Iranian Economic Review, Vol. 4, No. 4, 2000

Productivity Performance of The Iranian Electric Power Industry

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ABSTRACT

This paper is concerned with the estimation of total factor productivity (TFP) growth for the Iranian electric utilities during the period 1980-1993 on the basis of panel data. A translog cost function is used which accommodates firm - specific variability through a one - way error component model. The results show that the Iranian electricity supply industry experienced increasing returns to scale (IRS) during the period 1980-93, a high rate of technical change and total factor productivity growth during this period. Factor bias of technical change shows that the electricity supply industry has been labor and fuel saving.

INTRODUCTION

The analysis of cost structure and total factor productivity (TFP) growth are two basic subjects in the economic literature. The measurements of total factor productivity (TFP) growth and technical change in the electricity supply industry - as one of the major components of the energy sector - has attracted of many empirical researchers. It is essential for governments to know whether the electricity supply industry is developing in a satisfactory

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way so that consumers can obtain reliable electricity supply at affordable prices. These issues are even more critical in developing countries, because several of these countries have big problems in expanding electricity supply to keep pace with rapid expansion of demand. This also holds for the Iranian electricity supply industry, which is investigated here.

This paper analyzes the cost structure and total factor productivity growth of the Iranian electricity supply industry during the period 1980-93, applying a parametric approach and using econometric estimation of a translog cost function associated with input cost shares equations. The translog function, applied to electric utilities, has been used by for example, Christensen and Greene (1976), Nelson and Wohar (1983), Kumbhakar (1994), Nemoto et al., (1993), Bhattacharyya et al., (1997) in order to estimate returns to scale and TFP growth at both firm and industry levels. The reason why it has been used so much in empirical studies is because the translog is a flexible and general functional form which, does not impose any a priori restrictions on elasticity of scale and elasticities of substitution.

Data was collected for a panel consisting of twelve major Iranian electric utilities. While most studies of productivity have been based on time-series data, there is an emerging set of empirical applications based on balanced or imbalanced panel data, which provides a much more detailed evaluation of the relative performance of micro units, linking efficiency to productivity growth and technical change (Hsiao, 1986; Baltagi, 1995). For applications illustrating benefits of panel data, see e.g. Kumbhakar, and Hjalmarsson (1998).

The paper is organized as follows: The next section describes the industry structure, the third section explains the econometric model, including technical change, economies of scale, and TFP growth. The fourth section includes the estimation procedure. Description of data is presented in Section 5, while the sixth section includes the empirical results and their interpretations. Section 7 summarizes and draws conclusions.

2. THE INDUSTRY STRUCTURE

After construction of new thermal power plants as well as development of hydroelectric dams the nominal capacity of the country's power plants noticeably increased arriving at 7,921 MW by the time of the Islamic Revolution (1979), and at 18,212 MW by the year 1993. The installed capacity (nominal & actual) is shown in Figure 1. According to a schedule, construction of a number of hydro, steam, combined cycle and gas operated power plants is presently underway and are expected to come into full operation by the end of the year 1999. In addition to the above technologies, one nuclear site with 1,000 MW capacity is assumed to operate by 2003.

Per-capita power generation has increased with a pattern of growth equal to that of population growth, and has arrived at a rate of 376 W per head thus keeping up with the population growth rate. The existing power plants throughout the country have been configurated with regard to their role in generation of base load, medium load, peak load as well as output, loading speed and stabilization of the network in a way that the share of thermal power plants (including 52.2% for steam power plants, 21.2% for gas turbine, 11.4% for combined cycle plants, and 4.5% for diesel powerhouses) in 1993 has come to a total of 89.3% and the share of hydro power plants has arrived at the figure of 10.7%.

The above configuration clearly shows the impact of thermal power plants, especially steam power plants in generating the base load. Iran is considering an increase of 2,790 MW to the nominal capacity of hydro power plants by way of promoting the use of water power, as a result of which the share of the hydro power plants would be increased from 10.7% to 14.8%. This shows that thermal power plants will continue to provide the base load. Despite the fact that hydro power potentials of the Karun river alone has been estimated to be up to 16 GW which can greatly affect the structure of power plants, it should however be noted that the main drawback to implement the needed projects has been the enormity of the investments required to construct such huge installations and establishments.

In 1993 Iran's power plants, including those under the control of MOE and other organizations generated 76 TWh of energy, showing an increase of 10.8%. Out of the mentioned generated power, the share of MOE was 73.3 TWh with a growth rate of 11%. The above increase in power generation is due to the introduction of new power plants, extending the existing ones, and improving the optimal operation of plants. Keeping this in mind, the per-capital energy generation index provides a realistic picture of power generation capabilities and valuable information about the objectives. The per-capita power generation has been increased from 545 KWh in 1978 to 1,306 KWh in 1993. Although there has been a large population growth between 1978 and 1993, per-capita energy generation during these years has arrived to 2.4 fold of that of 1978 with an average annual growth rate of 6%, showing tremendous effort on the part of the personnel who were involved in the power generation industry.

Hydro power plants, with an efficiency of 85 to 90% are the most ideal form of generating power in the country. However, factors such as limited water resources, huge investment volumes and the long period of time involved in construction of dam and hydro power plants, and also availability of abundant fossil fuels, has strongly advocated the construction and operation of thermal power plants. Depending on their capacity, design and type the thermal power plants have different efficiencies, varying from 30-40% for steam, 20-33% for gas turbines and 32-47% for diesel. In 1993, the average efficiency of thermal power plants has arrived at 31.8%, showing an increase of 7.1% versus 1992, due to advanced technology. On the other hand, a umber of combined cycle power plants were also put in to operation in 1993, the final efficiency of which would be 43 to 50 percent. Since the gas turbines of these plants have only been operated, the total efficiency of plants in 1993 has not changed much. Figure 2 provides a picture of the increasing trend of the average efficiency changes for thermal plants during 1967 to 1993. It shows an increasing trend of average efficiency from 1979 onward, which has arrived at 32% in 1993.

2. THE ECONOMETRIC MODEL

2.1. The translog cost function

To set up the econometric model, the assumptions are as follows:

1. All electric utilities are publicly owned and not allowed to choose the level of production to maximize profits. They are required to supply all the electric power, which is demanded at regulated prices. The specification is thus that input levels are endogenous where as output level and prices are exogenous variables, and the objective is cost minimization. The cost function has as its arguments the level of output and factor prices. For studying the structure of production is the Iranian electric power industry, estimation of the cost function is more attractive than direct estimation of the production function.

2. The Iranian electric utilities are public utilities and therefore regulated firms. Interest payment information and allowed rate of return were not available, since most of the firms didn't have any interest payments within the period 1980-93. On the other hand, the management system was full hierarchy, so it was not possible to estimate a regulated translog cost function.

3. The translog cost function associated with cost share equations is used. These equations place no *a priori* restrictions on substitution possibilities among the factors of production. Equally important, it allows scale economies to vary with the level of output. This feature is essential to enable the unit cost curve to attain the classical U-shape. The translog function also approximates a wide variety of functional forms. The optimal

procedure, is to jointly estimate the cost function and the cost share equations as a multivariate regression system. Including the cost share equations in the estimation procedure has the effect of adding additional degrees of freedom without adding any unrestricted regression coefficients. This results in more efficient parameter estimates that would be obtained by applying OLS to the cost function alone (Christensen and Greene, 1976).

4. In the panel data literature estimation of error component models has dveloped in two directions: One is the fixed effects (FE) model and the other is the random effects (RE) model. In the FE model the firm-specific effects are assumed to be fixed parameters to be estimated. I apply the FE model here because this is an appropriate specification if we are focusing on a specific set of "N" firms and our inference is restricted to the behavior of this set firms (Hsiao, 1986 and Baltagi, 1995). In this paper, we study the cost structure of 12 regional electric utilities, which mostly utilize thermal power plants, one of them also has some hydroelectric capacity.

The production function is specified as

$$Y=F(X_1,X_2,\ldots,X_{k,t}) \tag{1}$$

where Y denotes output, X is a vector of k inputs, t is the time trend variable and F(.) represents the technology. Producers are assumed to have a cost minimization behavior, with the level of output Y and the factor prices $P_1,P_2,\ldots,P_k$ are given. The conditional input demand functions can be written as

$$X_j=G_j(P_1,P_2,\ldots,P_k,Y,t) \qquad j=1,2,\ldots,k \tag{2}$$

The minimum cost to produce Y are then given by

$$C=\sum_{j=1}^{k} P_j X_j = H(P_1,P_2,\ldots,P_k,Y,t) \tag{3}$$

According to the dual approach, a parametric form of the cost function is specified in (3), so the translog cost function can be expressed as

$$\begin{aligned} \operatorname{Ln} C_{it} &= b_0+\sum_{j=1}^{k} b_j \operatorname{Ln} P_{jit} + b_y \operatorname{Ln} Y_{it} + b_t t \\ &+\frac{1}{2}\left\{\sum_{j=1}^{k}\sum_{k=1}^{k} b_{jk} \operatorname{Ln} P_{jit} \operatorname{Ln} P_{kit} + b_{yy} \operatorname{Ln} Y_{it}^2 + b_{tt} t^2\right\} \qquad (4) \\ &+\sum_{j=1}^{k} b_{jy} \operatorname{Ln} P_{jit} \operatorname{Ln} Y_{it} + \sum_{j=1}^{k} b_{jt} \operatorname{Ln} P_{jit}\, t + b_{yt} \operatorname{Ln} Y_{it}\, t + U_{it} \end{aligned}$$

where the subscripts i=1,...,N indexes the number of firms (electric utilities) and t=1,...,T donotes the time period the ith firms is observed. C_{it} is the total cost, which is a function of the input prices (P_i), the level of output (Y), and time (t). The time trend t in the cost function represents shifts in the production technology. $U_{it}, (U_{it} = \mu_i + v_{it})$ is the stochastic error term which is composed of firm-specific effects (μ_i)[1] and a white-noise component (v_{it}). The symmetry restriction $b_{jk} = b_{kj}$ is imposed on the model and, to insure linear homogeneity of the cost function is prices, the following restrictions are imposed on its parameters

$$\sum_{j=1}^{k} b_j = 1, \ \sum_{j=1}^{k} b_{jk} = 0, \forall k \ \sum_{j=1}^{k} b_{jk} = 0 \text{ and } \sum_{j=1}^{k} b_{jt} = 0 \quad , \quad b_0=0$$

Using Shepard's lemma, the cost share equation for imput j (S_{jit}) can be expressed as

$$S_{jit} = \partial \, \text{Ln}\, C_{it} / \partial \text{Ln}\, P_{jit} = b_j + \sum_{j=1}^{k} b_{jk} \, \text{LnP}_{kit} + b_{jy} \, \text{LnY}_{it} + b_{jt} t + \eta_{jit} \qquad (5)$$

where η_{jit} is the error term associated with the jth share equation. The translog cost function (4) and the k-1 cost share equations (5) form the seemingly unrelated regression (SUR) model. The present model has cross-equation restrictions on the parameters and some structures are imposed on the variances of the error term in the cost function. The model utilizes a one-way error component model for the disturbances, which means that we assume only unobservable firm-specific effects. In the FE model the firm-specific effects, μ_i, are assumed to be fixed parameters to be estimated and the remainder disturbances stochastic with v_{it} independent and identically distributed, $v_{it} \sim \text{IID}(0, \sigma_v^2)$. The X_{it} (explanatory variables) are assumed independent of the v_{it} for all i and t. In this paper, we assume a fixed effects model and time-specific effects are replaced with a time trend.

2.2. Technical change and economies of scale

Technical change is defined as the rate of cost diminution over time, *ceteris paribus*, $\dot{T}$, can be obtained as

$$T = \partial \, \text{Ln}\, C_{it} / \partial t = b_t + b_{tt} t + \sum_{j=1}^{k} b_{jt} \, \text{Ln}\, P_{jit} + b_{yt} \, \text{Ln}\, Y_{it} \qquad (6)$$

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[1] *Firm-specific effects is written as* $(\mu_i = \sum_{i=1}^{N} b_i D_i)$ *where* D_i *is the firm dummy variables.*

Technical progress (regress) will be represented by a negative (positive) value of $\frac{\partial \mathrm{Ln}\, C_{it}}{\partial t}$ Technical change can be decomposed into three sepatate components: 1) pure technical change ($b_t + b_{tt}t$), which represents the effect of advancement of knowledge as such (since time is taken as an indicator of knowledge, this component is measured solely by terms containing t). 2) non-neutral technical change ($\sum_j b_{jt} \mathrm{Ln}\, P_{jit}$), which shows the effect of input price changes (and resulting substitution) on cost. 3) scale augmenting technical change ($b_{yt} \mathrm{Ln}\, Y_{it}$), which represents the part of cost change that can be attributed to changes in output, through exploitation of economies of scale.

One can also compute the elasticity of total cost with respect to output, cost elasticity for short (ε_{cy}). Cost elasticity is the inverse of the elasticity of scale of the production function, i.e., the inverse of elasticity of output with respect to a proportional change in all inputs, and can be expressed as

$$\varepsilon_{cy} = \partial \mathrm{Ln}\, C_{it} / \partial \mathrm{Ln}\, Y_{it} = b_y + b_{yy} Y_{it} + \sum_{j=1}^{k} b_{jy} \mathrm{Ln}\, P_{jit} + b_{yt} t \qquad (7)$$

Scale economies (SCE) defined as unity minus the elasticity of total cost with respect to output. This results in positive numbers for increasing returns to scale, and negative numbers for scale diseconomies or decreasing returns to scale, as discussed by Christensen and Greene (1976) and Nemoto et. al., (1993).

$$SCE = 1 - \varepsilon_{cy} \qquad (8)$$

2.3. Factor bias of technological change

In the case of a non-homothetic cost function, one can define the factor bias for input j (denoted by B_{jit}) as the rate of change in its cost share over time, evaluated at unchanged factor prices (Binswanger, 1974). For the translog cost function this is

$$B_{jit} = (\partial S_{jit} / \partial t)(1/S_{jit}) = b_{jt} / S_{jit} \qquad (9)$$

A positive value of B_{jit} indicates that technical change is the jth factor using, and negative value means that the technical change is the jth factor saving. Optimal factor proportions, and thereby factor shares, however depend on the level of output. In such cases, the above measure represents the combined effects of output change (the scale effect) and pure technical bias (the bias effect). Therefore, in order to determine pure factor bias the above measures must then be adjusted for changes in scale. For this adjustment I use the method suggested by Bhattacharyya *et al.*, (1997).

2.4. Total factor productivity growth

According to Denny, Fuss, and Waverman (1981), the formula for technical change under cost minimization framework is:

$$\dot{T}_{it} = \dot{C}_{it} - \sum_{j=1}^{k} \frac{P_{jit}X_j}{C_{it}} . \dot{P}_{jit} - \varepsilon_{cy}\dot{Y}_{it} \qquad (10)$$

where $\dot{C}_{it}$,$\dot{P}_{jit}$ and $\dot{Y}_{it}$ are the proportionate rates of growth of total cost, input prices, and output, respectively. Equation (10) does not depend on any functional form of the cost function, whereas equation (6) is derived from the translog cost function. However, the use of (10) requires knowledge of ε_{cy} (cost elasticity), which has to be estimated. The growth of the total factor productivity (TFP) is traditionally defined as the difference between the rate of growth of output and that of aggregated input, i.e.:

$$T\dot{F}P_{it} = \dot{Y}_{it} - \sum_{j=1}^{k} \frac{P_{jit}X_j}{C_{it}} . \dot{X}_{jit} \qquad (11)$$

The above relationship is related to technical change, returns to scale, and output growth rate in the following way (see Denny et al., 1981)

$$T\dot{F}P_{it} = -\dot{T}_{it} + (1 - \varepsilon_{cy})\dot{Y}_{it} \qquad (12)$$

Thus TFP growth equals technical change when $\varepsilon_{cy}=1$. Otherwise, the effect of scale economies (capatured by the second term in the above formula) has to be taken into account in determining TFP growth. Although equation (12) again does not depend on any functional form, it can not be used to compute TFP growth unless ε_{cy} is known. In the case of variable returns to scale, one must use equation (12) with ε_{cy} and $\dot{T}$ replaced by their estimated values from the cost function.

3. ESTIMATION PROCEDURE

The system of translog cost function and associated cost shares forms a seemingly unrelated regression (SUR) model which has to be estimated by iterative seemingly unrelated regression (ITSUR) method to obtain efficiency in the parameter estimation. To make the model operational, restrictions are imposed and the problem of singularity of the disturbance covariance matrix of the share equations solved. This is accomplished by dividing the first k-1 prices by the kth input price (labor and fuel prices are divided by the price of capital), thus eliminating the last term in each row and column of the parameter matrix. A nonsingular system is obtained by dropping the kth share equation. Then the cost function and (k-1) share equivalent to maximum likelihood estimates. The estimation is invariant with respect to the choice of which share equation is dropped. Two models were estimated: 1) a pooled model in which I assume the absence of firm-specific effects, in other words, I assume that the estimated cost functions for the electric utilities have the same intercepts. 2) a fixed effects model which includes firm-specific effects in the cost function. The latter given the same results as "within" estimation method, when the firm-specific are transformaed out (Greene, 1993 and Baltagi, 1995).

The time trend model was estimated (the rate of technical change is calculated as the percentage variation in cost function over time, *ceteris paribus*). A general index specification was also estimated, but in this case the model did not converge (the rate of technical change is calculated as in the time trend model but the time variable is replaced by an index, which is a function of time dummies for the years).

After estimating the input elasticities it is necessary to test the significance of estimated values. Such a test can be based on the Delta method (Greene, 1993; Battese *et al.*, 1997). The objective is to prove that the sample estimate will converge to the true elasticity, evaluated at the limiting values of the sample means of regressors, and to find the asymptotic distribution of elasticities. It should be noted that the calculated elasticities vary both by firm and over time. However, it is satisfactory to perform the test only for sample mean values of the elasticities.

4. DATA DESCRIPTION

The available data covers the period 1980 to 1993 for twelve regional electric power utilities. To simplify the prcess of modeling, the data for each company was aggregated so the data set includes total production costs including generation, transmission, and distribution costs. Input costs include total labor costs (C_l), capital expenditures (C_k) and fuel expenses (C_e). These regional power companies have thermal power stations (steam turbine, gas turbine, and diesel), while one firm also utilizes hydroelectric plants. The fuel used is mostly natural gas (in million cubic meters) and gas-oil (in million liters). Some of the electric utilities consume heavy-oil (in million liters). All costs (C_i), input prices (P_j) and output values (Y) are expressed in million Iranian Rials (Rs.), the quantity of electricity produced is measured in MWh, and the price of electricity produced is in Rs/kWh. To estimate the model, we used output value as the measure of output, since electricity industry is a multiproduct natural monopoly and it would be preferable to use output value instead of output quantity. Output value is deflated by the implicit GDP price index. We replaced input prices with their price indices. The labor price index is the wage index officially published by the Iranian central bank (Bank-e-markazi-e-Iran, 1994). The capital price index is the general index for capital estimated by the economists at the National University in Iran, since it was difficult to find a specific index for the price of capital in the power sector. The fuel price index is a weighted index regarding the consumption of different type of fuel estimated and published by the Ministry of Energy in Iran (MOE, 1994). All of the indexes are deflated to base year 1982=100. There is no data available on the interest payments of electric utilities.

Figure 3 shows the development of deflated average cost for different firms during the period 1980-1993. Khorasan, Sistan and Baluchestan, and Fars had the largest increase in the generating capacity. Summary statistics is shown in Table 1.

5. EMPIRICAL RESULTS

5.1. Specification of technology

Estimated parameters and their standard errors for the pooled and fixed effects models are shown in Table 2. Most of the parameters in both models are found to be statistically significant at the 10% level. Adjusted R^2 is 0.91 for the pooled model and 0.88 for the FE model. In order to choose the preferred model, the null hypothesis of pooled (restricted) model was tested against the FE (unrestricted) model. The χ^2 test indicated that the probability of the pooled model as the preferred model is low. The fixed effects estimation provides consistent and unbiased estimates of the parameters, so it was used in the analysis. Since the FE model is used, there is no generalized heteroscedasticity of error components in the model. For the correct computation of factor bias, it is necessary to examine whether the underlying cost function exhibits homotheticity. The χ^2 test was used again for testing the homothetic specification. Homotheticity of the cost function imposes the following restrictions on the parameters:

$$b_{ly} = b_{ey} = b_{ty} = 0$$

Specifying this as the null hypothesis, homotheticity of the model was rejected at the 5% level of significance.

5.2. Input elasticities and economies of scale

Input elasticities, i.e. the elasticity of cost with respect to the different inputs, and scale economies (SCE) by year and firm are reported in Tables 3 and 4, respectively. Considering Table 3, capital has by far the biggest input elasticity (E_k), with an overall mean of 0.78, increasing, although not monotonically, from 0.75 in 1980 to 0.83 in 1993. This high elasticity is to a large extent caused by a high capital cost share. Conversely, labor elasticity (E_L) has decreased from 0.20 in 1980 to 0.14 in 1993, with average of 0.17 for the entire period. The explanation for this development may be the changes in government employment policies towards liberalization in the electricity supply industry. There have been major changes in the number of employees and their costs within recent years. The official report indicates that in 1994 about 58,000 employees were employed in the electricity supply industry, 7.4% less than in 1993 and 16.7% less than in 1992 (MOE, 1995). The report also indicates that the labor force in the regional electric utilities themselves decreased by 10.4% from 1993 to 1994.

The lowest input elasticity is for energy (E_E) with an overall mean of 0.046 and more variation between years. Although for the electricity supply industry one should expect a much higher elasticity for energy (fuel), especially in the case of thermal power plants, there are some possible explanations:

1. First, the government for a long time has subsidized fuel prices, so the power stations obtain fuel at low cost. This is probably the main reason for this small elasticity. The nominal price started from 1.2 Rs/liter (≈ 1.76 ¢[1]/liter) in 1974 and had the same level until 1986 when it jumped to 2 Rs/liter. The next jump was in 1992 when the fuel price reached 5 Rs/liter (1.6 mill/liter). The deflated prices show that the fuel cost decreased from 3.82 Rs/liter (7.6 mill/liter) in 1974 to 0.65 Rs/liter (1.3 mill/liter) in 1993. The real domestic fuel price has thus decreased to approximately one-sixth of its initial price, and it is very low compared with its international price (MOE, 1994).

2. Recent analysis indicates that the long run marginal cost of electricity was 4.27 ¢/kWh in 1993 by which the fuel cost was 0.9 ¢/kWh (EPRC, 1996). This shows that the fuel cost can not be reflected in the total cost.

3. Despite the growing importance of thermal power plants, advances in the new vintages of energy technologies, such as steam turbine and combined cycle power plants, have had major effects on fuel consumption. These new technologies are energy-efficient and fuel saving, and some of the regional electric utilities use these new technologies.

4. The objective in this paper is measuring economies of scale and total factor productivity growth at the aggregate level, including generation, transmission, and distribution systems. Since in both transmission and

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1. ¢ = cent.

distribution system there are no fuel costs, the share of fuel in total costs of production is much lower than it would be for generation alone.

The elasticity of cost with respect to output (ε_{cy}) has decreased from 0.38 in 1980 to 0.33 in 1993, with an overall mean of 0.36, while economies of scale (SCE) increased from 0.62 in 1980 to 0.67 in 1993, with an overall mean of 0.64. This shows that the electricity supply industry in Iran is operating under large increasing returns to scale (IRS). As a matter of fact, the mean elasticity of scale, i.e., the inverse of cost elasticity, is 2.8, which is a very high figure, alghough possibly not unreasonable in such a capital-intensive technology. Moreover, the level of electricity production in all of the firms have increased steadily, and their actual (deflated) average costs have been generally diminishing except most recently Economies of scale is indicated in Figure 5.

One of the reasons for diminishing production costs was the frequent blackouts in the network, so the power stations were operating at low capacity utilization. In fact, SCE decreased during 1987-1990, when the electricity shortage reached a peak during this period.

The priority given by the government to rural and small town electrification resulted in a steady growth of generating capacity during the 1980s despite the war impediments. According to data published by MOE, the country's total installed capacity in 1991/92 was close to 19,000 MW, of which over 93% belonged to MOE. Of the Ministry's share of power generation, 68% was produced by steam engines, 17% by gas turbines and combined cycles, 14% by hydropower, and about 1% by diesel motors. Due to the shortage of spare parts, the war damages, and other related problems, only about 60% of installed capacity was utilized during most of the decade. Both, per capita production and consumption of electric power rose more than 70% during 1977-91 (Amuzegar, 1993).

Another important implication of IRS is in the field of regulation and reorganization of the industry structure. The power sector is a multiproduct rather than a single product industry which supplies a spectrum of differentiated goods, the major distinguishing features of which are time, location, and voltage level. For example, there are systematic seasonal and time-of-day variations in demand for electricity, so that, adopting the industry's own basic unit of duration (the half-hour), time differentiation alone could imply 17,520 different outputs in each year (Yarrow, 1986). In a multiproduct world, economies of scale are neither necessary nor sufficient for a monopoly to be natural but still, if there are globally increasing returns to scale for a single output, average costs decrease with output and exceed marginal costs at every output level. However, lack of data did not allow measurement of regulatory effects, economies of scope, and subadditivity of costs to investigate the sustainability of natural monopoly in the electricity market.

Table 4 shows the mean elasticities and economies of scale for each firm. For capital as well as labor, the variation among firms is small. The highest capital elasticities are for Tehran, Isfahan, and Khuzestan, with approximately 0.8, while the highest labor elasticity is for Sistan and Baluchestan. One reason for the latter figure may be its low rate of capacity utilization and electricity production (Figure 3).

The fuel elasticities (E_E) vary somewhat more among the firms, Tehran even had negative fuel elasticity (-0.016). This utility decreased its fuel consumption by 20% in the period 1980-93.

All the firms exhibited increasing returns to scale. Tehran was highest; its generating capacity decreased from 26.7 MW in 1980 to 8.6 MW in 1993. At the same time, its level of output increased (because of electricity import) and its deflated average cost decreased.

5.3. Technical change and its components

Tables 3 and 4 present the estimated values of several characteristics of technology and its change. Technical change measures the rate of downward shift of the cost function over time. The results indicate that the electricity supply industry had a strong technical progress (E_T) during the period 1980-93, with increasing trend from 9% in 1980 to 18% in 1993, with average 14% (Figure 6). There is surprisingly small variation among the firms, average technical progress was 14% for all firms. Pure technical change (E_P), representing advancement of knowledge, was favorable and statistically significant for all the firms, 9.3%.

Non-neutral technical change (E_N), which expresses the effects of input price changes on cost reduction, was also favorable but very small, with an average of 0.1% for the whole period and 0.2% for the firms. Scale - augmenting technical change (E_s), which represents the part of cost reduction attributable to changes in output level, through exploitation of economies of scale, had an average of 4.7% for the period and the firms. Tehran and Sistan & Baluchestan show the highest and lowest scale augmenting technical change, with 5% and 4.2%, respectively.

5.4. Total factor productivity growth

Total factor productivity (TFP) growth is reported in Tables 5 and 6. As the results in Table 5 show, TFP growth increased from 8.4% in 1981 to 20% in 1993, with the average of 17.2% for the period. The highest rate of growth was 30.1% in 1991, caused by a strong increase in the electricity production during this period as indicated in the Figure 7. The lowest rate was 7.4% in 1988, because of low capacity utilization and electricity production. Among the firms (Table 6), Sistan & Baluchestan had the highest rate of productivity growth (22,1%), with a sharp reduction in average cost after 1984, although energy supply increased. Gharb shows the lowest productivity growth (12.9%), because of reduction in energy production after 1985. The overall mean for the twelve regional electric utilities is 17.2%. The major reasons for this high rate of growth can be explained as follows:

a. The electric power industry has experienced the generation and transmission capacities expansion during 1980-1993. Obviously, this feature shows the high rate of economies of scale and TFP growth.

b. Improvements in the thermal efficiency of power plants are generally thought to be another important factor contributing to productivity growth during this period. Joshow (1987) proves that the increase in the thermal efficiency as a result of heat rate decline in the steam Rankine cycle causes productivity growth at the generating units[1]. Figure 2 indicates the increasing pattern of thermal efficiency.

c. The third important factor contributing to the high productivity growth is electricity trade among different electric utilities during 1980-1993. As Table 6 shows, some firms have the higher rates of productivity growth. For instance, Azarbaijan and Kerman had electricity imports from the interconnected network with the average of 86% and 87%, respectively.

5.5. Factor bias of technological change

The estimates of total bias for labor input (TB_L) and energy input (TB_E) by year and firm are presented in Tables 5 and 6, respectively. The corresponding scale-bias elements denoted by SB_L and SB_E and the pure-bias elements denoted by PB_L and PB_E were calculated by subtracting the scale effects from the total bias effects.

Table 5 shows that TB_L and TB_E have negative signs for the whole period, which means that the Iranian electricity supply industry has been

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[1] *The thermal efficiency of the Rankine cycle increases with the temperature and pressure of the steam, the thermal efficiency of the boiler, the efficiency of the turbine, and the size of the turbine and boilers. The thermal efficiency is measured by a generating unit's heat rate. The heat rate is equal to the number of BTU's of fuel consumed to generate a kWh of electricity. The lower the heat rate, the greater the thermal efficiency.*

both labor and energy saving. The average rates of total bias were 2.6% for labor and 14.5% for energy, with maximum 8.5% for labor in 1993, and minimum 1.7% in 1980. Maximum of energy saving was 32.7% in 1993 and minimum 6.9% in 1991 (Figure 8). Among the firms, Khorasan which is isolated from the network had the highest rate of labor saving (4.3%), and Khuzestan the lowest rate (1.6%). For energy, Khuzestan had the highest rate (87.7%), because of utilization of hydroelectric power plants and Sistan & Baluchestan had the lowest rate (1.7%).

As Table 5 shows, the scale-bias of labor has increased during this period, except in 1983-84 in which it had a slowdown from 2.6% to 1.6%. Considering the scale-bias of energy there is a slow down in the trend after 1984. With increasing output, a distinct bias can be observed in favor of labor (TB_L) and energy (TB_E). This is revealed by the changes in input shares along the expansion path. At unchanged prices, the shares of labor and fuel would rise at an overall average of 2.3% and 52.8%, respectively, if output increases along a given expansion path. The adjustments in bias, due to scale changes, would be in the opposite direction because cost reduction would cause a hypothetical opposite movement along the expansion path. Thus, the estimates of TB_L (2.6%) and TB_E (14.6%) underestimate the true bias of labor and fuel by SB_L (2.3%) and SB_E (52.8%), respectively. The effect of technical change would be 4.9% reduction in labor share (PB_L) and 65.3% reduction in fuel share (PB_E), which is shown by the pure-bias measure. The outcome is that the technology is labor and energy saving.

6. CONCLUSIONS

In this paper, a translog cost function and associated cost shares for a panel electric power utilities in Iran were estimated for the period 1980 to 1993. Technical change was specified with a time trend model, and the econometric panel data model has been formulated as a fixed effects one-way error component model. In order to find the asymptotic distribution of estimated elasticities, the Delta method has been used, and computed t-values showed that most of the estimated elasticities are significant at the 1% level (Table 7). The major findings are:

1. The electricity supply industry has been using a capital/energy-intensive technology generating a high capital input elasticity and a very low fuel input elasticity, due to heavily subsidized fuel prices.
2. The industry has exhibited large increasing returns to scale, mostly because of low capacity utilization. Among the firms, Tehran had the highest returns to scale.
3. Technical change was at a high level, with an increasing trend from

10% in 1980 to 18% in 1993. While the pure and scale augmenting effects were important, the non-neutral component was close to zero.

4. TFP growth was estimated using the translog cost function. On average, TFP growth was 17% according to the cost function due to high rate of electricity trade among different utilities.

5. Factor bias of technical change shows that the Iranian electricity supply industry has been both labor and energy saving. This energy saving is the result of decreasing fuel costs in the production process.

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TABLE 1. Summery Statistics

Variables	**Definition** (units)	**Mean**	**Std. dev.**	**Minimum**	**Maximum**
Input and Output quantities:					
L	Labor (employee)	3315	2152	509	10682
K	Capital value* (million Rs.)	47,645.81	81,641.7	3,332.11	783,603.6
E	Energy (million litre)	67,152.8	244,398.4	0	1,606,784.6
$\mathbf{Y_1}$	Output quantity (GWh)	2,833.13	2,990.83	85.6	14,453.8
$\mathbf{Y_2}$	Output value* (million Rs.)	6,901.6	8,431.54	165.92	43,137.02
Input prices:					
$\mathbf{P_L}$	Price of labor (index)	210	134.62	82.1	505
$\mathbf{P_K}$	Price of capital (index)	269.42	201.35	78.01	699.3
$\mathbf{P_E}$	Price of energy (index)	156.25	83.71	75.05	378.1
Costs:					
$\mathbf{L_{cost}}$	Labor cost* (million Rs.)	893.47	744,786	63.59	3,871.88
$\mathbf{K_{cost}}$	Capital cost* (million Rs.)	4,919.8	5,306.75	284.56	31,133.9
$\mathbf{E_{cost}}$	Energy cost* (million Rs.)	153.77	224,212	0	1,330.27
C	Total cost* (million Rs.)	5,967.05	5,853.91	414.5	32,857.5
Cost shares:					
$\mathbf{S_L}$	Share of labor	0.17	0.06	0.02	0.32
$\mathbf{S_K}$	Share of capital	0.78	0.08	0.59	0.98
$\mathbf{S_E}$	Share of energy	0.05	0.06	0	0.32

No. of observations=168

* All values are deflated to base year 1982.

List of regional electric utilities:

FIRM 1= Azarbaijan

FIRM 2= Isfahan

FIRM 3= Tehran

FIRM 4= Khorasan

FIRM 5= Khuzestan

FIRM 6= Sistan and Baluchestan

FIRM 7 = Gharb

FIRM 8 = Fars

FIRM 9 = Kerman

FIRM 10=Gilan

FIRM 11= Mazandaran

FIRM 12= Hormozgan

TABLE 2. System of cost and cost share parameter estimates (using ITSUR method)

	POOLED MODEL		FIXED EFFECT MODEL	
Parameter	**Estimate**	**Std err.**	**Estimate**	**Std err.**
b_0	2.659	2.677	-1.44	5.279
b_L	0.304*	0.064	0.303*	0.066
b_E	0.524*	0.066	0.525*	0.066
b_Y	0.313	0.362	1.268*	0.751
b_T	-0.059	0.079	-0.045	0.084
b_{LL}	0.416	0.032	0.072*	0.024
b_{EE}	-0.01	0.032	-0.051*	0.03
b_{YY}	0.03	0.024	-0.06	0.053
b_{TT}	-0.006*	0.002	-0.006*	0.002
b_{LE}	-0.047*	0.024	-0.032*	0.019
b_{LY}	-0.006*	0.004	-0.007	0.004
b_{LT}	-0.006*	0.002	-0.003*	0.001
b_{EY}	-0.031*	0.004	-0.031*	0.004
b_{ET}	-0.0005	0.002	-0.003	0.002
b_{YT}	-0.003	0.005	-0.003	0.005
$:_2$	-	-	0.036	0.084
$:_3$	-	-	0.73*	0.244
$:_4$	-	-	-0.25*	0.079
$:_5$	-	-	0.44*	0.114
$:_6$	-	-	-0.92*	0.151
$:_7$	-	-	-0.081	0.09
$:_8$	-	-	-0.09	0.078
$:_9$	-	-	-0.365*	0.1
$:_{10}$	-	-	-0.348*	0.093
$:_{11}$	-	-	-0.346*	0.08
$:_{12}$	-	-	-0.532*	0.1
Adj R^2 (cost)	0.91	-	0.88	-
Adj R^2 (labor sh.)	0.14	-	0.09	
Adj R^2 (fuel sh.)	0.25	-	0.24	-

* Paremeters are statistically significant at the 10% level.

Table 3. Mean input elasticities and Scale economies by year

	Input elasticities			Scale indicators		Components of technical change			
YEAR	E_L	E_K	E_E	E_{CY}	SCE	E_P	E_N	E_S	E_T
1980	0.198	0.751	0.049	0.384	0.615	-0.051	-0.0006	-0.046	-0.098
1981	0.188	0.769	0.042	0.379	0.62	-0.058	-0.0006	-0.046	-0.104
1982	0.185	0.773	0.04	0.372	0.627	-0.064	0.001	-0.047	-0.111
1983	0.188	0.773	0.038	0.366	0.633	-0.071	0.001	-0.047	-0.118
1984	0.191	0.773	0.036	0.363	0.637	-0.077	0.001	-0.047	-0.124
1985	0.193	0.774	0.032	0.357	0.642	-0.083	0.001	-0.048	-0.131
1986	0.175	0.786	0.037	0.357	0.643	-0.09	0.001	-0.047	-0.136
1987	0.158	0.804	0.036	0.348	0.652	-0.096	0.001	-0.047	-0.143
1988	0.154	0.789	0.056	0.362	0.638	-0.103	0.001	-0.047	-0.148
1989	0.153	0.782	0.065	0.368	0.632	-0.109	0.001	-0.047	-0.153
1990	0.151	0.769	0.078	0.372	0.627	-0.116	0.001	-0.047	-0.158
1991	0.155	0.785	0.059	0.353	0.646	-0.122	0.001	-0.048	-0.166
1992	0.153	0.808	0.038	0.336	0.663	-0.129	0.001	-0.048	-0.174
1993	0.14	0.826	0.033	0.329	0.67	-0.135	0.001	-0.048	-0.181
Mean	0.17	0.783	0.046	0.36	0.639	-0.093	0.001	-0.047	-0.139
Std dev.	0.02	0.04	0.031	0.056	0.056	0.02	0.001	0.003	0.025

Table 4. Mean input elasticities and Scale economies by firm

	Input elasticities			Scale indicators		Components of technical change			
FIRM	E_L	E_K	E_E	E_{CY}	SCE	E_P	E_N	E_S	E_T
1	0.169	0.789	0.041	0.352	0.648	-0.093	0.002	-0.047	-0.139
2	0.167	0.802	0.031	0.332	0.667	-0.093	0.002	-0.049	-0.14
3	0.156	0.86	-0.016	0.243	0.756	-0.093	0.002	-0.053	-0.145
4	0.168	0.794	0.038	0.344	0.655	-0.093	0.002	-0.048	-0.14
5	0.164	0.820	0.017	0.304	0.695	-0.093	0.002	-0.05	-0.142
6	0.182	0.717	0.100	0.463	0.536	-0.093	0.002	-0.042	-0.134
7	0.173	0.770	0.057	0.382	0.617	-0.093	0.002	-0.046	-0.138
8	0.169	0.790	0.041	0.35	0.65	-0.093	0.002	-0.048	-0.139
9	0.175	0.758	0.067	0.399	0.6	-0.093	0.002	-0.045	-0.137
10	0.173	0.766	0.060	0.387	0.612	-0.093	0.002	-0.046	-0.138
11	0.171	0.781	0.048	0.364	0.636	-0.093	0.002	-0.047	-0.139
12	0.176	0.755	0.069	0.405	0.595	-0.093	0.002	-0.045	-0.137
Mean	0.17	0.783	0.046	0.36	0.64	-0.093	0.002	-0.047	-0.14
Std dev.	0.02	0.04	0.031	0.056	0.056	0.026	0.002	0.003	0.025

Table 5. Total Factor Productivity growth and Factor bias by year

	TFP growth(%)	Components of labor bias			Components of energy bias		
YEAR	Estimated	TB_L	SB_L	PB_L	TB_E	SB_E	PB_E
1980		-0.017	0.009	-0.026	-0.108	0.294	-0.402
1981	8.4	-0.02	0.012	-0.032	-0.163	0.638	-0.801
1982	18.7	-0.022	0.014	-0.036	-0.109	0.366	-0.475
1983	17.1	-0.037	0.026	-0.063	-0.173	0.62	-0.793
1984	15.2	-0.022	0.016	-0.038	-0.176	0.667	-0.843
1985	16.8	-0.021	0.016	-0.037	-0.187	0.273	-0.46
1986	12.9	-0.021	0.017	-0.038	-0.076	0.295	-0.371
1987	21.8	-0.022	0.019	-0.041	-0.149	0.298	-0.447
1988	7.4	-0.021	0.018	-0.039	-0.074	0.316	-0.39
1989	11.1	-0.021	0.018	-0.039	-0.17	0.273	-0.443
1990	18.6	-0.02	0.017	-0.037	-0.144	0.661	-0.805
1991	30.1	-0.022	0.021	-0.043	-0.069	0.318	-0.387
1992	24.9	-0.021	0.022	-0.043	-0.13	0.682	-0.812
1993	20	-0.085	0.096	-0.181	-0.326	1.796	-2.122
Mean	17.2	-0.026	0.023	-0.049	-0.145	0.528	-0.653
Std dev.	0.129	0.027	0.029	0.056	0.215	0.8	0.97

Table 6. Total Factor Productivity growth and Factor bias by firm

	TFP growth(%)	Components of labor bias			Components of energy bias		
FIRM	Estimated	TB_L	SB_L	PB_L	TB_E	SB_E	PB_E
1	18.6	-0.0216	0.019	-0.041	-0.091	0.433	-0.524
2	15.3	-0.029	0.026	-0.055	-0.589	2.075	-2.664
3	17.2	-0.028		-0.064	-0.774	3.663	-4.437
4	18.5	-0.043	0.034	-0.077	-0.079	0.334	-0.413
5	15.9	-0.016	0.016	-0.032	-0.877	*	-0.877
6	22.1	-0.029	0.02	-0.049	-0.017	0.052	-0.069
7	12.9	-0.017	0.012	-0.029	-0.104	0.416	-0.520
8	16.5	-0.033	0.031	-0.064	-0.075	0.388	-0.463
9	18.8	-0.032	0.027	-0.059	-0.095	0.362	-0.457
10	14.4	-0.018	0.014	-0.032	-0.184	0.835	-1.019
11	16.4	-0.024	0.019	-0.043	*	*	*
12	19.4	-0.026	0.021	-0.047	-0.087	0.328	-0.415
Mean	17.2	-0.026	0.023	-0.049	-0.146	0.528	-0.653
Std dev.	0.129	0.027	0.03	0.056	0.215	0.8	0.97

* The estimated values are not siginficant.

TABLE 7. Mean and Standard error of input and output elasticities of cost

Parameter	Mean	Std. err.	t-value*
Elasticity of labor (E_L)	0.17	0.006	30.605
Elasticity of energy (E_E)	0.046	0.004	10.95
Elasticity of output (E_Y)	0.361	0.079	4.559
Technical change (E_T)	-0.139	0.007	-20.71

* Critical t- value at 1%: 2.57

FIGURE 1. INSTALLED CAPACITY (GW)

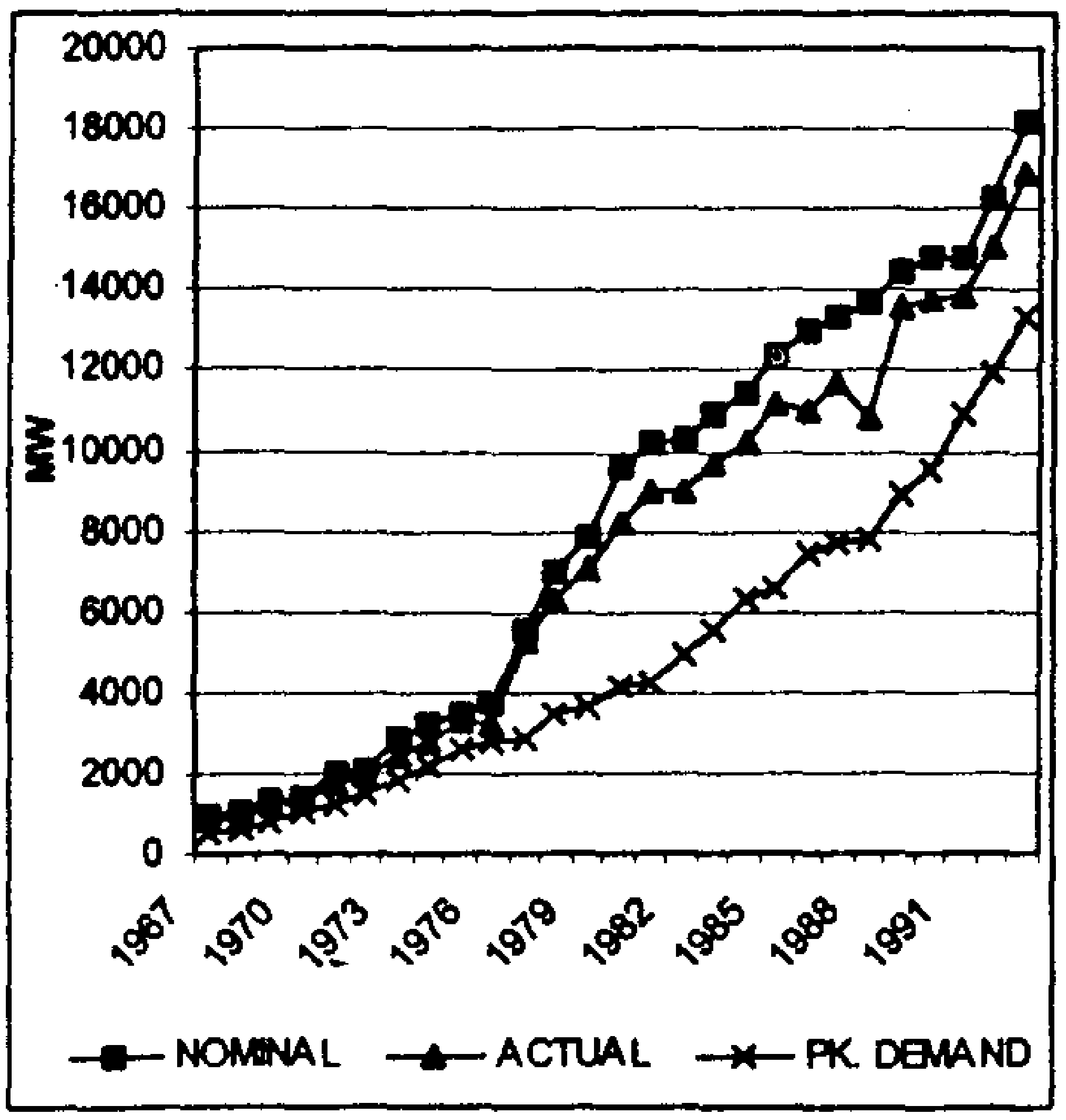


FIGURE 2. EFFICIENCY OF THERMAL UNITS

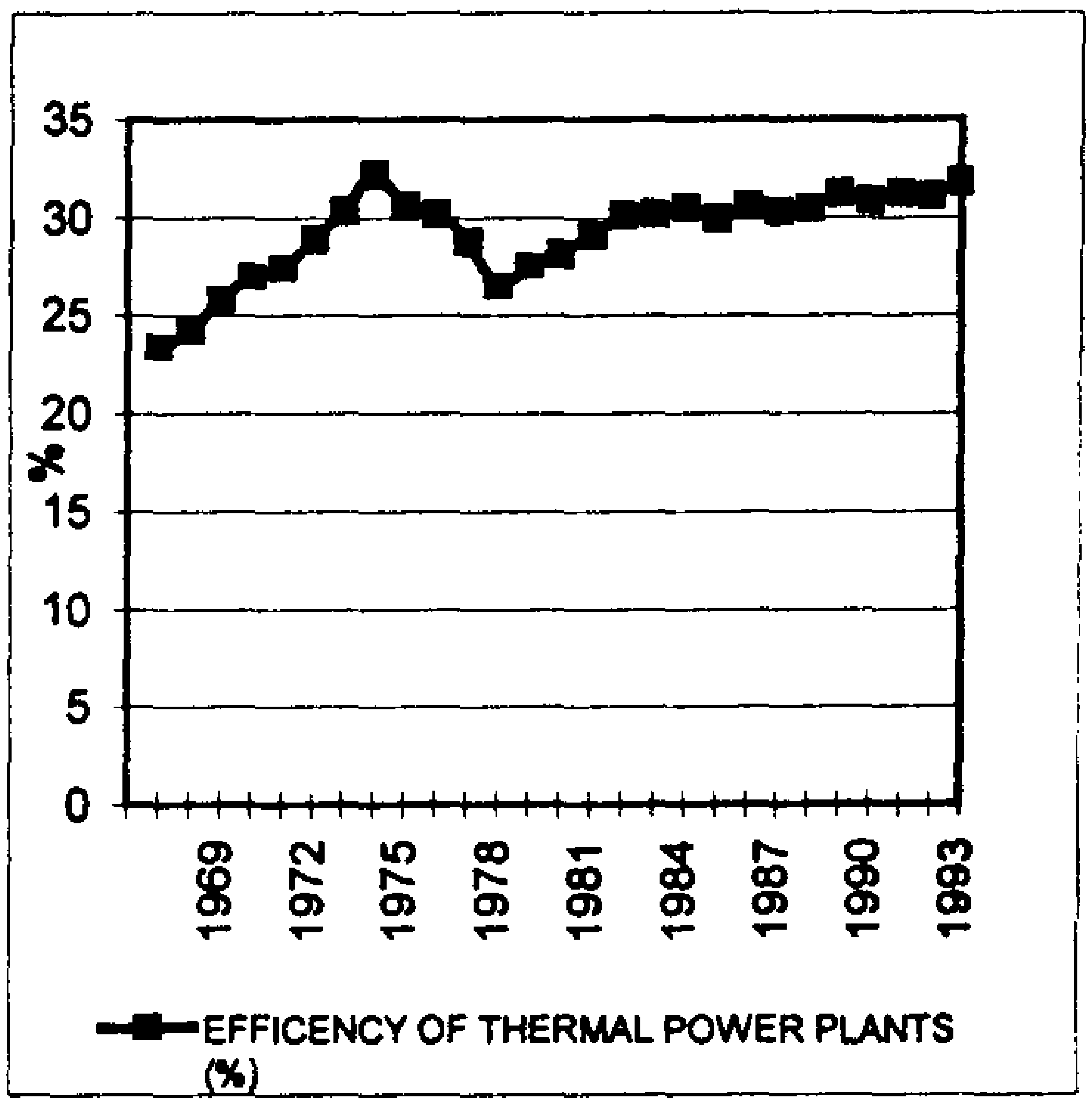


FIGURE 3. DEVELOPMENT OF DEFLATED AVERAGE COST

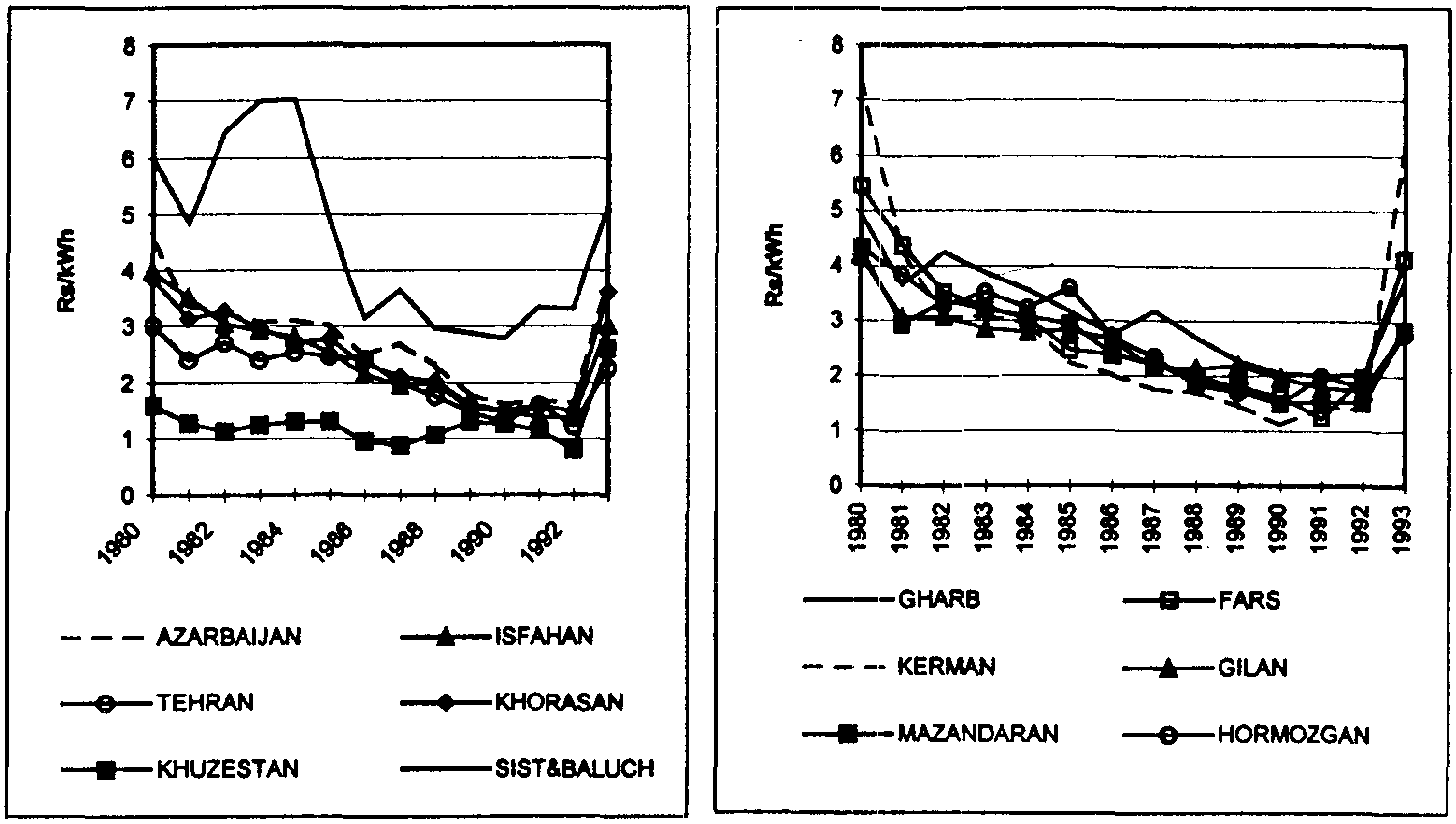


FIGURE 4. DEVELOPMENT OF ENERGY PRODUCTION (GWh)

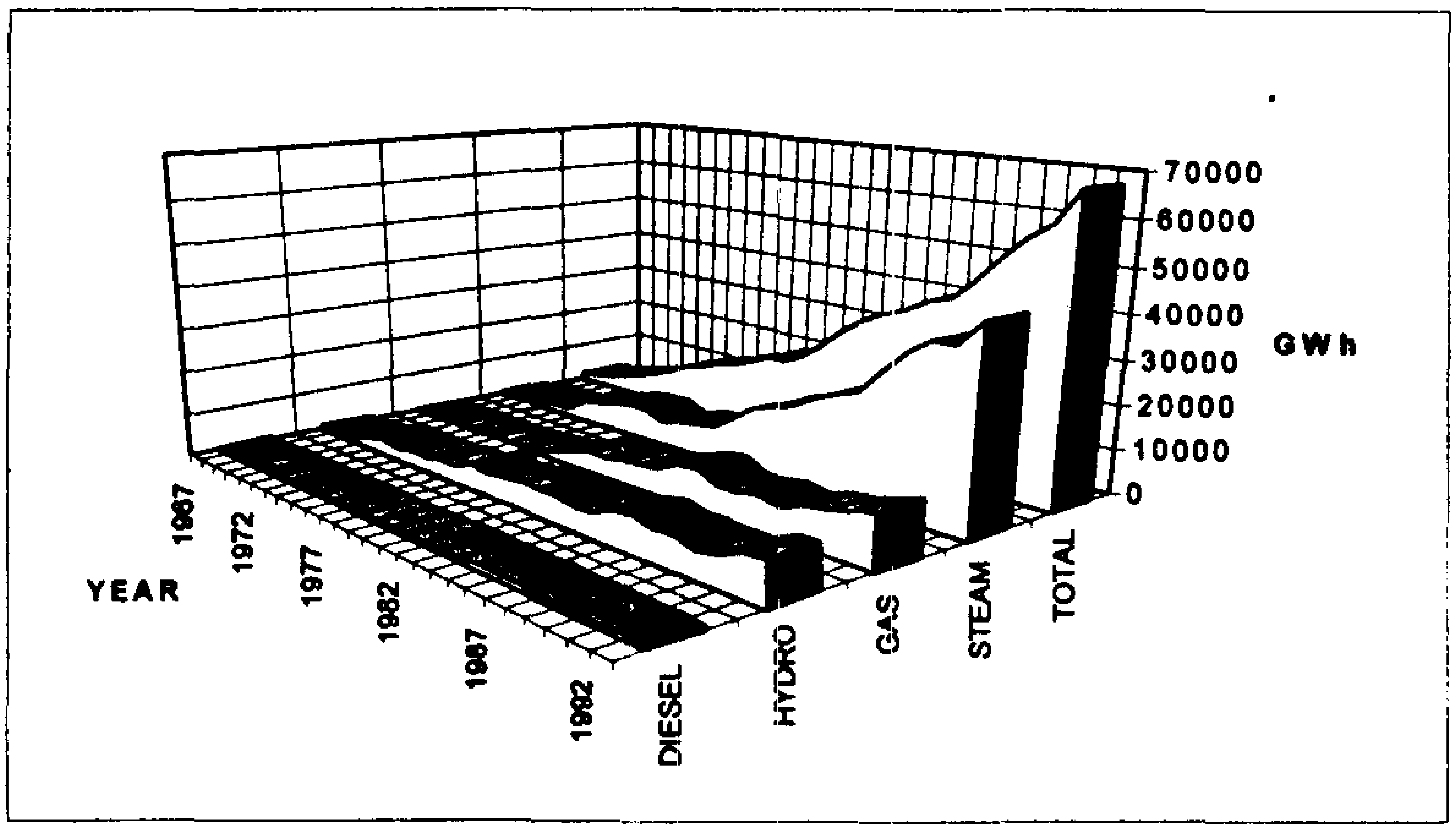


FIGURE 5. ECONOMIES OF SCALE IN THE ELECTRICITY INDUSTRY

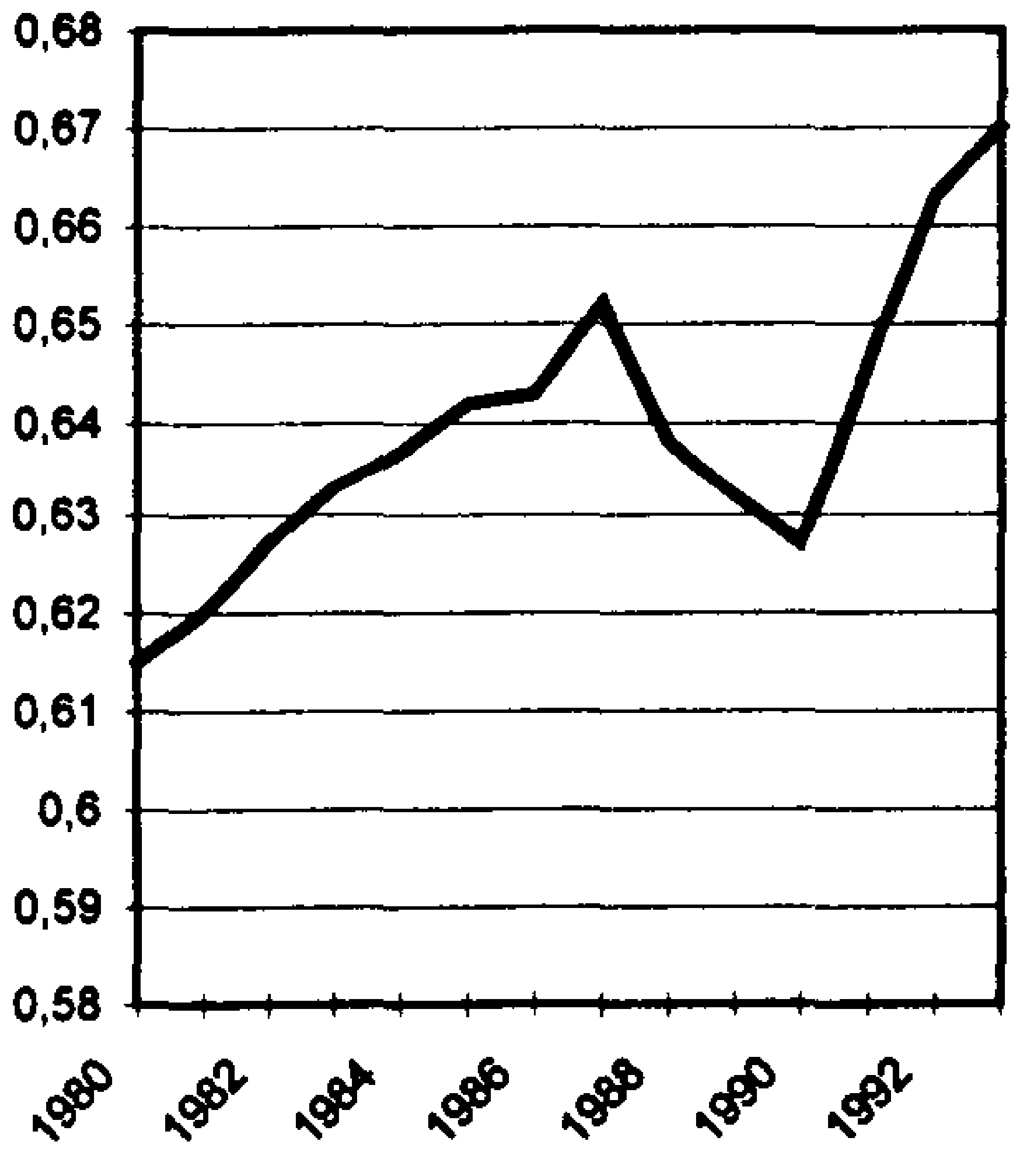


FIGURE 6. RATE OF TECHNICAL CHANGE

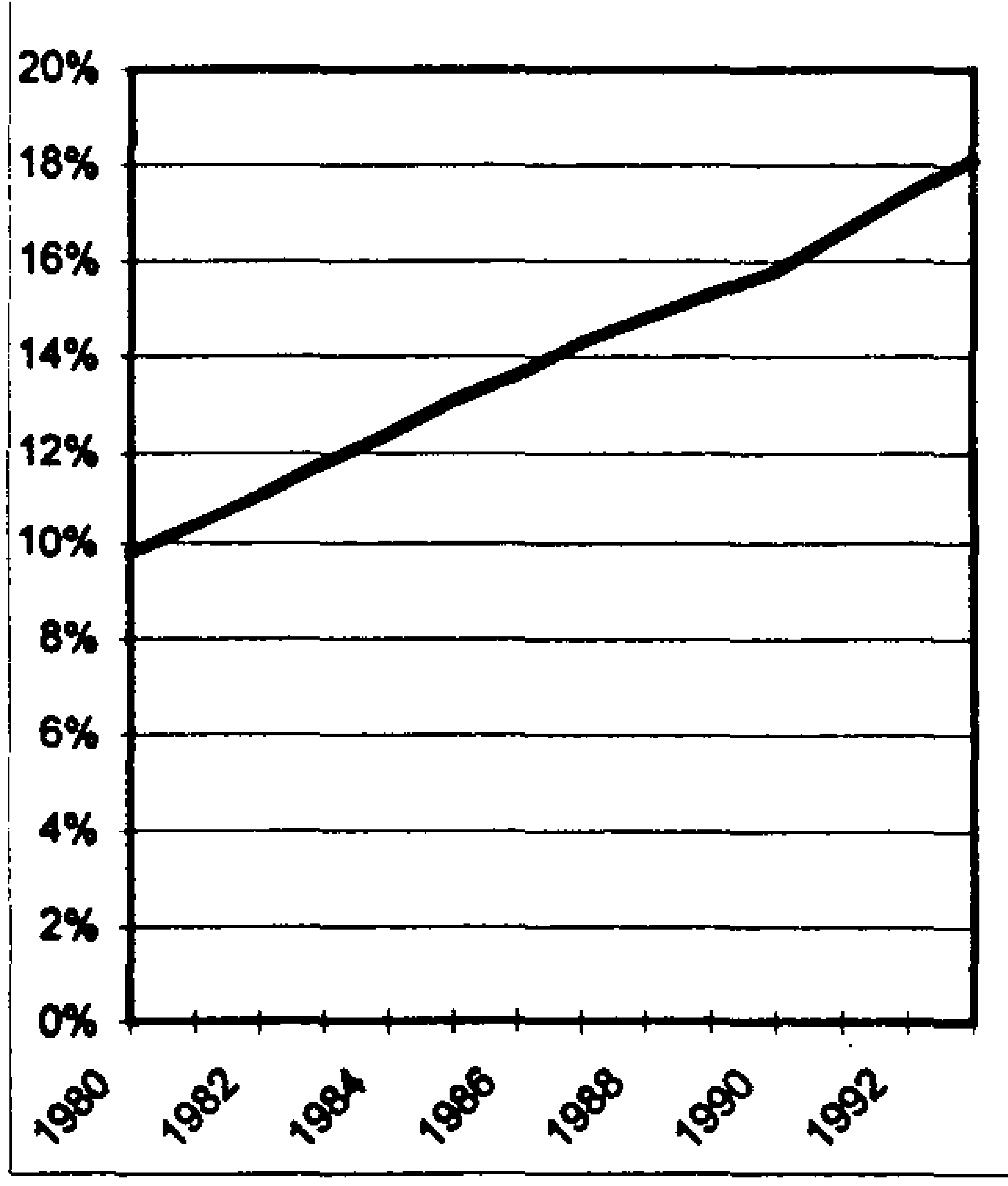


FIGURE 7. TOTAL FACTOR PRODUCTIVITY GROWTH (%)

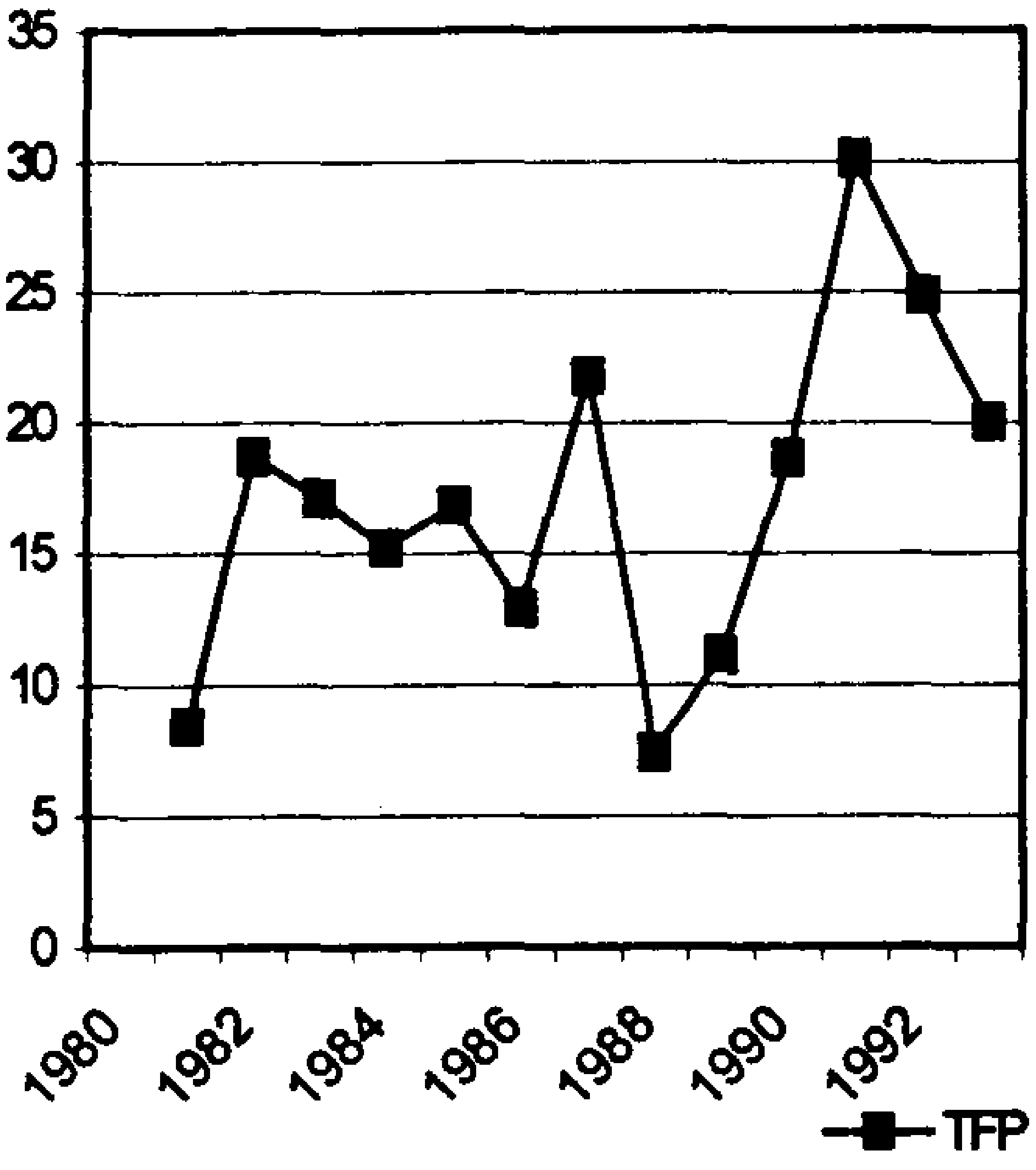
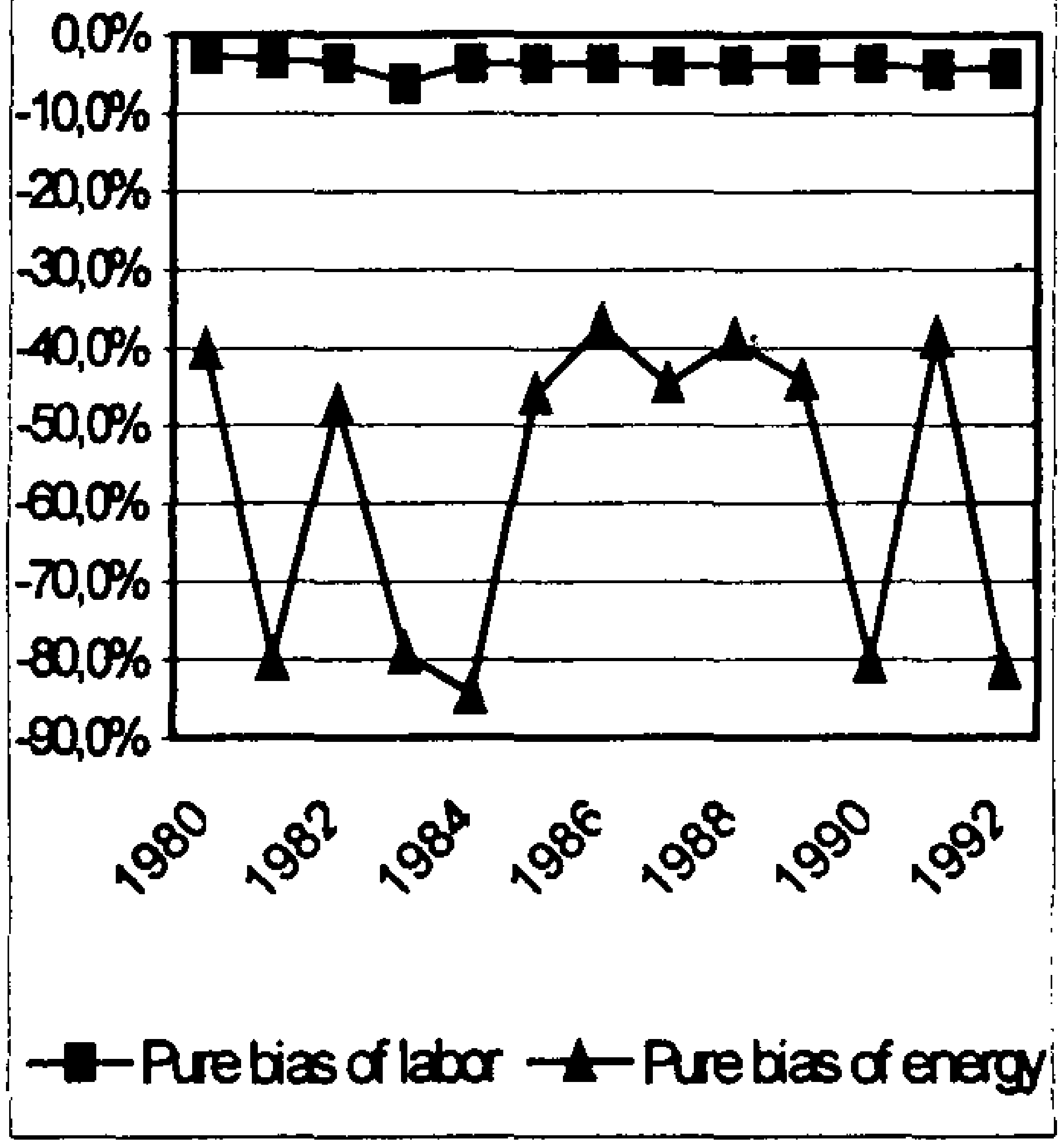


FIGURE 8. FACTOR BIAS OF TECHNOLOGICAL CHANGE



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Olson explores this conclusion with particular respect to the Soviet Union and its successor states, but with applicability to the problems of many other places where prosperity remains elusive.

Institutions, Incentives and Economic Reforms in India

Antony Lanyi and Satu Kahkonen (eds.)

India, Sage Publishing, 2000

India embarked on the process of economic reforms in 1991. After an initial spurt, there has been a distinct slowing down as evidenced by relatively low industrial growth and per capita incomes. The contributors to this important volume maintain that a country cannot achieve economic growth and development simply by having the government not interfere in the economy. To the contrary, they argue that without the appropriate institutional and polotical underpinnings, economic reforms will be only partially successful. Not only could they fail but they may even lead to outcomes that are worse than the original situation.

The discussions are set in the framework of the `new institutional economics´ which encompasses the fundamental legal, political and social rules that establish the basis for production, exchange and distribution. Understanding these factors implies a reform effort which is broad-based and multi-pronged and which takes into account incentives for the stakeholders in both the private and public sectors.

The original essays in this volume illustrate the efficacy of this new institutional approach with reference to a number of crucial policy areas -- privatization, fiscal policy, agricultural reform, labor policy, and financial sector development. In each of these sectors, the contributors demonstrate the need for a reform effort based not only on known policy prescriptionns, but also on devising means of overcoming those institutional factors and incentives which impede reform. Among the issues discussed are the interplay ofcenter-state relations and their impact on policy; the poor incentive structures faced by both tax payers and government officials; inadequate coordination among different levels of government which results in the poor delivery of services; outdated marketing strategies that impede agricultural growth; and strategies to improve the operations of the financial and labor markets.