Measuring productivity in the telecommunication sector

Peru's experience (OSIPTEL)
February 2007

CONTENTS

BASIC PRINCIPLES

- The maximum level of average price variation applicable for each basket of services for a given period of time is determined (since September 2001).

- 3 baskets of services:

    - Basket C: Installation charge.
    - Basket D: Monthly rental and local call rates.
    - Basket E: Long-distance calls.

- Prices are adjusted upwards to reflect cost increases and downwards to reflect corporate productivity gains.

- The productivity coefficient is set every three years. Tariff adjustments are made every quarter.

IMPLEMENTATION MECHANISM

$$RT_{jn} = \sum \left(alfa_{ijn-1} \cdot \frac{T_{ijn}}{T_{ijn-1}} \right) \leq F_n$$

Cap rate

- RT_{jn} = Cap rate for basket “j” in quarter “n”.
- $alfa_{ijn-1}$ = Weighting factor for service “i” in basket “j” during the quarter n-1, i.e. its income contribution within the basket.
- T_{ijn} = Charge for service “i” in basket “j” in quarter n.
- T_{ijn-1} = Charge for service “i” in basket “j” in quarter n-1.

Control factor

$$F_n = (1 - X) * \frac{IPC_{n-1}}{IPC_{n-2}}$$

$$F_n = (1 + \pi) * (1 - X)$$

Productivity coefficient

PRACTICAL EXAMPLE

- Basket comprising two services (x,y)
- Current price vector (P_x,P_y) = (100,100)
- Annual productivity coefficient (8%)
- Income contribution vector for last quarter (75%,25%)
- Annual inflation (1.9%)

$$F_n = (1+\pi) * (1-X) \Rightarrow F_n = (1+0.00472) * (1-0.0194) = 0.9852$$

$$RT_{jn} = \sum \left(\alpha_{ijn-1} * \frac{T_{ijn}}{T_{ijn-1}} \right) \Rightarrow \left[0.75 * \frac{99}{100} \right] + \left[0.25 * \frac{97.09}{100} \right] = 0.9852$$

1% reduction

2.91% reduction

1.48% reduction

INCENTIVE-BASED REGULATION (1)

- It is the company that benefits from productivity gains in the short term, while in the medium term such gains are passed on to the users through application of the productivity coefficient.
- The regulatory time-lag acts as an incentive for efficient operation of the regulated company (effort to reduce costs). The arrangement does not create perverse effects on capital investment.
- Dynamic efficiency in the industry is promoted since the company has an incentive to adopt technologies that will enable it to operate more efficiently (better service at lower rates).
- The company is free to modify its charges for the different components making up the baskets of products, as long as it remains within the established price caps (commercial flexibility).

INCENTIVE-BASED REGULATION (2)

- The company has an incentive to focus on setting the lowest prices in segments where it faces competition and higher prices in less competitive segments.
- Application of the regulatory mechanism does not guarantee efficiency in terms of cost allocation (cost-oriented prices).
- However, the company may pursue the objective of ensuring that prices reflect its actual costs. It is possible for the company to set high prices in high-cost areas and low prices in lower-cost areas even when it might be socially desirable to maintain some form of geographical subsidies.
- There might be a risk that the regulated company could find it beneficial to cut costs by sacrificing quality of service to some extent (minimum quality standards, adequate checking).

CHANGE IN PRICE LEVEL

- The regulator's primary objective is to simulate competitive conditions in markets which are non-competitive. The price cap mechanism fulfils that objective through the application of existing results for a competitive market.

- In a competitive market in long-term equilibrium, only normal profits accrue, i.e. there is identity between income level and total costs (economic costs)

$$IT = CT \Rightarrow p*Y = w*Z$$

$$\Delta p = \Delta w - [\Delta Y - \Delta Z] \quad \textbf{(1)}$$

Change in prices of inputs (Δw)

Productivity level ($[\Delta Y - \Delta Z]$)

COMPARATIVE EFFICIENCY

- Estimating the "productivity coefficient" entails a comparison between the operator's cost and productivity benchmarks and those of the economy as a whole (or of the industry).

$$\Delta p_E = \Delta w_E - [\Delta Y_E - \Delta Z_E] \quad \textbf{(2)}$$

- From (1) and (2):

$$\Delta p = \Delta p_E - [\Delta w_E - \Delta w] + [\Delta TFP - \Delta TFP_E]$$

Where:

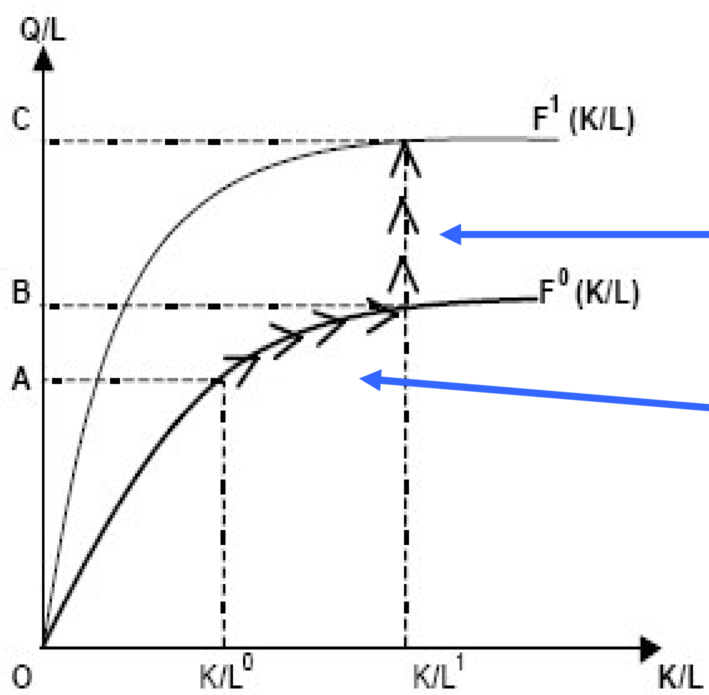
$\Delta Y - \Delta Z = \Delta TFP$

Relative change in costs + **Relative change in productivity**

Productivity coefficient ("X")

GROWTH THEORY (1)

- Economic literature recognizes two main approaches to explaining economic growth. The first of these identifies technological progress as the main engine for long-term growth (Solow, R. 1957).



Increase in labour productivity is "partitioned" into two components:

A component corresponding to technological progress.

A component corresponding to the increase in the ratio K/L on the production function (increased use of inputs).

GROWTH THEORY (2)

- The second approach is called new or endogenous growth theory. It identifies factor accumulation (investment in human capital, knowledge and physical capital) as the main driver of the long-term growth process (Romer, P. 1990).

SOLOW RESIDUAL

- The theoretical debate on which factor is the main driver of economic growth has stretched beyond the confines of theoretical literature and generated a large amount of empirical research.
- "Growth accounting" seeks to explain economic growth through its different components: factor accumulation and technological development.
- Since it is impossible to measure technological progress directly from real data, it is measured indirectly as a "residual", i.e. as the part of growth that cannot be explained by factor accumulation (Solow residual).
- This method has been extended both by Jorgenson and Griliches (1967), to incorporate different types of production factors, and by Hall (1988), to incorporate imperfect competition in the analysis.

MEASUREMENT METHODS (1)

- In the approach developed by Solow, the literature recognizes two measurement methods: the primal method and the dual method.
- The first of these is the most widely used and takes as a starting point the growth rate of actual output and production factors, together with their marginal products.
- The dual approach, by contrast, starts from the growth rate of output price and factor prices, and has recently been used by Hsieh (2002).
- If there is identity between price data and quantity data, then the value obtained with the dual approach will be the same as obtained under the primal approach.

MEASUREMENT METHODS (2)

- A third possible methodology involves the development of econometric models.
- The production function methodology for measuring productivity consists in estimating, by means of econometric techniques, the contribution of each production factor to the output level, and the resulting residual.
- That residual, which is the portion of output that cannot be explained by the contributions of each production factor, is interpreted as a measure of the total factor productivity and constitutes the cornerstone of the methodology.

PRIMAL APPROACH: Basic approach

- The primal approach starts with a standard production function such as:

$$Y = F(A, K, L, M)$$

- Taking logarithms and differentiating the whole with respect to time, it emerges that the total output growth rate can be disaggregated into the respective contributions of (i) technological progress and (ii) factor accumulation:

$$\frac{\dot{Y}}{Y} = \left(\frac{F_A A}{Y}\right)\left(\frac{\dot{A}}{A}\right) + \left(\frac{F_K K}{Y}\right)\left(\frac{\dot{K}}{K}\right) + \left(\frac{F_L L}{Y}\right)\left(\frac{\dot{L}}{L}\right) + \left(\frac{F_M M}{Y}\right)\left(\frac{\dot{M}}{M}\right) \quad \textbf{(3)}$$

PRIMAL APPROACH: Hicks-neutral

- In most cases, it is assumed that technological progress is Hicks-neutral (1932):

$$Y = A\,F(K, L, M)$$

- Equation (3) from the previous slide can then be written as follows:

$$\frac{\dot{Y}}{Y} = \left(\frac{\dot{A}}{A}\right) + \left(\frac{F_K K}{Y}\right)\left(\frac{\dot{K}}{K}\right) + \left(\frac{F_L L}{Y}\right)\left(\frac{\dot{L}}{L}\right) + \left(\frac{F_M M}{Y}\right)\left(\frac{\dot{M}}{M}\right) \qquad \textbf{(4)}$$

- We derive the growth rate of total factor productivity:

$$GTFP = \frac{\dot{Y}}{Y} - \left(\frac{F_K K}{Y}\right)\left(\frac{\dot{K}}{K}\right) - \left(\frac{F_L L}{Y}\right)\left(\frac{\dot{L}}{L}\right) - \left(\frac{F_M M}{Y}\right)\left(\frac{\dot{M}}{M}\right) \qquad \textbf{(5)}$$

PRIMAL APPROACH: Marginal productivities

- The most controversial term is the one relating to marginal productivities of each of the production factors, which are non-observable variables.

- The solution developed by Solow to this data problem is to assume that companies maximize profits in a situation of perfect competition in the factor market: marginal productivities for each factor are equal to the price of each.

$$GTFP = \frac{\dot{Y}}{Y} - \left(\frac{RK}{Y}\right)\left(\frac{\dot{K}}{K}\right) - \left(\frac{WL}{Y}\right)\left(\frac{\dot{L}}{L}\right) - \left(\frac{P_M M}{Y}\right)\left(\frac{\dot{M}}{M}\right)$$

$$GTFP = \frac{\dot{Y}}{Y} - s_K\left(\frac{\dot{K}}{K}\right) - s_L\left(\frac{\dot{L}}{L}\right) - s_M\left(\frac{\dot{M}}{M}\right) \quad \textbf{(6)}$$

PRIMAL APPROACH: Hall's approach

- The company could exert some power in the factor market, such that production factor prices may not be taken as given.

- Hall (1988) shows that, under these conditions, the solution is to weight the growth rate of the various production factors by the respective contributions of their prices to total costs.

$$GTFP = \frac{\dot{Y}}{Y} - \left(\frac{RK}{C}\right)\left(\frac{\dot{K}}{K}\right) - \left(\frac{WL}{C}\right)\left(\frac{\dot{L}}{L}\right) - \left(\frac{P_M M}{C}\right)\left(\frac{\dot{M}}{M}\right)$$

$$\Rightarrow GTFP = \frac{\dot{Y}}{Y} - s_K^{emp}\left(\frac{\dot{K}}{K}\right) - s_L^{emp}\left(\frac{\dot{L}}{L}\right) - s_M^{emp}\left(\frac{\dot{M}}{M}\right) \quad \textbf{(7)}$$

DUAL APPROACH: Basic approach

- The first reference to the dual approach was made by Griliches and Jorgensen (1967). Recent applications by Hsieh (2002).

- The dual approach is based on identity between inputs and the sum of costs and profits.

$$PY = RK + WL + P_M M + \Pi$$

- Differentiating both sides of the equation with respect to time and dividing by the total cost, C = RK + WL+ P_MM:

$$\frac{\dot{Y}}{Y} = \frac{RK}{C}\left(\frac{\dot{K}}{K} + \frac{\dot{R}}{R}\right) + \frac{WL}{C}\left(\frac{\dot{L}}{L} + \frac{\dot{W}}{W}\right) + \frac{P_M M}{C}\left(\frac{\dot{M}}{M} + \frac{\dot{P}_M}{P_M}\right) + \frac{\Pi}{C} . \frac{(\dot{\Pi / PY})}{(\Pi / PY)} - \frac{\dot{P}}{P}$$

DUAL APPROACH: Equivalence

- Placing the terms involving quantity growth rates on the left-hand side of the equation:

$$\frac{\dot{Y}}{Y}-\frac{RK}{C}\frac{\dot{K}}{K}-\frac{WL}{C}\frac{\dot{L}}{L}-\frac{P_M M}{C}\frac{\dot{M}}{M}=\frac{RK}{C}\frac{\dot{R}}{R}+\frac{WL}{C}\frac{\dot{W}}{W}+\frac{P_M M}{C}\frac{\dot{P}_M}{P_M}+\frac{\Pi}{C}\cdot\frac{\dot{\overline{\Pi/PY}}}{\Pi/PY}-\frac{\dot{P}}{P}$$

- The "dual" estimate of the growth in total factor productivity will be a share-weighted growth rate of factor prices, minus the company-wide product price growth rate.

$$GTFP_{Dual}=\frac{RK}{C}\frac{\dot{R}}{R}+\frac{WL}{C}\frac{\dot{W}}{W}+\frac{P_M M}{C}\frac{\dot{P}_M}{P_M}+\frac{\Pi}{C}\cdot\frac{\dot{\overline{\Pi/PY}}}{\Pi/PY}-\frac{\dot{P}}{P} \quad \textbf{(8)}$$

PRIMAL MEASUREMENTS: Relevant variables

- In the conceptual framework developed, there are two problems that have to be resolved in order to utilize the primal equation: (i) How to measure the output growth rate?, (ii) How to measure the factor-use growth rate?
- There are some problems even before measuring the rate of growth of output. The first stems from the fact that many companies do not produce only one product: How can these different products be aggregated into a significant measure of overall actual production?
- In many cases, there are no measures of the company’s output but only measures of income: How then can we obtain a measure of actual output for these products?
- Similar problems arise for estimating factor use.

PRIMAL - OUTPUT: Aggregation

- The growth rate of total output may be calculated as a weighted average of the growth rate of each individual product, with the weighting based on the share of consumer spending on each product.

$$\frac{\dot{Y}}{Y} = \sum_i \left(\frac{y_i \, p_i}{E^Y} \cdot \frac{\dot{y}_i}{y_i} \right) \qquad \textbf{(9)}$$

- It will subsequently be necessary to express the above equation in discrete terms in order to be able to implement the primal approach empirically. This entails employing aggregation indices, more specifically the Fisher index.

PRIMAL - OUTPUT: Quantity indicator (1)

- In some cases, there are no precise data on specific products, whereas a breakdown of income generated is available.
- The growth rate of income levels could be used as a proxy for the output growth rate. Since both quantity and price levels are subject to change, this assumption will result in overestimation.

$$\dot{E}^Y / E^Y = \sum_i \left(\frac{y_i p_i}{E^Y} \right) . [(\dot{y}_i / y_i) + (\dot{p}_i / p_i)]$$

$$Distortion = \sum_i \left(\frac{y_i p_i}{E^Y} \right) . (\dot{p}_i / p_i)$$

PRIMAL - OUTPUT: Quantity indicator (2)

- The methodology applied empirically is the “deflated income” approach. This makes it possible to estimate a price index closely related to the sector concerned and use it as an income deflator in order to estimate quantity indicators:

$$q_{estimated} = \frac{\text{Actual income}}{\text{Price index}}$$

- A more complex solution has been put forward in a work by Levinsohn and Melitz (2001). If it is assumed that the consumer has a CES utility function, it can be shown that the quantity of a product produced is a direct function of the income therefrom:

$$Y = \left(\sum_i y_t^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \Rightarrow \quad y_i = [y_i p_i]^{\frac{\sigma}{\sigma-1}}$$

PRIMAL - OUTPUT: Quantity indicator (3)

- Accordingly, the aggregate output growth rate may be expressed as a function of the growth rate of total spending:

$$(\dot{Y}/Y) = \frac{\sigma}{\sigma - 1}.(\dot{E^{Y}}/E^{Y})$$

Complexity in estimating elasticity of substitution.

PRIMAL - INPUTS: Aggregation

- The growth rate of total labour may be calculated as a weighted average of the growth rate of each type of labour, with the weighting based on the wages of each type of worker as a share of total salary costs.

$$\dot{L}/L = \sum_i \left(\frac{w_i l_i}{E^L} \right) . (\dot{l}_i / l_i)$$

- A similar exercise is conducted for equipment and capital:

$$\dot{M}/M = \sum_i \left(\frac{p_{M_i} m_i}{E^M} \right) . (\dot{m}_i / m_i)$$

$$\dot{K}/K = \sum_i \left(\frac{r_i k_i}{E^K} \right) . (\dot{k}_i / k_i)$$

PRIMAL - INPUTS: Generations of capital

- It is highly probable that, within a given type of capital, different generations will exist. It is considered that the quality of capital of a given generation diminishes at a constant geometrical rate. The quantity of capital at time t is given by:

$$K_t = \sum_i (1-\delta)^{t-i} . I_{t-i}$$

- This methodology, known as the "perpetual inventory" method, is commonly expressed as follows:

$$K_t = (1-\delta) K_{t-1} + I_t$$

- In sum, we need data on the company's past investment and an estimate of the parameter measuring the drop in efficiency, generally equivalent to depreciation rates.

PRIMAL - INPUTS: Economic cost of capital

- The second main problem associated with measurements of the use of capital is that typically we cannot observe the rental price.

- The usual way of dealing with the rental price of capital is to have recourse to the arbitration condition suggested by Christensen and Jorgenson (1969):

$$r_i^1 = \left[\frac{1}{1-tax}\right]\left(WACC p_i^0 + \delta_i p_i^1 - (p_i^1 - p_i^0)\right)$$

Opportunity cost (WACC p_i^0) · **Depreciation cost** ($\delta_i p_i^1$) · **Revaluation level** ($p_i^1 - p_i^0$)

- WACC, and in particular the cost of assets, is estimated using the CAPM method.

DUAL: Relevant variables

- Under this approach, the following information would be necessary for calculating GTFP:
    - o Growth rate of the price of the company's output, and wage growth rate.
    - o Growth rate of the rental price of capital (R).
    - o Growth rate of the price of inputs (PM).
    - o Growth rate of contribution to profits.
    - o Approximate calculation of contribution to total cost of labour, capital and profits.

DUAL – PRICE OF OUTPUT: Growth

- In line with the conceptual framework developed, the total output price is to be defined as the weighted average of the price of each individual product of the company, where the weighting is based on each product's contribution to total spending.

$$\frac{\dot{P}}{P} = \sum_i \left(\frac{y_i \, p_i}{E^Y} \cdot \frac{\dot{p}_i}{p_i} \right)$$

Contribution to total cost

DUAL – PRICE OF INPUTS: Growth

- As indicated, a second parameter required to implement the dual approach is approximate calculations of the rate of growth of factor prices.
- The method for aggregating wages, the rental price and the price of equipment is exactly the same as for calculating capital stock, actual labour force and total quantity of equipment under the primal approach (average rates).

$$\frac{\dot{K}}{K} = \sum_i \left(\frac{r_i k_i}{E^K} \cdot \frac{\dot{r}_i}{r_i} \right)$$

$$\frac{\dot{W}}{W} = \sum_i \left(\frac{w_i l_i}{E^W} \cdot \frac{\dot{w}_i}{w_i} \right)$$

$$\dot{P}_M / P_M = \sum_i \left(\frac{p_{M_i} m_i}{E^M} \right) . (\dot{p}_M / p_{M_i})$$

DISCRETE ANALYSIS: Indices

- Insofar as the physical production of each service will vary independently and separately from that of all the others, it is necessary to use some kind of technique to aggregate these changes into a discrete indicator of the overall change in quantity of services produced.
- The same idea applies to the change in physical units of inputs used, and can also be extended to changes in the prices of end services and changes in the prices of inputs. This will be achieved using “indices”.
- There are several indices that may be used to carry out the different quantity and price aggregations. The most commonly used indices for productivity studies are basically the Fisher index and theTornqvist-Theil index.

DISCRETE ANALYSIS: Fisher index

- Fisher indices are defined as the geometric mean of the Laspeyres index and the Paasche index.

Fisher quantity index

$$IQ_{Fisher} = \sqrt{IQ_{Lasp} * IQ_{Paas.}}$$

$$IQ_{Lasp.} = \frac{\sum_{j=1}^{m} P_{jt-1} * y_{jt}}{\sum_{j=1}^{m} P_{jt-1} * y_{jt-1}}$$

$$IQ_{Paas.} = \frac{\sum_{j=1}^{m} P_{jt} * y_{jt}}{\sum_{j=1}^{m} P_{jt} * y_{jt-1}}$$

DISCRETE ANALYSIS: Tornqvist-Theil index

- The Tornqvist-Theil index is defined such that its application directly yields a logarithmic rate of change reflecting the approximate change in discrete variables.

Quantity index (Output)

$$\sum_{i=1}^{n} s_i \ln\left(\frac{y_i^1}{y_i^0}\right)$$

$$\Downarrow$$

$$s_i = \frac{1}{2}\left(\frac{p^1 y^1}{R^1} + \frac{p^0 y^0}{R^0}\right)$$

Quantity index (Inputs)

$$\sum_{j=1}^{m} s_j \ln\left(\frac{z_j^1}{z_j^0}\right)$$

$$\Downarrow$$

$$s_j = \frac{1}{2}\left(\frac{w^1 z^1}{c^1} + \frac{w^0 z^0}{c^0}\right)$$

DISCRETE ANALYSIS: Estimation

- With available data on quantities and income, it is possible to estimate the Fisher index. The income is defined for a base period:

$$Ijt^{95} = \frac{I_{j95}}{q_{j95}} * q_{jt} = \frac{P_{j95} * q_{j95}}{q_{j95}} * q_{jt} = P_{j95} * q_{jt}$$

- The price index of the service "j" in the period "t" is therefore:

$$IP_{jt} = \frac{I_{jt}}{I_{jt}^{95}} = \frac{P_{jt} * q_{jt}}{P_{j95} * q_{jt}} = \frac{P_{jt}}{P_{j95}}$$

$$IQLasp. = \frac{\sum_{j=1}^{m} Ipjt-1 * Ijt^{95}}{\sum_{j=1}^{m} Ipjt-1 * Ijt-1^{95}}$$

$$IQ_{Paas.} = \frac{\sum_{j=1}^{m} I_{pjt} * I_{jt}^{95}}{\sum_{j=1}^{m} I_{pjt} * I_{jt-1}^{95}}$$

COMPANY ΔY ESTIMATE: Output (1)

1. Income data is recorded:

Category of service	1998	1999	2000	2000 PF	2001	2001 PF	2002	2003
Basic monthly rental	691.420	782.120	877.999	877.846	895.920	895.920	860.937	871.745
Metered local service	558.003	691.211	770.543	770.400	677.405	677.405	699.178	677.509
Local - other	80.738	81.162	69.025	69.023	76.214	76.214	92.678	98.440
Installation	130.337	19.976	13.949	13.949	13.856	13.856	20.254	20.639
National long-distance	348.136	292.309	303.653	303.601	297.541	297.541	247.912	192.603
International long-distance	506.753	472.811	348.302	348.302	298.744	298.744	153.671	104.794
Public telephones	432.874	561.553	658.318	658.203	679.343	679.343	739.924	695.287
Mobile service	633.290	779.750	785.559					
Cable TV	172.269	199.266	248.400	248.357	270.300	270.300	291.973	316.835
Business communications	180.056	226.145	278.320	212.201	195.495	195.495	197.956	264.484
Directory services	106.431	110.464	96.432	96.432	87.920			
Other	14.044	29.709	70.786	103.771	101.534	96.354	125.164	170.665
Total operating income	**3.854.350**	**4.246.475**	**4.521.285**	**3.702.085**	**3.594.271**	**3.501.171**	**3.429.647**	**3.413.001**

Notes:

(1) Historical values are estimated by adjusting the income values using a factor based on the wholesale price index (IPM)

(2) PF – Pro forma information

Source: Telefónica del Perú S.A.A.

COMPANY ΔY ESTIMATE: Output (2)

2. Data on quantities is recorded:

Service	1998	1999	2000	2000 PF	2001	2001 PF	2002	2003
Basic monthly rental	1.555.093	1.688.619	1.717.117	1.717.117	1.722.462	1.722.462	1.815.139	1.968.879
Metered local service	7.696.254	8.466.443	8.469.242	8.469.242	9.812.226	9.812.226	9.528.457	9.197.045
Local - other	1.555.093	1.688.619	1.717.117	1.717.117	1.722.462	1.722.462	1.815.139	1.968.879
Installation	240.800	255.473	171.987	171.987	180.124	180.124	248.690	325.734
National long-distance	652.607	611.824	566.894	566.894	500.392	500.392	444.122	346.181
International long-distance	363.709	399.043	395.690	395.690	484.905	484.905	429.128	566.943
Public telephones	1.319.244	1.556.906	1.970.674	1.970.674	1.621.850	1.621.850	1.673.669	1.740.095
Mobile service	504.995	712.117	898.173					
Cable TV	305.200	327.344	349.447	349.447	341.720	341.720	340.001	363.088
Business communications (1)	180.056	236.035	299.414	217.992	205.770	206.020	215.320	309.079
Directory services (1)	73.745	73.973	62.238	62.238	55.642			
Other (1)	14.044	31.008	76.150	106.603	106.870	101.542	136.143	199.441

Notes:

(1) Estimates.

(2) PF – Pro forma information

Source: Telefónica del Perú S.A.A., except last three lines which are OSIPTEL estimates

Estimated for deflated income

COMPANY ΔY ESTIMATE: Output (3)

3. The Fisher index is estimated as follows:

$$Q^{F}_{t,t-1}=\left[\frac{\sum_{i=1}^{N}\frac{I_{it-1}}{I^{98}_{it-1}}*I^{98}_{it}}{\sum_{i=1}^{N}\frac{I_{it-1}}{I^{98}_{it-1}}*I^{98}_{t-1}}*\frac{\sum_{i=1}^{N}\frac{I_{it}}{I^{98}_{it}}*I^{98}_{it}}{\sum_{i=1}^{N}\frac{I_{it}}{I^{98}_{it}}*I^{98}_{it-1}}\right]^{1/2}$$

Item		1999	2000	2001	2002	2003
Laspeyres index (by period) (a)		1,1508	1,1026	1,0067	1,0092	1,0732
Paasche index (by period) (b)		1,1491	1,0922	0,9830	1,0130	1,0650
Fisher index (by period) (c) = [(a)x(b)]$^{1/2}$		**1,1499**	**1,0974**	**0,9948**	**1,0111**	**1,0691**
Growth rate [ln(c)] (1)		**13,97%**	**9,29%**	**-0,52%**	**1,10%**	**6,68%**
Simple 5-year average (1999-2003)					**96-2003**	**6,10%**

Notes:

(1) Logarithmic growth rate

COMPANY ΔZ ESTIMATE: Inputs (1)

1. Economic cost by type of input:

	1998	1999	2000	2000 PF	2001	2001 PF	2002	2003
Labour	499.901	562.775	537.257	425.948	467.589	458.243	414.354	421.399
Equipment and services	1.319.402	1.191.072	1.336.744	1.132.693	1.141.084	1.106.700	1.078.276	1.125.906
Capital								
Land	13.225	15.215	17.138	15.467	19.074	19.042	12.685	10.440
Buildings	59.708	76.526	93.333	90.814	101.511	101.337	76.141	63.666
Telephone plant								
Switching equipment	462.122	565.710	648.701	395.632	377.143	376.498	295.096	285.121
Transmission equipment	184.096	248.730	293.673	296.865	296.381	295.874	241.544	224.261
Cable and similar	515.744	584.728	613.863	604.771	601.471	600.441	470.900	419.953
Other equipment	130.281	191.950	234.923	217.283	223.859	232.034	205.540	189.406
Furniture	4.026	7.303	8.660	8.651	8.917	8.884	5.558	4.297
Vehicles	1.810	1.689	1.755	1.830	2.034	2.031	1.806	1.216
Other equipment	37.487	63.785	109.781	132.944	130.627	130.060	96.790	62.980

COMPANY ΔZ ESTIMATE: Inputs (2)

2. Level of use by type of input:

	1998	1999	2000	2000 PF	2001	2001 PF	2002	2003
Labour	4.535	4.643	4.461	3.935	3.966	3.805	4.315	4.488
Equipment and services	925.554	804.292	871.167	738.185	734.391	712.262	690.139	700.664
Capital								
Land	100.780	105.167	107.119	96.567	99.710	99.710	102.865	100.880
Buildings	296.776	355.311	401.982	390.688	394.038	394.038	395.314	363.539
Telephone plant								
Switching equipment	1.299.212	1.522.692	1.656.454	1.009.105	933.343	933.343	853.777	855.325
Transmission equipment	517.569	669.494	749.893	757.187	733.475	733.475	698.837	672.753
Cables and similar	1.449.966	1.573.883	1.567.496	1.542.537	1.488.502	1.488.502	1.362.414	1.259.803
Other equipment	366.271	516.663	599.874	554.204	553.999	575.216	594.672	568.192
Furniture	8.213	14.393	16.329	16.294	16.776	16.743	11.608	9.123
Vehicles	3.818	3.438	3.415	3.556	3.939	3.939	3.900	2.674
Other equipment	59.472	98.270	162.630	196.722	196.601	196.084	156.706	102.475

COMPANY ΔZ ESTIMATE: Inputs (3)

3. The Fisher index is estimated as follows:

$$Z_{t,t-1}^{F} = \left[\frac{\sum_{j=1}^{M} \frac{C_{jt-1}}{C_{jt-1}^{98}} * C_{jt}^{98}}{\sum_{j=1}^{M} \frac{C_{jt-1}}{C_{jt-1}^{98}} * C_{j-1}^{98}} * \frac{\sum_{j=1}^{M} \frac{C_{jt}}{C_{jt}^{98}} * C_{jt}^{98}}{\sum_{j=1}^{M} \frac{C_{jt}}{C_{jt}^{98}} * C_{jt-1}^{98}} \right]^{1/2}$$

Item	1999	2000	2001	2002	2003
Laspeyres index (by period) (a)	1,0340	1,0679	0,9816	0,9730	0,9788
Paasche index (by period) (b)	1,0343	1,0687	0,9818	0,9705	0,9795
Fisher index (by period) (c) = [(a)x(b)] $^{1/2}$	**1,0342**	**1,0683**	**0,9817**	**0,9717**	**0,9791**
Growth rate [ln(c)] (1)	**3,36%**	**6,60%**	**-1,85%**	**-2,87%**	**-2,11%**
Simple 5-year average (1999-2003)				**96-2003**	**0,63%**

COMPANY ΔZ ESTIMATE:
Inputs - Capital (1)

1. The accounting value of capital stock at time t (by type of activity) $= V_{kj,t}^{Acc.}$

Asset		1997	1998	1999	2000	2000 PF	2001	2001 PF	2002	2003
Land		125.404	139.561	153.376	158.650	143.298	149.289	149.290	151.819	148.852
Buildings		337.203	445.140	546.002	626.064	579.750	576.801	576.801	580.325	502.536
Telephone plant										
	Exchanges	1.420.187	2.008.342	2.233.695	2.596.679	1.497.430	1.244.763	1.244.763	1.254.348	1.295.605
	Transmission	558.303	808.008	1.061.233	1.123.604	1.123.604	1.030.209	1.030.209	1.015.184	989.898
	Cable & access	1.711.014	2.107.185	2.275.745	2.289.001	2.289.001	2.082.102	2.082.102	1.904.253	1.850.420
	Other equipment	366.254	602.518	841.169	906.882	822.395	803.822	865.412	875.293	817.797
Furniture		4.735	17.214	22.981	24.600	24.180	25.049	24.954	8.891	18.397
Vehicles		5.059	4.958	4.597	5.361	5.277	6.274	6.273	5.134	2.813
Other equipment		51.933	105.855	169.214	306.952	291.920	285.187	283.685	174.089	130.938
Total		**4.580.092**	**6.238.782**	**7.308.012**	**8.037.793**	**6.776.855**	**6.203.496**	**6.263.489**	**5.969.336**	**5.757.256**

COMPANY ΔZ ESTIMATE: Inputs - Capital (2)

2. The actual depreciation rates for each period have to be estimated, for use as intermediate variables. This is done by dividing the accounting cost in terms of depreciation by the average accounting value of fixed assets.

- Accounting cost in terms of depreciation = $G_{kj,t}^{Depreciation}$
- Mean accounting value of capital stock = $V_{kj,t}^{Av.acc.} = \dfrac{V_{Kj,t}^{Acc.} + V_{Kj,t-1}^{Acc.}}{2}$
- Estimated rates = $\delta_{kj,t} = \dfrac{G_{kj,t}^{Depreciation}}{V_{kj,t}^{Av.acc.}} = \dfrac{G_{kj,t}^{Depreciation}}{\left[V_{kj,t}^{Acc.} + V_{kj,t-1}^{Acc.}\right]/2}$

COMPANY ΔZ ESTIMATE: Inputs - Capital (3)

3. The physical units by type of asset are estimated, deflating the accounting value for each type of asset by the purchase price.

Physical units of capital = $$K_{jt} = \frac{V^{Acc.}_{kj,t}}{P_t}$$

→ The purchase price index is taken as the average period-end IPM.

4. The average capital stock is estimated per year.

Average capital stock = $$\overline{K}_{j,t} = \frac{K_{j,t} + K_{j,t-1}}{2}$$

5. The value of economic depreciation by type of asset is estimated.

Economic depreciation = $$V_{depre.t} = \sum_{j=1}^{9} \overline{K}_{j,t} * P_t * \delta_{kj,t}$$

COMPANY ΔZ ESTIMATE: Inputs - Capital (4)

6. Asset revaluation levels are estimated. These are obtained by multiplying the average number of physical units of capital by the recorded variation in the purchase price.

Economic revaluation = $$V_{revalt} = \sum_{j=1}^{9} \overline{K}_{j,t} * [P_t - P_{t-1}]$$

7. The value of the opportunity cost of capital is estimated for each period. This is obtained by multiplying the opportunity cost of capital (WACC) by the economic value of capital stock at previous-period prices.

Opportunity cost = $$COP_t = \sum_{j=1}^{9} \left[\overline{K}_{j,t} * P_{t-1}\right] * WACC_t$$

COMPANY ΔZ ESTIMATE: Inputs - Capital (5)

8. Having estimated the economic opportunity cost, and the economic cost in terms of depreciation and revaluation, and having identified the accounting cost in terms of income tax payment, we estimate the "total economic cost of capital" as follows.

$$CTC_t = COP_t + V_{depre.t} - V_{reval.t} + IR_t$$

9. Using that estimate, we also estimate the economic rate actually paid by way of income tax.

Opportunity cost =

$$t_e = \frac{IR_t}{CTC_t}$$

COMPANY ΔZ ESTIMATE: Inputs - Capital (6)

10. Below, we estimate the economic cost of capital by type of asset.

$$W_{kj,t} = \frac{1}{1-t_e}\left[COP_{kj,t} + V_{deprekj,t} - V_{revalkj,t}\right]$$

Item	1998	1999	2000	2000 PF	2001	2001 PF	2002	2003
Unit cost by type of asset								
Land	13.225	15.215	17.138	15.467	19.074	19.042	12.685	10.440
Buildings	59.708	76.526	93.333	90.814	101.511	101.337	76.141	63.666
Telephone plant								
Exchanges	462.122	565.710	648.701	395.632	377.143	376.498	295.096	285.121
Transmission	184.096	248.730	293.673	296.865	296.381	295.874	241.544	224.261
Cables & access	515.744	584.728	613.863	604.771	601.471	600.441	470.900	419.953
Other equipment	130.281	191.950	234.923	217.283	223.859	232.034	205.540	189.406
Furniture	4.026	7.303	8.660	8.651	8.917	8.884	5.558	4.297
Vehicles	1.810	1.689	1.755	1.830	2.034	2.031	1.806	1.216
Other equipment	37.487	63.785	109.781	132.944	130.627	130.060	96.790	62.980
Total cost of capital	**1.408.500**	**1.755.634**	**2.021.827**	**1.764.257**	**1.761.016**	**1.766.200**	**1.406.061**	**1.261.339**

COMPANY ΔTFP ESTIMATE:

Company productivity:

$$\Delta TFP = \Delta Y - \Delta Z = 6.10\% - 0.63\% = 5.47\%$$

COMPANY ΔW ESTIMATE: Price of inputs

1. On the basis of the data on total costs and quantities used, we derive an estimate of the Fisher price index.

$$W_{t,t-1}^{F} = \left[\frac{\sum_{j=1}^{M} \frac{C_{jt}}{C_{jt}^{98}} * C_{jt-1}^{98}}{\sum_{j=1}^{M} \frac{C_{jt-1}}{C_{jt-1}^{98}} * C_{j-1}^{98}} * \frac{\sum_{j=1}^{M} \frac{C_{jt}}{C_{jt}^{98}} * C_{jt}^{98}}{\sum_{j=1}^{M} \frac{C_{jt-1}}{C_{jt-1}^{98}} * C_{jt}^{98}} \right]^{1/2}$$

Item	1999	2000	2001	2002	2003
Laspeyres index (by period) (a)	1,0512	1,0388	1,0329	0,8966	0,9892
Paasche index (by period) (b)	1,0515	1,0395	1,0331	0,8944	0,9900
Fisher index (by period) (c) = $[(a)x(b)]^{1/2}$	**1,0513**	**1,0392**	**1,0330**	**0,8955**	**0,9896**
Growth rate [ln(c)] (1)	**5,01%**	**3,84%**	**3,25%**	**-11,04%**	**-1,05%**
Simple 5-year average				**99-2003**	**0,00%**

ECONOMY-WIDE ΔTFP ESTIMATE:

1. The table below shows the estimates resulting from several studies. Here, OSIPTEL opted for the most conservative result, i.e. a productivity rate for the economy of 0.5%.

Years	Vega Centeno 1997	Seminario y Beltrán 1998	Vallejos y Valdivia 1999	Hofman 2000	Valderrama, et. al. 2003	Carranza, et. al. 2003	Miller 2003
1950-59	1.1	1.0	2.7	1.9	2.0	1.8	aprox. 1.5
1960-69	1.3	2.5	1.7		1.7	1.7	aprox. 1.5
1970-75	-0.6	1.8	-0.6		-0.5	-0.5	aprox. -0.1
1976-80	-1.0	-1.3					
1981-85	-1.4	-3.6	-4.0	--	-3.9	-3.5	-2.8
1986-90	-3.4	-3.7					
1991-95	-0.4	3.4			--	--	--
1991-99	**--**	**--**	**1.8**	**2.0**	**0.7**	**1.1**	**0.5**

ECONOMY-WIDE ΔW ESTIMATE: Price of inputs

1. This variable is determined from the equation:

$$\Delta W_E = \Delta P_E + \Delta TFP_E.$$

Growth rate of price of inputs for the economy $\Delta W^E = \Delta P^E + \Delta T^E$	Growth rate of consumer price index ΔP^E	Growth rate of TFP for the economy ΔT^E
2.83%	2.33%	0.5%

PRODUCTIVITY COEFFICIENT: Results

Company productivity:

$$\Delta TFP - \Delta TFP_E = 5.47\% - 0.50\% = 4.97\%$$

$$\Delta W - \Delta W_E = 2.83\% - 0.00\% = 2.83\%$$

$$x = 7.8\%$$

REFINEMENTS: Economic surplus

- "The aim is to recognize the average impact of competitive pressures in the different telecommunication markets on aggregate profit of the industry as from opening of the market, by estimating the rate of change of the economic operating surplus.
- The baseline equation was modified to introduce the economic surplus variable. Thus, the equation for the estimate for 2004 in respect of basket D was:

$$X = (\Delta TFP - \Delta TFP_E) + (\Delta W_E - \Delta W) + (\Delta M - \Delta M^{ind})$$

- Where:

$$\Delta M = \Delta \mathrm{Ln(R)} - \Delta \mathrm{Ln(C)}$$

THANK YOU