baltagi (1985)].

We, therefore, consider three extensions of the standard random effects model. First, we assume that the variance of the country-specific effects varies across country. That is, instead of assuming $\mu_i \sim i.i.d.(0, \sigma^2_\mu)$, we assume $\mu_i \sim (0, \sigma^2_{\mu_i})$. Thus, we consider a generalized error components model [Mazodier and Trognon (1978), Baltagi and Griffin (1988)] with country-specific variances. In other words, heteroskedasticity in this model is captured through variances of country-specific effects. Second, the single equation model of Baltagi and Griffin is extended to a multiple equations framework. Third, the generalized error components model is extended to a multiple equation case, by decomposing error terms of share equations similar to that of ϵ_{it_i}. Instead of assuming, $\theta_{in} \sim i.i.d.(0, \Sigma_\theta)$, and $\kappa_{iq} \sim i.i.d.(0, \Sigma_\kappa)$, we capture heteroskedasticity in share equations in terms of country-specific variances $\theta_{in} \sim (0, \Sigma_{\theta_{in}})$, and $\kappa_{iq} \sim (0, \Sigma_{\kappa_{iq}})$.

Following are the assumptions on the error terms associated with equation 13:

1. $\nu_{it_i} \sim i.i.d.(0, \sigma^2_{\nu_i})$
2. $\mu_i \sim (0, \sigma^2_\mu)$
3. $\xi_{int_i} \sim i.i.d.(0, \Sigma_\xi)$
4. $\vartheta_{iqt_i} \sim i.i.d.(0, \Sigma_\vartheta)$
5. $\theta_{in} \sim (0, \Sigma_{\theta_{in}})$
6. $\kappa_{iq} \sim (0, \Sigma_{\kappa_{iq}})$
7. μ_i, ν_{it_i}, ϑ_{iqt_i}, θ_{in}, and κ_{iq} are independent of each other, and also independent of ξ_{int_i}, ϑ_{iqt_i}, and their components.

Due to the presence of heteroskedasticity in the cost function, application of standard SUR technique, or iterative SUR (ITSUR) is likely to give inefficient parameter estimates. The efficient method of estimation would be the one that takes heteroskedasticity into account. For this, we apply a transformation on the cost function and share equations that makes the error terms homoskedastic [Baltagi and Griffin (1988)], and then use the ITSUR procedure to estimate the system of transformed cost and share equations. To make the necessary transformations, the variance components associated with the cost function and share equations must be known. That is, σ_{ν_i}, σ_μ, σ_η, σ_ζ, Σ_{ϑ_i}, and Σ_{ξ_i} are to be estimated first. These parameters are estimated using the following steps.

1. After a within transformation of cost function and share equations, the system of

equations (consisting of the cost function and share equations (12)) are estimated using the SUR technique, ignoring heteroskedasticity. Residual of cost and share equations are then used to estimate σ_μ, σ_θ, and σ_κ from their respective mean square errors. This process gives an unbiased estimator of σ^2_μ, σ^2_θ, and σ^2_κ. Since the share equations are extended to include the fixed-effect terms, to maintain consistency, for this step, the cost function is modified to include the $\sum_i \theta_{in} \ln w_{int_i}$ and $\sum_i \kappa_{iq} \ln z_{iqt_i}$ terms, $\forall\ i = 1, \ldots, I$.

2. The system of equations in (12) is estimated once again using ITSUR, this time without a within transformation or heteroskedasticity correction. Then we estimate $V(\epsilon_{it_i}) = \lambda^2_{C_i} = (\sigma^2_{\nu_i} + \sigma^2_\mu)$ from $\hat{\lambda}^2_i = \sum_{t_i}^{T_i} \hat{\epsilon}^2_{it_i}/T_i$ for each i, where $\hat{\epsilon}^2_{it_i}$ is the estimated residual of the cost function obtained from step 2. Similarly, using estimated residuals of input share equations (S_n) and capital share equation (S_z) we estimate $V(\eta_{int_i}) = \lambda^2_{S_{ni}}$ and $V(\zeta_{izt_i}) = \lambda^2_{S_{zi}}$, where $\lambda^2_{S_{ni}} = (\sigma^2_{\theta_n} + \sigma^2_{\xi_{in}})$ and $\lambda^2_{S_z i} = (\sigma_{\kappa_q} + \sigma^2_{\vartheta_{iq}})$.
3. Using steps 1 and 2, we estimate $\hat{\sigma}^2_{\nu_i} = \hat{\lambda}^2_{C_i} - \hat{\sigma}^2_\mu$, $\hat{\sigma}^2_{\xi_{in}} = \hat{\lambda}^2_{S_{ni}} - \hat{\sigma}^2_{\theta_n}$, and $\hat{\sigma}^2_{\vartheta_{iz}} = \hat{\lambda}^2_{S_{zi}} - \hat{\sigma}^2_\zeta$.
4. Finally, the transformation parameters Λ_{C_i}, $\Omega_{S_{ni}}$, and Ψ_{zi}, for each i, is calculated as

$$\Lambda_{C_i} = 1 - \frac{\sigma_\mu}{\sqrt{(\sigma^2_\mu + T_i \sigma^2_{\nu_i})}}$$
$$\Omega_{S_{ni}} = 1 - \frac{\sigma_{\theta_n}}{\sqrt{(\sigma^2_{\theta_n} + T_i \sigma^2_{\xi_{ni}})}}$$
$$\Psi_{Z_i} = 1 - \frac{\sigma_{\kappa_z}}{\sqrt{(\sigma^2_{\kappa_z} + T_i \sigma^2_{\vartheta_{zi}})}}.$$

Given estimated values of Λ_{C_i}, $\Omega_{S_{ni}}$, and Ψ_{Z_i}, we transform the cost function, input share equations, and capital share equation in (12) as follows. We rewrite the system of equations, for notational simplicity, as

$$\begin{aligned} \mathcal{C}_{it_i} &= H_{it_i} \Delta_C + \epsilon_{it_i} \\ \mathcal{S}_{int_i} &= G_{int_i} \Delta_{S_n} + \eta_{int_i} \\ -\mathcal{S}_{izt_i} &= M_{izt_i} \Delta_{S_z} + \zeta_{izt_i}, \end{aligned} \tag{15.1}$$

where $\mathcal{C}_{it_i} = \ln C_{it_i}, \mathcal{S}_{int_i} = S_{int_i}$ and $-\mathcal{S}_{izt_i} = -S_{izt_i}$; and H_{it_i}, G_{int_i}, and M_{izt_i} are the data matrices that contain right hand side variables of cost, variable input share, and capital share equations, respectively. And Δ_C , Δ_{S_n} , and Δ_{S_z} are parameter vectors associated with H_{it_i} , G_{int_i} , and M_{izt_i}, respectively. The transformed model, therefore, can be written as

$$
\begin{aligned}
\tilde{\mathcal{C}}_{it_i} &= \tilde{H}_{it_i}\Delta_C + \tilde{\epsilon}_{it_i} \\
\tilde{\mathcal{S}}_{int_i} &= \tilde{G}_{int_i}\Delta_{S_n} + \tilde{\eta}_{int_i} \qquad (15.2)\\
-\tilde{\mathcal{S}}_{izt_i} &= \tilde{M}_{izt_i}\Delta_{S_z} + \tilde{\zeta}_{izt_i}
\end{aligned}
$$

where

$$
\begin{aligned}
&\tilde{\mathcal{C}}_{it_i} = \mathcal{C}_{it_i} - \Lambda_{C_i}\frac{1}{T_i}\sum_{t_i}\mathcal{C}_{it_i}\,,\ \tilde{H}_{kit_i} = H_{kit_i} - \Lambda_{C_i}\frac{1}{T_i}\sum_{t_i}H_{kit_i}\,, (k=1,\ldots,K)\,,\\
&\tilde{\mathcal{S}}_{int_i} = \mathcal{S}_{int_i} - \Omega_{in}\frac{1}{T_i}\sum_{t_i}\mathcal{S}_{int_i}\,,\ \ \tilde{G}_{lit_i} = G_{lit_i} - \Omega_{S_{in}}\frac{1}{T_i}\sum_{t_i}G_{lit_i}\,,\ (l=1,\ldots,L)\,,\\
&-\tilde{\mathcal{S}}_{izt_i} = -\mathcal{S}_{izt_i} - \Psi_{iz}\frac{1}{T_i}\sum_{t_i}-\mathcal{S}_{izt_i}\,,\ \tilde{M}_{uzt_i} = M_{uzt_i} - \psi_{iz}\frac{1}{T_i}\sum_{t_i}M_{uit_i}, (u=1,\ldots,U)\,;\\
&\tilde{\epsilon}_{it_i} = \epsilon_{it_i} - \Lambda_i\frac{1}{T_i}\sigma_{t_i}\sum_{t_i}\epsilon_{it_i},\ \forall i\,,\ \tilde{\eta}_{int_i} = \eta_{int_i} - \Omega_i\frac{1}{T_i}\sigma_{t_i}\sum_{t_i}\eta_{it_i}\ \forall i\,,\ \text{ and}\\
&\tilde{\zeta}_{izt_i} = \zeta_{izt_i} - \Psi_i\frac{1}{T_i}\sigma_{t_i}\sum_{t_i}\zeta_{izt_i}\,, \forall i.
\end{aligned}
$$

After this transformation, the new error terms ($\tilde{\epsilon}_{it_i}$, $\tilde{\eta}_{int_i}$, $\tilde{\zeta}_{izt_i}$) become homoskedastic. Next, we estimate the remaining parameters, using ITSUR technique to the system equation (15.2).

V. The Data

For estimation of this multi-output-multi-input model, we used two outputs, two variable inputs, one quasi-fixed factor (capital), and an index of deregulation. Dollar (US$) value of total telecommunication revenue is decomposed into two outputs – revenue from standard telephone services (y_1) and revenue from other telecommunication services (y_2). Two variable factors used in the model are – labor (L) and materials (O). Input O is derived by subtracting wages and salaries from total operational expenses. Since no price is available for O, CPI is used as its price. We normalize the cost function by prices of O. Capital (Z) is the total value of investment capital expressed in US dollar. Disembodied technological change is introduced in terms of a time trend t.

In this analysis, instead of using the number of access lines as an output, we used revenue as output to allow for a diverse set of telecommunication services now available under telecom industry. Mobile communications alone now represent 25% of the telecommunication market. So a significant portion of telecom revenue comes from mobile communications. Besides mobile communication, the growth of Internet services in 1990s have emerged as a leading potential revenue driver. This has increased the size of telecommunications market in two ways - by creating a new service called internet access, and, by stimulating sales of traditional and new access services. So output y_1 represents revenue from standard telephone services; and y_2 represents revenue earned form all other telecom services offered.

Number of labor employed (L) and their wage and salaries (W) are obtained from various issues of OECD Communications Outlook [OECD]. Total expenditure on wages and salaries has declined in the OECD countries. At the same time, average wages and salaries per employee and per access line have increased in most countries [OECD (1999)]. Between 1987 and 1997, the total number of employee in telecom sector in OECD countries has declined from 2.8 millions to 2.6 millions. While incumbent PTOs continue to reduce their workforce, the number of jobs created by new services and new market entrants has, in recent years, largely offset the job reductions. On the one hand increased digitalization, which requires lot less maintenance, and continued out-sorcesing reduced employments, but on the other hand, increased competitive marketing generated lot more marketing positions. However, the new generation recruits are more educationally and technically advanced. So hiring wage of new employees and their per capita overheads are higher than the group they replaced.

Data on whether a country has monopoly, duopoly, or competition in (i) local, (ii) long distance (national), (iii) international, and (iv) lease lines is also available in various issues of OECD Communications Outlook. An index of deregulation (τ) is constructed using this information. For each area of operation a value is assigned to indicate the degree of competition. If competition exists, a value 3 is assigned; if duopoly prevails then a value of 2, and 1 if monopoly exists. The sum of these values for each year is divided by the maximum possible value - 12. So τ is always positive and less than equal to 1, $[1 \geq \tau_{it_i} > 0]$. A value close to 1 means higher level of competition, whereas a value close to zero indicates high monopoly concentration.

Due to non-availability of data, not all OECD countries are included in this study - 25 out of 29 countries are included in this study. Even for the countries included, often data is not complete. In some cases missing intermediate data points were handled by interpolation/imputation. Countries included and the number of years a country is observed are given in Table 2.

Disembodied technological change is introduced in the model in terms of t, so the year when a country first shows up in the data is very important. If the same starting year is used for all countries then the late comers get a higher value of t, which overestimates their TFP growth rate. To avoid this problem in our model the t series of a country starts from the year when that country first shows up in the dataset.

VI. Results

The system of equations (12.1, 12.2, and 12.3, with 13.1, 13.2, and 13.3 imposed) is estimated simultaneously using the Iterative Seemingly Unrelated Regression (ITSUR) method. Due to a large number of coefficients, estimated parameters of the intermediate steps (step 1 and step 2) are not reported in the paper. Parameter estimates of the heteroskedasticity corrected error components model is reported in Table 1. More than two-thirds of the estimated parameters are statistically significant at least at the 5% level of significance. Values of firm specific variances, $\lambda^2_{C_i}$, $\lambda^2_{S_{ni}}$, $\lambda^2_{S_{zi}}$, $\sigma^2_{\nu_i}$, $\sigma^2_{\vartheta_{iq}}$ and $\sigma^2_{\xi_{in}}$; and hence values of transformation parameters Λ_{C_i} , $\Omega_{S_{ni}}$, and Ψ_{zi} differ considerably across countries. Ranges of three transformation parameters - Λ_{C_i} , $\Omega_{S_{ni}}$, and Ψ_{zi} are $0.00-0.94$, $0.39-0.96$ and $0.42-0.96$, respectively. For two countries, σ^2_{μ} came out to be negative. Since variances are non-negative by definition, we replace them with zeros [Baltagi and Griffin (1988)]. Consequently, the estimated Λ_{C_i} for those countries are set to zero. Wide dispersions of transformation parameters justifies the need for heteroskedasticity corrections.

Total factor productivity growth ($TFPZ$) rates of selected 25 OECD countries are given in Table 2. Decomposition of TC into its source components is given in Table 3. The overall TFP growth ($TFPZ$) rate was positive for all countries. The average annual TFP growth rate over the study period is found to be 5.3%. Compared to the average annual TFP growth rates of total industrial sector (1.2%) and manufacturing sector (2%) of these countries, over the same period of time, performance of the telecommunications sector is remarkable. On the whole, TC is the largest component of $TFPZ$. Among the three constituents of $TFPZ$, TC is found to be most important, contributing 57% of $TFPZ$. The second important factor is $QFAC$, accounting for 33% of $TFPZ$. The remaining 10% is due to $SCLC$. During the study period, 1990-1997, $TFPZ$ increased by 48.5%. Three constituents of $TFPZ$ - TC, $QFAC$, and $SCLC$ - increased by 26.8%, 14.1%, and 4.6%, respectively (see Table 4, Chart 1). Among 25 countries considered in this study, the highest

$TFPZ$ rate is observed for Germany (10.2%), followed by Japan (8.7%), Italy (7.9%), and Spain (7.9%). The largest component of $TFPZ$ of these countries is quasi-fixed factor augmented TFP growth - $QFAC$. All four countries experienced major investments in their telecommunications sector during this period. In the case of Germany, there was a major capital investment during post-reunification years, which contributed to this phenomenal growth of $QFAC$. In Italy and Japan, there was a huge expansion of the mobile telecom sector. In Italy, the mobile penetration rate jumped from 13.8 per 1000 in 1992 to 204.1 per 1000 in 1997.[14] Other European countries like France, Czech Republic, Switzerland, and Turkey also experienced phenomenal (above average) productivity growth during the study period.

Among the components of TC, the pure effect of time (PTC), which shows the effect of changes in all exogenous variables has been favorable for all countries. Over the study period it increased by 5%, with an average growth rate of 0.5% (see Table 5, Chart 2. The scale component of TC (STC) was positive for all counties; with a average growth rate of 0.8% per annum; and it increased by 6.2% over the study period. The non-neutral component (NTC), reflecting the relative effect of factor price changes on TC, is found to be very small but positive for all countries. Capital has the highest impact on TC - the average annual KTC is found to be 1.2%; and it increased by 10%. The contribution of regulatory changes on TC is represented by RTC, which captures the impact of regulatory changes on TC. This has a positive effect on TC for all countries, except for Japan. The average annual contribution of regulatory changes on TC, i.e., RTC is found to be 0.5%; and over the study period it increased by 4.1%.

VII. Conclusion

During the last decade telecommunications industry in the OECD countries has undergone major changes due to liberalization, deregulations, technological inventions/innovations, product diversification, and general economic development. This study analyzes total factor productivity (TFP) growth of the telecom sector in selected OECD countries using a flexible dual cost function. Regulatory changes are included in the cost function to assess its impact on TFP growth. To examine the sources of growth, TFP growth has been decomposed into its constituent elements.

An unbalanced panel data of 25 countries covering the period 1990 - 1997 is used in this study. A system of equations, cost function and its cost share equations, including

[14] In fact the higher cost of joining the fixed networks relative to a mobile subscription caused a substitution effect.

a capital share equation, is estimated using the Iterative Seemingly Unrelated Regression technique. To make corrections for heteroskedasticity and unbalanced nature of the panel an heteroskedasticity corrected error components model is estimated.

Results show that over the 8-year period, the selected OECD countries attained a 48% TFP growth. The main source of this TFP growth is technological change (TC) – contributing almost 57% of the growth. For further investigation, TC component has been decomposed into its five constituent elements. Capital investment has played an important role - almost 40% of technological change was due to capital investment; and 33% of total factor productivity growth was due to capital investment. Regulatory changes, which occurred at different paces in different countries, has a positive impact on total productivity.

Table 1. Parameter Estimates of Error Components Model*

Parameter		Parameter	
α_o	7.0419 (1.3407)	$\gamma_{y_1\tau}$	0.0270 (0.0972)
α_{y_1}	−0.1083 (0.3792)	$\gamma_{y_2\tau}$	−0.2565 (0.1107)
α_{y_2}	0.5364 (0.2886)	$\gamma_{w_l\tau}$	0.0001 (0.0057)
α_{w_l}	0.6585 (0.0954)	$\gamma_{w_l y_1}$	−0.0280 (0.0135)
α_z	−0.0006 (0.0009)	$\gamma_{y_1 z}$	−0.0504 (0.0083)
α_τ	−0.0156 (0.0033)	$\gamma_{y_1 t}$	−0.0626 (0.0132)
α_t	−0.0123 (0.0915)	$\gamma_{y_2 w_l}$	−0.0021 (0.0084)
$\beta_{y_1 y_1}$	0.4214 (0.0615)	$\gamma_{y_2 z}$	0.0055 (0.0103)
$\beta_{y_2 y_2}$	0.1058 (0.0261)	$\gamma_{y_2 t}$	0.0503 (0.0115)
$\beta_{w_l w_l}$	0.0864 (0.0089)	$\gamma_{w_l z}$	0.0002 (0.0003)
β_{zz}	0.0010 (0.0004)	$\gamma_{w_l t}$	0.0080 (0.0028)
β_{tt}	−0.0202 (0.0088)	γ_{zt}	−0.0167 (0.0035)
$\beta_{\tau\tau}$	−1.6031 (0.6082)	$\gamma_{z\tau}$	0.0100 (0.0053)
$\gamma_{y_1 y_2}$	−0.1898 (0.0376)	$\gamma_{t\tau}$	0.1108 (0.0375)

* Asymptotic standard errors in parentheses.

Table 2. Average Annual TFP Growth and Its Components

Country	Years	TFPZ	SCLC	TC	QFAC
Australia	5	3.83	0.23	2.17	1.43
Austria	6	4.36	0.42	2.76	1.18
Belgium	5	3.44	0.31	2.51	0.61
Canada	7	5.13	−0.02	2.08	3.07
CzechRepublic	6	5.47	1.32	3.49	0.67
Denmark	8	3.72	0.40	2.64	0.68
Finland	7	2.68	0.23	1.83	0.62
France	5	7.39	0.20	2.75	4.44
Germany	8	10.22	0.23	3.65	6.33
Greece	8	6.08	1.02	4.28	0.79
Hungary	3	4.18	1.00	2.68	0.50
Iceland	8	4.30	1.33	2.95	0.02
Ireland	6	2.97	0.23	2.53	0.20
Italy	6	7.90	0.19	2.76	4.96
Japan	4	8.71	0.23	2.44	6.04
Luxemburg	8	5.39	1.18	4.13	0.08
Mexico	6	4.68	0.12	2.60	1.96
Netherland	6	4.15	0.41	2.58	1.16
NewZealand	5	2.29	0.19	1.92	0.18
Norway	8	4.06	0.56	2.80	0.70
Portugal	8	6.73	1.05	4.49	1.20
Spain	8	7.91	0.23	3.55	4.14
Switzerland	7	5.50	0.62	3.09	1.80
Turkey	8	5.34	0.56	4.08	0.71
All		5.30	0.53	3.00	1.77

Table 3. Average Annual Technological Change & Its Components

Country	TC	PTC	STC	NTC	KTC	RTC
Australia	2.17	0.30	0.65	0.04	0.99	0.18
Austria	2.76	0.36	0.84	0.03	1.01	0.52
Belgium	2.51	0.31	0.70	0.03	0.96	0.51
Canada	2.08	0.33	0.68	0.03	0.89	0.15
CzechRepublic	3.49	0.64	0.98	0.21	1.35	0.30
Denmark	2.64	0.57	0.55	0.03	1.11	0.39
Finland	1.83	0.35	0.47	0.03	0.82	0.15
France	2.75	0.30	0.82	0.03	1.09	0.51
Germany	3.65	0.61	0.94	0.05	1.48	0.58
Greece	4.28	0.81	1.03	0.09	1.52	0.82
Hungary	2.68	0.26	0.66	0.13	1.06	0.58
Iceland	2.95	0.70	0.54	0.04	0.98	0.70
Ireland	2.53	0.32	0.89	0.04	0.81	0.47
Italy	2.76	0.33	0.82	0.03	1.07	0.50
Japan	2.44	0.27	0.94	0.01	1.21	−0.01
Luxemburg	4.13	0.94	0.89	0.08	1.30	0.92
Mexico	2.60	0.31	0.95	0.06	0.94	0.34
Netherlands	2.58	0.37	0.60	0.03	1.04	0.53
NewZealand	1.92	0.26	0.49	0.04	0.78	0.35
Norway	2.80	0.56	0.53	0.04	1.08	0.59
Portugal	4.49	0.88	1.03	0.10	1.69	0.78
Spain	3.55	0.55	1.20	0.04	1.25	0.50
Switzerland	3.09	0.51	0.70	0.02	1.23	0.62
Turkey	4.08	0.78	1.45	0.25	1.47	0.87
All	3.00	0.52	0.82	0.06	1.16	0.52

Table 4. TFP Growth & Its Components

Year	Total Country	TFPZ	SCLC	TC	QFAC
1990	21	100.00	100.00	100.00	100.00
1991	21	104.18	100.24	102.38	101.56
1992	23	108.87	100.74	104.89	103.14
1993	24	113.21	101.05	107.64	104.63
1994	23	118.91	101.64	110.62	106.40
1995	19	125.44	102.45	114.33	108.50
1996	14	135.78	103.73	119.86	111.15
1997	11	148.48	104.59	126.64	114.12

Table 5. Technological Change & Its Components

Year	TC	PTC	STC	NTC	KTC	RTC
1990	100.00	100.00	100.00	100.00	100.00	100.00
1991	102.38	100.21	100.74	100.04	100.96	100.43
1992	104.89	100.50	101.50	100.08	101.92	100.85
1993	107.64	100.87	102.26	100.14	102.93	101.31
1994	110.62	101.35	103.01	100.20	103.98	101.79
1995	114.33	102.03	103.86	100.27	105.24	102.38
1996	119.77	103.24	104.97	100.38	107.05	103.08
1997	126.78	104.96	106.22	100.54	109.02	104.80

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