*CAN FISCAL POLICY EXPLAIN TECHNICAL INEFFICIENCY OF PRIVATISED FIRMS? A PARAMETRIC AND NONPARAMETRIC APPROACH**

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Abstract

The massive interests of economic literature about the privatisation gave a notable impulse to the discussion about this theme in the pre and post privatisation firms performance. Basically in every case after privatisation the level of profit increases. Does this mean that privatisation is certainly able to increase efficiency? In this field a large part of the literature leave out the complex problem that public firms usually are subject to objectives and constraints that differently from private firms can affect the overall economic efficiency. Unfortunately many authors ignore the effects of taxation during the process of privatisation, but in real term there are significant tax issues that must be considered by public and private decision maker. In this paper we concentrate the attention on the efficiency measures with the purpose to identify and measure sources of successful performance that can be used in policy planning and allocation of resources. Several techniques to calculate these frontier functions have been used, some of them parametric, others non-parametric to empirically investigate the relationship between taxation on firm's income and efficiency in the period pre and post-privatisation. In this work we use both econometric and mathematical programming approaches for measuring efficiency. The econometric tool provide maximum likelihood estimates of a stochastic production and cost functions to distinguish noise from inefficiency. Instead, the mathematical programming approaches are non-stochastic and they do not make strict assumptions on the functional form of production and the statistical properties of the data. The general results obtained from the 3 different tools (Stochastic Frontier, Data Envelopment Analysis and Neural Network) are consistent. In fact, we see that privatization enhanced efficiency in three out of four sample firms.

1.1. Introduction

The productivity of an economic entity is usually expressed by the ratio of its output and its input and is function of many factors such as technology, efficiency etc. Several economists has studied efficiency estimation. Debreu (1951), Koopmans (1951), Farrel (1957) introduced, more than half a century, the analysis of efficiency estimation into the economics literature. Then, other authors like Leibenstein (1966), Varian (1985) and Bauer (1990) worked on this topics. At present there has been a very large number of theoretical and empirical papers devoted to the measurement of productive efficiency. Several techniques to calculate these frontier functions have been used, some of them parametric, others non-parametric.

In this paper we concentrate on the efficiency measures in some privatised firms with the purpose to identify and measure sources of successful performance that can be used in policy planning and allocation of resources.

Diamond and Mirrlees (1971), Dasgupta and Stiglitz, (1972) considered that an optimal tax scheme implies overall production efficiency under a given set taxes; later Huizinga and Nielsen (1997) also showed there is overall production efficiency if private sector profit tax revenues suffice. Unfortunately many authors ignore the effects of taxation during the process of privatisation, but in real term there are significant tax issues that must be considered by public and private decision maker. Private production differs from public production because it is subject to a distorting investment tax. In fact, government has access to saving and private profits taxation; therefore, it sets, out of constraint, the threshold of production, physical investment and tax policy. When the company is privatised, it must consider that the new juridical status implies the application of new fiscal charge that were previously not levied.

Bolton and Roland (1992) have considered how privatisations should be carried out so as to minimize the subsequent need for the government to raise revenue through distorting taxation; generally the government has to levy taxes, this could implies a higher taxation of private activity that reduces the value of borderline activities by the private activity. On this base and considering that large part of literature has investigated on the role of tax rule[3] on profits; we

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*Though the paper is the result of the work of both authors, the § 1.1, 1.2, 1.6 and 1.7 are by Alfano, the § 1.3, 1.4, and 1.5 are by D'Orio, of course the conclusions, § 1.8 has written jointly.

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[3] Like depreciation allowances, investment tax credit, deductibility of interest ect, Alesina et al. (1999)

empirically investigate, using parametric and non-parametric approaches, on the relationship between taxation on firm's income and efficiency in the period pre and post-privatisation.

This paper, considering the complexity of the problem, uses alternative methodologies for assessing corporate performance of privatised firms within the British Economy. The sample includes data about four of the major privatised British company (British Aerospace, British Gas, British Telecom and British Steel). The choice of estimation method has been an issue of debate (see Berger 1993, Seiford and Thrall 1990) since every method has its advantages and disadvantages. We use both, econometric and mathematical programming approaches for measuring efficiency. The econometric tool provides a maximum likelihood estimate of a stochastic production function to distinguish noise from inefficiency. Instead, the mathematical programming approaches are non-stochastic: it does not make strict assumptions on the functional form of production and the statistical properties of the data. The paper is organised as follows: in Section 1.2 there are some general notes on the set of data used in all the estimations, section 1.3 introduces the Stochastic Frontier approach and gives us a detailed explanation of the estimation. Section 1.4 explains the general characteristic of the Data Envelopment Analysis technique and gives us a explanation of the estimation, while paragraph 1.6 illustrate the limits of these tools and suggest how these limits can be overcame using a Neural Network analysis. In paragraph 1.7 there is a comparison of the output of the estimations and finally in paragraph 1.8 there are some general comments on the results obtained.

1.2. Data: a general issue

In this paper, rather than comparing several organisations[4] at a single point of time we will adopt a longitudinal analysis of decision making unit (DMU) of the same firm. In this way we will assess changes in technical efficiency related to tax effects pre and post-privatisation (via the use of proxy variables). Data Envelopment Analysis, Stochastic Frontier and Neural Network are usually used with panel data. In our case, given the nature of the firms and according to Boussafiane, Martin and Parker paper's (1997), it is not possible to carry on a panel data analysis. In fact, the whole sample firms were in a monopoly position market or there were no firms in the internal market that could be considered as having the same technical conditions.

The main idea is to consider the time series data of each firm's as a different DMU and to analyse the relevant changes in efficiency as the result of changes in the control variables on privatisation and corporate governance. More, this paper has the purpose to investigate on the effectiveness of privatisation and corporate governance considering the modification of fiscal status of each firms. In fact, by "privatization decision, the government in effect trades off the relative efficiency of public production against the private investment distortion created by tax policy"[5]. Therefore our purpose is to investigate if the British policy goals of privatisation, like to promote economic efficiency and reduce government interference in the economy, have been reached during the Thatcher government. In this way we will be able to differentiate more clearly on the influence of tax factor on the British programs of ownership change and on the performance of firms privatisation. The considered indices give evidence in the field of productivity, profitability and investment before and after taxation in the four considered firms. In Table 1 there are some information on the sample firms studied. Data are in constant 1990 prices. We deflated them by the appropriate industry indices . The analysed data are: turnover or sales for a proxy of the output and raw material costs, staff costs, depreciation costs, other costs, profit before tax, taxation, retained profit for year, investments, tangible assets as measures of inputs and control variables. As a general note to read the Tables, the shaded area is referred to values relative to the private period while the non-shaded are is referred to data relative to the public period.

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[4] The reason to adopt this approach is linked by the fact the considered firms, as British Telecom, British Gas, British Aerospace, even if they are no more monopolist in the internal market cannot be compared with other firms operating in the same market because they are bigger than the rivals. In fact, even if we cannot consider British Gas a monopolist anymore but it was a monopolist at the time it was privatised. So, now it could be easily done an analysis of efficiency based on panel data for the airways sector or for the gas sector or for the telecommunications sector. But this seems not help us in the investigation on "does tax policy influences efficiency of these firms?"..

[5] Huizinga H. and Bo Nielsen Sren point out how in an open system "private investment decision is distorted by a source-based investment tax" and either in a close system private "investment decision is distorted by either a private investment tax or a saving tax".

Organisation	*Date of sale*	*Sample data*
British Aerospace	*February 1981-May 1985 (Government sold its remaining but kept special £1 share to ensure Company continues under UK control*	*1978/2000*
British Telecom	*November 1984*	*1981/2000*
British Gas	*December 1986*	*1876/1997*
British Steel	*December 1988*	*1975/1998*

Table 1 General information on the sample.

1.3. Models for Stochastic frontier (SF) approach

Since Farrell's article in 1957 there has been a large literature which investigate the frontier of the production function estimation. Current literature suggests multiple approaches that moves from the deterministic to stochastic.

The stochastic frontier production function is a method of estimating efficiency for a group of firms over time proposed by Aigner, Lovel and Schmidt (1977) and Meeusen and van den Broeck (1977). In its original specification it involved a production function specified for cross-sectional data, which had an error term that is composed of two different components. The first of the two components is used to account for random effects, while the second effect it is used to account for technical inefficiency. So, we can express the model in the usual form $Y_i = \beta x_i + u_i$ and taking in to account the previous point we can split the error term in its two components *V* and *U* so that we have:

$$Y_i = \beta x_i + (V_i - U_i)$$

where *i* is the index that consider the number of firms, *Y* is the production (or the log of the production), *x* is a *kx1* vector of the input quantities (or the log of the input quantities) and β is a vector of unknown parameters. *V* are random variables that are assumed to be independent and identically distributed (i.i.d.). $N(0,\sigma_v^2)$ and are independent of the *U* that are non-negative random variables which are assumed to account for the technical inefficiency in production and are assumed to be iid $N(0,\sigma_u^2)$. In the literature there are several variants of the previous model allowing for different distributions of the *U* and *V* term as for instance a half-normal distribution, a truncated distribution or two-parameters gamma distributions (see Kalirajan and Shand 1999 for a survey).

Probably the two most interesting variations of this kind of model are the one of Battese and Coelli (1992) in which the inefficiency effects *U* are non-negative random variables, which are assumed to be i.i.d. as truncations at zero of the $N(n,\sigma^2_u)$ distribution and *n* is a parameter to be estimated and the one proposed by Kumbhakar, Ghosh and McGukin (1991) who proposed that the inefficiency effects *(U)* are expressed as an explicit function of a vector of firm specific variables and a random error. Battese and Coelli (1995) adapted these two models in a way in which allocative efficiency is imposed, the first order profit maximising conditions removed and panel data is permitted is the most useful for our purpose. The model, following the example of Battese and Coelli (1995), has the following form:

$$Y_{it} = \beta x_{it} + (V_{it} - U_{it})$$

where *Y*, *x* and *b* are defined as before and *V* are random variables which are assumed to be iid $N(0,\sigma^2)$ and independent of the *U* which are non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero of the $N(m,\sigma^2\upsilon)$ distribution where $m_{it} = z_{it} d$ where *z* is a *px1* vector of variables which may influence the efficiency of a firm and *d* is an *1xp* vector of parameters to be estimated.

1.3.1. The method: a three step estimation

The procedure to estimate efficiency with a stochastic frontier approach is based on a three step procedure. This three steps process will proceed to estimating the maximum likelihood estimates of the parameters of a stochastic frontier production function. Estimates of the function are obtained with an Ordinary Least Squares. At this point, all the estimators (β) with the exception of the intercept *(β_0)* will be unbiased.

A grid search on γ is conducted[6]. The values for the parameters β (except for β_0) are set to the OLS values. The parameters δ are set to zero at this stage. The grid search across the parameter space of γ considers values for γ ranging from 0.1 to 0.9 in increments of size 0.1. The values selected in the grid search are used as a starting values in an

[6]It can be useful at this stage to define gamma following the approach of Battese and Corra 1977. $\sigma^2 = \sigma_V^2 + \sigma_U^2$ *so we can define* $\gamma = \sigma_U^2 / (\sigma_V^2 + \sigma_U^2)$ *or* σ_U^2 / σ^2

iterative procedure[7] to obtain the final maximum likelihood estimates. The routine here starts with the grid search values and the program then updates the vector of parameter estimates by the Davidson-Fletcher-Powell method and it stops the search when the convergence criterion is satisfied. In this work the convergence criterion is satisfied if the proportional change in the likelihood function and each of the parameters is less than 0.00001.

1.3.2. Estimation results

Before showing the results of estimations, it is important to specify some important features on the nature of data used. Here, as a result of the estimation we will finish with two set of estimators, βs and δs. The betas are the parameters of the inputs used for each firm plus an intercept term usually labelled beta 0. The set of inputs considered for each firm is exactly the same of the previous estimation. This mean that, beta(1) is referred to PRIME MATERIALS(1), beta(2) to SALARIES(2), beta(3) to DEPRECIATION(3) and beta(4) for OTHER COSTS(4). In the set of control variables delta1 is referred to the role played by Investment, delta2 accounts as a measure of the tax charge in each year and delta3 considers the profit before tax as a measure of the firm capability to produce net profits. In Table 2 there is the meaning of each of the estimated parameters and the expected signs.

Parameter	Variable connected	Expected sign	Parameter	Variable connected	Expected sign
beta 0	Intercept term		beta 4	OTHER COSTS	+
beta 1	PRIME MATERIALS	+	Delta 1	INVESTMENT	negative since if the index of goodness of investment increases the inefficiency has to reduce
beta 2	SALARIES	+	Delta 2	CORPORATION. TAXATION	positive because if corporate taxation increases is seen as a source of inefficiency
beta 3	DEPRECIATION	+	Delta 3	PROFIT BEFORE TAX	negative because if the profit from ordinary activity will increase the inefficiency can decrease

Table 2 Meaning and expected signs of the parameters

In Table 3 there are the estimation of the parameters for British Aerospace. All the Betas have the expected sign except for beta 2 (Salaries). The set of control variables is significant and all the deltas have the expected.

	Coefficient	**Standard error**	**t-ratio**		**Coefficient**	**Standard error**	**t-ratio**
Beta 0	1053,61130	0,99999	1053,61290	Delta 1	-2,30501	0,92435	-2,49365
Beta 1	1,01325	0,15258	6,64085	Delta 2	7,83849	2,80731	2,79217
Beta 2	-0,69321	0,29236	-2,37108	Delta 3	-2,27052	0,78027	-2,90991
Beta 3	7,11755	2,00532	3,54933				
Beta 4	1,00657	0,10070	9,99602				

Table 3 British Aerospace Final estimates.

Given the previous estimation, the efficiency index deriving from a stochastic frontier estimation for British Aerospace is summarised in Table 4.

DMU	**Efficiency score.**	**DMU**	**Efficiency score**	**DMU**	**Efficiency score**	**DMU**	**Efficiency score**
1(1979)	0. 905	7 (1985)	1	13 (1991)	1	19 (1997)	1
2 (1980)	1	8 (1986)	1	14 (1992)	1	20 (1998)	1
3 (1981)	1	9 (1987)	1	15 (1993)	1	21 (1999)	1
4 (1982)	1	10 (1988)	1	16 (1994)	1	22(2000)	1
5 (1983)	1	11 (1989)	1	17 (1995)	1	23(2001)	0.999
6 (1984)	1	12 (1990)	1	18 (1996)	1	Average	0.999

Table 4 British Aerospace Technical efficiency estimates

In the set of control variables all of them are significant. We notice that, the level of investments matters to reduce inefficiency. A higher level of taxation increases inefficiency. So we find a direct connection between the level of

[7]This procedure uses the Davidson-Fletcher-Powel Quasi-Newton method: see Coelli (1995).

efficiency and the level of taxation. Furthermore, the level of significance is far better than the one obtained in other studies that use the stochastic frontier method (see for instance Coelli 1995). The level of profit before tax helps to reduce inefficiency. The reason of this is that quite often the retained profit are transformed in investments.

For British Aerospace we can see that there were not difficult periods in terms of efficiency connected with level of taxation and investments. In a work of D'Orio (2001) it is shown that the level of efficiency for this firm is strongly connected with the board quality. In fact, the history of British Aerospace had some "crisis" but they were related to "board difficulties" more than "investment" troubles.

In Table 5 there are the estimation of the parameters for British Gas. All the Betas have the expected sign except for beta 4 (Others Costs). The set of control variables is significant except for the delta 3 (Profit before tax) and all the deltas have the expected sign. Again the level of investment and the level of taxation help to explain the level of efficiency achieved by the firm. Again taxes increases inefficiency while investments reduce it.

	Coefficient	**standard error**	**t-ratio**		**Coefficient**	**standard error**	**t-ratio**
Beta 0	3998,59420	1,00000	3998,5960	Delta 1	-0,31032	0,14369	-2,1596
Beta 1	0,88365	0,18645	4,7393	Delta 2	2,25873	1,39768	1,6161
Beta 2	1,86451	0,86022	3,2348	Delta 3	-0,28196	0,66970	-0,4210
Beta 3	0,67464	1,03774	0,6501				
Beta 4	-1,53288	0,36504	-4,1992				

Table 5 British Gas Final estimates

Given the previous estimation, the efficiency index deriving from a stochastic frontier estimation for British Gas are summarised in Table 6.

DMU	**Efficiency score**	**DMU**	**Efficiency score**	**DMU**	**Efficiency score**	**DMU**	**Efficiency score**
1(1976)	0.991	7 (1982)	0.937	13 (1988)	0.929	19 (1994)	0.995
2(1977)	0.990	8 (1983)	0.951	14 (1989)	0.953	20 (1995)	0.993
3 (1978)	0.980	9 (1984)	0.983	15 (1990)	0.987	21 (1996)	1
4 (1979)	0.930	10 (1985)	0.971	16 (1991)	0.978	22 (1997)	0.931
5 (1980)	0.914	11 (1986)	0.929	17 (1992)	0.996	Average	0.962
6 (1981)	0.917	12 (1987)	0.909	18 (1993)	0.997		

Table 6 British Gas Technical efficiency estimates

From the results obtained it is possible to note that British Gas had three periods of crisis: the first one between 1979 and 1983 the second one from 1986 till 1989 and finally, the level of efficiency drops in 1997. Here we can summarise that two acts of intervention caused serious suffering in the gas industry, the fine tuning of the 1980s and the "take or pay" contract of the end of 1990s. The government imposition of 30% real raise in domestic price during the 3 years from 1980 was something really unusual in the British Gas history. If we observe the results obtained for 1980, 1981, 1982 and 1983 we see that they are very low. This confirm that such fine tuning of an industry's price structure was quite unusual and of a considerable amount and furthermore it was a measure that completely tilted the pricing balance of the market supplied. Probably this represented an improvement in efficiency terms, reversing the favourable treatment of the domestic market but the profitability of British Gas suffered from this measure. In the years following privatisation the efficiency score shows again a low value. This could be due to two reasons: the new tax rules applied to the new "privatised" firm and to the end of the restructuring program conducted under public ownership. The strict regulation imposed to British Gas probably reduced profitability of the firm but, at the same time, increased the welfare of million of customers that observed a drastic fall in the price of domestic gas. The crisis of 1997 is the effect of a "take or pay" contract. The mistake of the management was that they signed a contract without considering the increasing competition and the reduced necessity of supplies in the gas market. The amount of this contract was worth about £16 billion over 5 years. In the past resulting losses would have been more easily met by cross-subsidisation from elsewhere in the monopoly business but the new competitive environment limits such strategy. This adds some further explanations to the bad financial performance of British gas in the last few years. It is clear that the new competitive environment and some bad management decisions have not been a good for British Gas but we cannot talk of a clear failure of privatisation for the community since consumer gained several advantages from the increased competition in the gas sector. The average value of the index under public ownership is of 0.97 while under private ownership it is 0.954. For this index it seems that for British Gas privatisation led to a reduction in efficiency. As we said, privatisation reduced profitability but, given the increased competition the resulting consumer welfare was higher.

In Table 7 there are the estimation of the parameters for British Steel. All the Betas have the expected sign. The set of control variables is significant except for the delta 2 (Tax) but only delta 3 (Profit Before tax) has the expected sign.

	Coefficient	standard error	t-ratio		Coefficient	standard error	t-ratio
Beta 0	-1089,9825	3,2097333	-339,58664	Delta 1	0,31536467	0,16470276	1,9147503
Beta 1	1,8356925	0,17010472	10,791543	Delta 2	-0,88072271	1,2672762	-0,694973
Beta 2	0,22981098	0,22250861	1,0328184	Delta 3	-0,49354774	0,18799599	-2,62531
Beta 3	4,4907949	1,7186806	2,6129317				
Beta 4	0,79244628	0,26601386	2,9789661				

Table 7 British Steel Final estimates.

Given the previous estimation, the efficiency index deriving from a stochastic frontier estimation for British Steel are summarised in Table 8 .

DMU	Efficiency score	DMU	Efficiency score	DMU	Efficiency score	DMU	Efficiency score
1(1975)	0.999	7 (1981)	0.869	13 (1987)	0.966	19 (1993)	0.919
2(1976)	0.923	8 (1982)	0.918	14 (1988)	0.997	20 (1994)	0.942
3 (1977)	0.956	9 (1983)	0.857	15 (1989)	0.999	21 (1995)	0.996
4 (1978)	0.908	10 (1984)	0.928	16 (1990)	1	22 (1996)	1
5 (1979)	0.917	11 (1985)	0.925	17 (1991)	0.962	23 (1997)	0.986
6 (1980)	0.897	12 (1986)	0.958	18 (1992)	0.938	24(1998)	0.963

Table 8 British Steel Technical efficiency estimates

From the data it is possible to see that the more interesting period for British Steel to be examined is the one from 1978 till 1985. Here the efficiency of the firm was relatively low but with the MacGregor period of chairmanship the situation changed and after MacGregor's cure British Steel corporation had a long period of relatively high efficiency. The average value of the index under public ownership is of 0.93 while under private ownership it is 0.97. Even for this index it seems that for British Steel privatisation led to an increase in efficiency.

It is clear that the average of the index under public ownership was lower than the one under private. But the big shake-out on British Steel has been the MacGregor period. Here the foundations of the new efficient course was built. We refer to MacGregor's time as "a private behaviour of a public manager". It is worth exploring the possible meaning and interpretation of the non significance of the parameter connected to taxation. The steel sector has been subject to steel quotas from the early 1980s. So, quite often, the government was forced to fund British Steel losses to "save" the UK steel sector. This means that the connection between taxation and efficiency was not really strong since the Government was keen to pay for every loss obtained by British Steel just to maintain operative the sector. Under private ownership the early 1990s were difficult years because the public actor was not contrasting anymore the negative effects of quotas and the increasing competition from countries of the Far East. This process lead to the merging between British Steel and Koninkljke Hoogovens to achieve scale gains and regain profitability.

In Table 9 there are the estimation of the parameters for British Telecom. All the Betas have the expected sign. The set of control variables is not significant and only Delta 1 (Investment) has the expected sign.

	Coefficient	standard error	t-ratio		Coefficient	standard error	t-ratio
Beta 0	1346,7711	0,9999997	1346,7715	Delta 1	-0,4876	0,76897121	-0,63405452
Beta 1	0,7118	0,16175686	4,4002967	Delta 2	-0,3429	1,245347	-0,27537739
Beta 2	0,8645	0,061859049	13,975398	Delta 3	0,1589	0,56145718	0,28303096
Beta 3	2,7681	0,28396797	9,7479499				
Beta 4	0,6165	0,18122068	3,4021816				

Table 9 British Telecom Final estimates.

Given the previous estimation, the efficiency index deriving from a stochastic frontier estimation for British Telecom are summarised in Table 10.

DMU	Efficiency score	DMU	Efficiency score	DMU	Efficiency score	DMU	Efficiency score
1 (1981)	0.967	6 (1986)	0.995	11 (1991)	0.994	16 (1996)	0.994
2 (1982)	0.979	7 (1987)	0.993	12 (1992)	0.981	17 (1997)	0.995
3 (1983)	0.938	8 (1988)	0.982	13 (1993)	0.982	18(1998)	0.993
4 (1984)	0.954	9 (1989)	0.987	14 (1994)	0.989	19(1999)	0.995
5 (1985)	0.994	10(1990)	0.994	15 (1995)	0.991	20 (2000)	0.997

Table 10 British Telecom Technical efficiency estimates

In the set of control variables the only one that has the expected sign is Delta1 while the others are not significant. So, in the case of British Telecom the level of investments increases the level of efficiency achieved. In British Telecom 1983 and 1984 were years in which efficiency was relatively low while after this period, if we exclude a very small drop in 1988, 1989, 1992 and 1993 the efficiency score was relatively high. The results obtained are quite similar with the one obtained with DEA. The programme of restructuring of BT started to give effect after 1985. In 1985 the new legislation enabled British Telecom to become more responsive to competition in UK and to expand its operations globally. Commercial freedom granted to British Telecom allowed it to enter into new joint ventures and, if it so decided, to engage in the manufacture of its own apparatus. As we can see from the index, after 1985 the values are close to the maximum. As noted, in 1988, 1989 and 1992 the efficiency indicator is under the maximum value: competition here is requiring new measures to be efficient, as the market need. The average value of the index obtained with the SF estimation under public ownership is 0.96 while under private ownership it is 0.991. Even for this index it seems that for British Telecom privatisation led to an increase in efficiency.

1.4. The Data envelopment Analysis (DEA) model

The non-parametric method used to estimate efficiency in privatised firms is a Data Envelopment Analysis (DEA). To assess the efficiency of decision making units we use a linear programming technique. This method is very useful when we need to consider a framework characterised by several inputs and several outputs. Data Envelopment Analysis (DEA) is a linear programming-based technique for measuring the relative performance of DMUs in presence of multiple inputs and outputs, otherwise any comparisons is difficult. It provides a means for assessing the relative efficiencies of DMUs with minimal prior assumptions on input–output relations in these units. DEA is largely used for numerous applications, in fact; it does not require any underlying assumptions about inputs and outputs; it allows to consider simultaneously multiple inputs and multiple outputs; it provides to differentiate between efficient and inefficient DMUs and can be used to detect the sources of deficiency for each of the inefficient DMUs specific inefficiencies.

DEA analysis has replaced the deterministic parametric frontier analysis and has increased the analysis of productive efficiency in different sector economy (Hjalmarsson and al. 1996). Recently this non-parametric method has been used to estimate efficiency in privatised firms. To assess the efficiency of decision making units we use a linear programming technique. This method is very useful when the analysis considers a framework characterised by several inputs and several outputs.

In this study we performed a pooled DEA because:

- the considered firms are or were monopolist at the time of privatisation and several of them are still taking some monopolist advantage at least in the internal market;
- an international comparison could be useful, but different macroeconomic conditions between countries and different costs of inputs will lead to further complications.

This is the main reason why the DMUs analysis is more effective even if in this case to talk of efficient firms it is a bit misleading. With this kind of analysis we find the efficiency score of each DMU, looking if some DMUs are more efficient than others, figure out the set of efficient DMUs based on the set of non-dominated solution (see S. Y. Sohn and H. Choi)

Moreover, most DEA analyses compare the performance of DMUs in the same time period. One approach to work with longitudinal data is to compare cross-sectional across the time periods. This approach treats the performance of a DMU in each time period as being independent from the which ones realised in the previous period. For cross-section/time series/panel data we use a Malmquist index to examine changes across time periods. This provides two types of information:

- efficiency evaluations for each DMU between each successive pair of periods;
- decomposition of productivity change into two mutually exclusive components: efficiency and technical change.

In this case we consider a model with just one output and four inputs. Charnes, Cooper and Rhodes (1978) introduced this sort of method for the first time in 1978. Since than there have been several works using DEA (e.g. Lovell 1993, Ganley and Cubbin 1992, Coelli and Perelman 1996, Murillo-Zamorano and Vega-Cervera 2000). The basic idea of DEA is to evaluate a sort of distance function for a group of firms in the same industry or for a group of decision making units (i.e. if we use a time series for just one firm). In a general case we consider data on K inputs and M outputs (in our case 1) for each of the N firms (or decision making units) considered. For i-th firm these are represented by the column vectors x_i and y_i respectively. The full set of data are so represented by the matrix *KxN* for the inputs and the *MxN* matrix for the output. In our case this matrix will be just a vector with *i* dimension where *i* represent the different decision making units over time *N*.

Data Envelopment Analysis can be explained using a ratio form. For each firm we need to obtain a measure of the ratio of all outputs over all inputs such us $\frac{\alpha y_i}{\beta x_i}$ where α and β are two vectors of size *Mx1* for α and *Kx1* for β where again *M* is the number of output (1 in our case) and *K* is the number of inputs. To find the optimal values of the parameters α and β we need to solve the following problem :

$$\max_{\alpha,\beta} \frac{\alpha y_i}{\beta x_i} \text{ subject to} : \frac{\alpha y_j}{\beta x_j} \leq 1 \text{ and } u, v \geq 0$$

This classical formulation gives us a problem (see Coelli and Perelman 1996) of infinite solutions. In fact if we find two vector α^* and β^* as a solution, every combination $\gamma\alpha^*, \gamma\beta^*$ will also be a solution so, following again Coelli *et al.* 1998, it is better to rearrange the previous problem in a slightly different way as:

$$\max_{\psi,\zeta} \psi y_i \quad \text{subject to } \zeta x_i = 1; \ \ \psi y_j - \zeta x_j \leq 0 \ \text{ and } \ \psi, \zeta \geq 0$$

where the pedix *j* it refers to the number of firms in the sample and it goes from 1 to N. An equivalent envelopment form of the previous multiplier form of DEA is the following (using duality):

$$\min_{\theta,\lambda} \theta \quad \text{subject to} \quad -y_i + Y\lambda \geq 0 \ \ ; \ \ \theta x_i - X\lambda \geq 0 \ \text{ and } \ \lambda \geq 0$$

This envelopment form, for the fewer constraints that it has, is the one that has been more widely used but there is a price to pay since if we are able to estimate the multiplier form of the DEA model we will get more information since the weights ψ, ζ can be interpreted as normalised shadow prices and, in a more general purpose, the multiplier form can be used to determine returns to scale properties in models with variable returns to scale.

1.4.1. The Model

The previous envelopment form is usually associated with constant returns to scale (CRS) assumption. In this study I have done the estimation even for the assumption of variable returns to scale (VRS) for two reasons. First, this assumption seems to explain better some features of the organisation studied[8]; and second by conducting a CRS and a VRS DEA upon the same data allows us to decompose the technical efficiency (TE) scores obtained into two components, one due to scale inefficiency and one due to "pure" technical inefficiency (i.e. wrong input mix or managerial inefficiency). If we have a difference between the two TE scores for a specific Decision Making Unit this indicates that the Decision Making Unit has scale inefficiency and we can calculate this inefficiency using the difference between the VRS TE score and the CRS TE score. Further details will be given when I will comment on the results. To apply a variable return to scale assumption to the previous envelopment form some slight modification are needed. In particular I am referring to the need of adding the convexity constraint to the previous model to obtain:

$$\min_{\theta,\lambda} \theta \ \text{ subject to} -y_i + Y\lambda \geq 0 \ ; \ \theta x_i - X\lambda \geq 0 \ ; \ \lambda \geq 0 \ \text{ and } \ N1'\lambda = 1$$

where *N1* is a *Nx1* vector of ones. This approach forms a convex hull of intersecting planes which envelope the data points more tightly than the CRS conical hull. This is the main reasons why the TE scores obtained with VRS are greater than or equal to the one obtained with CRS.

1.4.2. Estimation results

In Table 11 there are the estimations of efficiency for all the sample firms considering an assumption of variable return to scale. For British Aerospace we have 20 observations from 1978 to 1997. It was not possible to obtain previous data on BAe because it was organised as British Aerospace just in that year. The average under public ownership (4 observations) is 100% while under private ownership (16 observations) it is 97,7%. Again under public ownership efficiency is slightly higher than under private but here there are at least two major features to point out. The number of observations under public ownership is extremely lower that under private ownership. This is not due to a lack in data but just to the fact that British Aerospace was created in 1977 and privatised in 1981. If we use only the first 4 values of

[8] A preliminary DEA with a constant return to scale assumption has been done but the results obtained with a variable return to scale assumptions seems to catch a bit more elements. However there are not considerable difference in the results obtained with the two assumptions. So, just to clarify, the comments will be based on the VRS assumptions even if i will provide the estimation for the CRS.

the index after privatisation we obtain a value of 99.5% that shows that the difference in performance is extremely small.

We would like to stress here that we are avoiding to state when we obtain a very high value of the index that the efficiency is the maximum possible. The nature of data does not allow this conclusion. We could instead say that given the nature of the sector studied some DMU are more efficient than others. This because we do not have panel data with several different firms but data on the same firms for different periods of time. So each DMU is relatively more efficient than others but we cannot say anything in terms of absolute efficiency (several organisation studied were monopolies at the time of privatisation). To answer the question if privatisation enhanced efficiency in British Aerospace is not an easy task.. Since privatisation the company has been deeply unstable, unable to cope with its industrial scale and deep-seated financial weaknesses. The company has also suffered from disruptive changes in management. In 1988 and 1989 the efficiency index scores the lowest value of the whole series. Given the fact that this index has a quite homogenous trend, the fact that the value for 1988 is 91% is quite worrying and extremely significant. The reasons for this poor performance are connected with the Board troubles and with Rover acquisitions in 1988. In September 1989 the recession doomed the CEO strategy. Airlington Properties was purchased at the peak of the property boom and now the scope for developing surplus company property and selling it off for huge gains dissolved as the property market slumped. Furthermore, car sales were also considerably depressed. The value of the efficiency index for the year is relatively low.

The large losses of the early 1990s led to a major rationalisation of the company including the sale of Rover in 1994. Since 1992, the company has been trying to integrate parts of the business where gains can be made by putting together business units to achieve management and scale economies. But the value of the efficiency index for 1992 is only 93%, again, a relatively low value in a very homogenous series.

British Aereospace				***British Gas***				***British Steel***				***British Telecom***			
1978	1.000	**1990**	1.000	**1976**	1.000	**1988**	0.965	**1975**	1.000	**1987**	1.000	**1981**	1.000	**1993**	1.000
1979	1.000	**1991**	1.000	**1977**	1.000	**1989**	1.000	**1976**	1.000	**1988**	1.000	**1982**	1.000	**1994**	1.000
1980	1.000	**1992**	0.940	**1978**	1.000	**1990**	1.000	**1977**	1.000	**1989**	0.985	**1983**	0.936	**1995**	1.000
1981	1.000	**1993**	1.000	**1979**	0.890	**1991**	1.000	**1978**	1.000	**1990**	1.000	**1984**	0.948	**1996**	1.000
1982	1.000	**1994**	1.000	**1980**	0.841	**1992**	0.953	**1979**	0.968	**1991**	0.937	**1985**	1.000	**1997**	1.000
1983	1.000	**1995**	1.000	**1981**	0.771	**1993**	0.857	**1980**	1.000	**1992**	0.953	**1986**	1.000	**1998**	1.000
1984	1.000	**1996**	1.000	**1982**	0.701	**1994**	0.789	**1981**	0.934	**1993**	1.000	**1987**	0.997	**1999**	1.000
1985	0.983	**1997**	1.000	**1983**	0.728	**1995**	0.782	**1982**	0.928	**1994**	1.000	**1988**	1.000	**2000**	1.000
1986	1.000	**1998**	0.969	**1984**	0.957	**1996**	0.985	**1983**	0.949	**1995**	1.000	**1989**	1.000		
1987	1.000	**1999**	0.796	**1985**	1.000	**1997**	1.000	**1984**	1.000	**1996**	1.000	**1990**	1.000		
1988	0.910	**2000**	0.989	**1986**	1.000			**1985**	1.000	**1997**	0.954	**1991**	1.000		
1989	0.978			**1987**	0.943			**1986**	1.000	**1998**	0.951	**1992**	0.994		

Table 11 DEA results of the sample firms.

For British Gas we have 22 observations. The average of the index of efficiency under public ownership is 88.89% while under private ownership it is equal to 93.95%. So the average efficiency for British Gas is higher under private ownership. Two things to point out: even if the average is higher under private ownership, we have 5 “frontier” DMU (efficiency=1) under public ownership while 4 under private ownership. Looking at the data, the decline under public ownership began in 1979 till 1983 when measures to allow privatisation of British Gas were implemented. When British Gas was privatised the index of efficiency was at a maximum. Until 1992 the performance of British Gas was convincingly positive. The years from 1993 till 1996 were strongly influenced by a very inefficient contract.

The so-called “take or pay” contract seriously affected efficiency in terms of profitability of British Gas. To ensure adequate supplies and not foreseeing the current glut in the gas market, the company entered into so-called “take or pay” contracts with gas producers under which it contracted to pay for supplies whether they were required or not. In the past resulting losses would have been more easily met by cross-subsidisation from elsewhere in the monopoly business but the new competitive environment limited such strategy. British Gas is trying now to renegotiate the contracts but, to make the things even worse, Transco, which now yields much of the company’s earnings, faced a stringent price review by Ofgas in 1996. This adds some further explanations to the bad financial performance of British Gas in recent years. The first proposal for privatisation of British Gas came in 1980 with the suggestion that British Gas showrooms should be sold. Plans that are more ambitious gained credibility in the 1984. This is due even to the regained efficiency (95.7%) of the firm at this time. Two acts of intervention caused serious suffering in the gas industry, the fine tuning of the 1980s and the “take or pay” contract. The government imposition of 30% real raise in domestic price during the 3 years from 1980 was something really unusual in the British Gas history. If we observe the results obtained for 1981, 1982 and 1983 we see that there are the lowest obtained in all the period studied (results in line with the one obtained by Boussafiane *et al.* 1997). In fact, the efficiency was 77% in 1981, and fell to around 70% for 1982 and 1983. This confirm that such fine tuning of an industry’s price structure was quite unusual and of a considerable amount and furthermore it was a measure that completely tilted the pricing balance of the market supplied.

Probably this represented an improvement in efficiency terms, reversing the favourable treatment of the domestic market but the profitability of British Gas suffered from this measure.

The Government announced the decision to privatise British Gas in May 1985.At this time British Gas was fully efficient (TE=1) The firm's profitability was an asset that the government pointed out a lot during the privatisation plan. In fact, from 1979 till 1984 the TE scores were under the maximum value. From 1985 till 1991 British Gas has scored very well with several DMUs on the boundary and very good results even in cases were the TE score was not at the maximum. However, in 1992 we can observe a reverse in the trend of the score: something important changed. The Secretary of State forced the company to open its contract market to competitors and in few years there were 42 independent gas marketing companies supplying contract customers in the commercial and industrial markets. In 1994 and 1995 British Gas scored the lowest ratio on efficiency during private ownership (around 78%). This was the beginning of an uneasy story of regulation. The strict regulation imposed to British Gas probably reduced profitability of the firm but, at the same time, increased the welfare of million of customers that observed a drastic fall in the price of domestic gas. Why was British Gas unable to react in an efficient way to this regulation? The fact that really caused troubles to British was the "timing" of regulation and not regulation itself. As we saw, in these years British Gas was facing a "take or pay" contract. The mistake of the management was that they signed a contract without considering the increasing competition and the reduced necessity of supplies in the gas market. The amount of this contract was worth about £16 billion over 5 years. In the past resulting losses would have been more easily met by cross-subsidisation from elsewhere in the monopoly business but the new competitive environment limits such strategy. British Gas is trying now to renegotiate the contracts but, to make the things even worse, Transco, which now yields much of the company's earnings, faced a stringent price review by Ofgas in 1996. This adds some further explanations to the bad financial performance of British gas in the last few years.

The effectiveness of privatisation for British Gas it is quite controversial. The reason of this controversy is basically due to two reasons. It is true that several DMU's scores had a better value and trend during public ownership but this is mainly due to the very favourable environment that British Gas was facing before privatisation and to the several constraint and regulatory policy that the Government implemented after the privatisation of the firm. It is clear that the new competitive environment and some bad management decisions have not been a good for British Gas but we cannot talk of a clear failure of privatisation for the community since consumer gained several advantages from the increased competition in the gas sector.

For British Steel we have 24 observation from 1975 to 1998. British Steel was privatised in 1988. The value of the average efficiency index under public ownership is 98,3% while it is 98% under private ownership. So it seems that British Steel was slightly more efficient under public ownership. Here an important point is to note that from 1984 to 1988, after that British Steel was not facing a "favorable" environment anymore, the declining trend has been reversed and kept to a very high level until privatisation. These were the "Mac Gregor's years". Nine DMU were fully efficient under public ownership while just 6 under private ownership. The analysis could help to understand if privatisation was for the Government an efficient tool to achieve some scheduled targets. As we said in the "step by step" conclusions highlighted at the end of each firm's study, in certain cases there has been an improvement in the performance of the firm, in other cases this improvement has not been so clear or relevant. The important point here is to understand if we can talk of a failure or of a success of privatisation. To give an answer to this question we have to keep in mind which one were the objectives of privatisation. Several times to improve efficiency has been seen as the only objective of privatisation. If this was the objective then we have to point out two things: not all the privatisations were successful in regard to this target and, more important, the same target could be probably obtained even under public ownership.

If we observe, for instance, British Steel data, we realise that a serious improvement in performance was obtained prior to privatisation. Here the MacGregor's group of manager was perfectly able to behave in a "private" way to achieve important improvements in performance and a restructuring of the firm. However, probably this was a single case. In all the other cases that I analysed , I was not able to recognise a "pattern" in the data that could suggest a possible "private behaviour" of a "public manager".

For British Telecom we have 20 observations from 1981 to 2000. British Telecom was privatised in 1985. The average of the index under public ownership it is 97,68% while under private ownership it is 99,9 that shows how British Telecom "private" DMU are relatively more efficient than "public" DMU". As we saw in the firm's history, this is probably due to an increased competition in the sector after privatisation. British Telecom was separated from the Post Office in 1981 and became a free-standing corporation though still publicly owned. The efficiency index for 1983 and 1984 indicates that there was not a situation of full efficiency. In fact the values of about 94% are a clear indicator that something could be done to improve the situation. The years between 1987 and 1990 shows several maximum value for the index. The small lack in efficiency for 1987 can signal a minor problem in the reorganisation of the company once it was facing a stronger competition. From then on the score achieved is at the maximum or close to the maximum in 1992 and in 1995. Again, it is important to notice that, under public ownership British Telecom was basically a monopolist in the sector, after privatisation the sector has been opened to competition in many services for customer. In terms of efficiency, the results obtained with the DEA estimation show a clear situation. In fact, the only "private" year in which we observe some input slacks is 1992 while during public ownership the situation about possible input slack is a bit more complex. In the previous analysis we concluded saying that privatisation was for sure a good way to increase competition in the sector and, probably, to increase welfare for the customers. Here we can say even that British Telecom, during its private years, was quite effective to face the increasing competition.

1.5. A general comment on results: similarities and differences between the two methods

Given the DEA results obtained, at this stage of the work it is possible to give more evidence on the fundamental question: has privatisation enhanced efficiency? Has fiscal policy affected technical inefficiency of the considered firms? Before giving some comments on the issue a note on the methodology is needed. The usual way in which DEA is used and is more effective is with panel data. In this study it was not possible to carry on a study with panel data basically for one reason: the firms considered are or were monopolist at the time of privatisation and several of them are still monopolist at least in the internal market. An international comparison could be useful but at the same time the different macroeconomic conditions between different states and the different costs of inputs all over the world will lead to further complications. This is the main reason why a DMUs analysis is more effective even if in this case to talk of efficient firms is a bit misleading. With this kind of analysis we can see if some DMUs are more efficient than others but we cannot say anything on the general efficiency of the firm. So we can see if privatisation has increased efficiency of DMUs but we cannot say anything on the efficiency of the firm overall. The fundamental difference in objectives under public and private ownership is crucial. Maximum profit sometimes is not the main target for public firm so, considering this issue, the firm can be efficient as well in pursuing the given objectives.

At this point, it is necessary to compare the results obtained with the two methods. In Table 12 there is a comparison for each firm studied of the two efficiency scores obtained. British Gas shows a clear result in both analyses, British Telecom seems to be the most flexible firm in changing environments and another case of privatisation with a successful outcome, British Steel has a higher value of the efficiency index under public ownership but for this firm the MacGregor period under public ownership was a time in which efficiency increased considerably. For British Aerospace instead probably the observations under public ownership are not enough to give a final judgement. Probably for British Aerospace the Rover acquisition was a bad management decision and, in terms of efficiency, this caused private ownership to be less effective than the public one.

For British Gas the trend of the two indices is quite similar but the magnitude of the values is different. In fact, for the years 1976, 1977, 1978 the DEA gives a maximum value while the Stochastic Frontier (SF) gives a slightly decreasing trend even for high scores. In1979 the DEA index drops quite consistently and maintains this decreasing trend till 1982, starting to raise in 1983 and going back to high value in 1984 to 1986, it drops again in 1987 and 1988 and it goes back to the maximum from 1989 to 1991. In 1992 the DEA index starts to decrease until 1995 and it jumps back to high value in 1996 scoring the maximum in 1997. The trend of the SF index is similar for several periods of time but the variations are smoother. Furthermore, the control variables, related to investment and tax, helps to avoid the sudden and wide variation there are one of the limits of the Dea methods. If we consider the period between 1992 and 1997 the SF index doesn't show the variations that we observe in DEA. As we saw the take or pay contract gave some troubles to British Gas management but the signal that we receive from DEA seems over-amplified. Ones we add the control variable such as investment, tax and retained profit, we can note that the sources of inefficiency signaled from DEA were strictly connected to investment plans and fiscal policy and hence not only to the take or pay contract costs. In the SF index the period between 1979 and 1982 included, is a period of "crisis" as already indicated from DEA estimation. The difference in the results are on the level of variation of efficiency. In fact, we observe small differences between the considered DMUs in the SF results while the DEA scores suggests that the efficiency in 1979 was 88% while in 1982 was 70%. Again SF shows smoother results than DEA.

British Gas			*British Aerospace*			*British Telecom*			*British Steel*		
DMU	***DEA***	***SF***	***DMU***	***DEA***	***SF***	***DMU***	***DEA***	***SF***	***DMU***	***DEA***	***SF***
1976	1.000	0.991	**1978**	1.000	0.905	**1981**	1.000	0.967	**1975**	1.000	0.999
1977	1.000	0.990	**1979**	1.000	1	**1982**	1.000	0.979	**1976**	1.000	0.923
1978	1.000	0.980	**1980**	1.000	1	**1983**	0.936	0.938	**1977**	1.000	0.956
1979	0.890	0.930	**1981**	1.000	1	**1984**	0.948	0.954	**1978**	1.000	0.908
1980	0.841	0.914	**1982**	1.000	1	**1985**	1.000	0.994	**1979**	0.968	0.917
1981	0.771	0.917	**1983**	1.000	1	**1986**	1.000	0.995	**1980**	1.000	0.897
1982	0.701	0.937	**1984**	1.000	1	**1987**	0.997	0.993	**1981**	0.934	0.869
1983	0.728	0.951	**1985**	0.983	1	**1988**	1.000	0.982	**1982**	0.928	0.918
1984	0.957	0.983	**1986**	1.000	1	**1989**	1.000	0.987	**1983**	0.949	0.857
1985	1.000	0.971	**1987**	1.000	1	**1990**	1.000	0.994	**1984**	1.000	0.928
1986	1.000	0.929	**1988**	0.910	1	**1991**	1.000	0.994	**1985**	1.000	0.925
1987	0.943	0.909	**1989**	0.978	1	**1992**	0.994	0.981	**1986**	1.000	0.958
1988	0.965	0.929	**1990**	1.000	1	**1993**	1.000	0.982	**1987**	1.000	0.966
1989	1.000	0.953	**1991**	1.000	1	**1994**	1.000	0.989	**1988**	1.000	0.997
1990	1.000	0.987	**1992**	0.940	1	**1995**	1.000	0.991	**1989**	0.985	0.999
1991	1.000	0.978	**1993**	1.000	1	**1996**	1.000	0.994	**1990**	1.000	1
1992	0.953	0.996	**1994**	1.000	1	**1997**	1.000	0.995	**1991**	0.937	0.962
1993	0.857	0.997	**1995**	1.000	1	**1998**	1.000	0.993	**1992**	0.953	0.938
1994	0.789	0.995	**1996**	1.000	1	**1999**	1.000	0.995	**1993**	1.000	0.919
1995	0.782	0.993	**1997**	1.000	1	**2000**	1.000	0.997	**1994**	1.000	0.942
1996	0.985	1	**1998**	0.969	1				**1995**	1.000	0.996
1997	1.000	0.931	**1999**	0.796	1				**1996**	1.000	1
			2000	0.989	0.999				**1997**	0.954	0.986
									1998	0.951	0.963

Table 12 Comparing the two methods.

The two indices indicate a clear improvement in performances before privatisation. For British Aerospace the situation is similar. The DEA index has some drops (1992, 1998 and 1999) while the SF index is really flat. The large losses of the late 1980s led to a major rationalization of the company including plant closure and redundancies. The 1992 value of 0.94 signals a lack in efficiency and the sale of the Rover car division to the German Company BMW in 1994 is the reaction of BAEs management to the crisis. For British Telecom the two indices give basically the same results with the exception in magnitude for the years 1981 and 1982. Again there is evidence that the efficiency improves consistently before privatisation. So, the process of rationalization (investment in technologies, rules governing tax relief etc.) that usually happens before privatisation seems to be very effective. British Steel has two major features: the private period shows the same results with the exception of 1993 and 1994 and the other feature is that during the public ownership period while the DEA shows maximum value from 1975 to 1978 , the SF starts to signal the deep crisis that characterized the late 1970s and early 1980s. Given the story of MacGregor appointments as Chairman it seems again that the SF method is able to describe more precisely what happens. A similar history happens for the difficulties of early 1990s. In fact, while the DEA index just signals this crisis with the two drops of 1991 and 1992, the SF index explain much better the evolution of this crisis.

1.6. Limits of SF and DEA approaches in the case of non linear production functions

The used approaches provide some useful results, such as the effectiveness of restructuring programs ante privatisation, the importance of tax relief (connected with the difference in objectives existing between public and private owned enterprises) for the public owned firms and the most effective of investment policies of private firms, but both have been criticised by some literature[9] because they assume only a few restrictions when estimating production frontiers. In particular, :

the SF,

a) has been modelled through Cobb-Douglas specifications or "through more flexible transcendental logarithmic form where we include non-linear effects into a linear parametric model" (Santín González and Valiño Castro),
b) needs a number of strong assumptions about the form of relationship between dependent variables and explanatory factors;

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[9] See Performance and Innovation Unit, moderning government, adding it up – Improving analysis and modeling in central Government, Case studies, Cabinet Office.

The DEA:

a) assume "convexity of the set of feasible input/output combinations, variables returns to scale and strong disposability of inputs and outputs" (Santín González and Valiño Castro);
b) requires a big data set;
c) creates a separate linear program for each DMU and cannot predict the efficiency level of the new DMU without another DEA analysis and even if is good to estimate the relative efficiency of a DMU it doesn't compare with the "theoretical maximum",
d) converge very slowly to the absolute efficiency,
e) can implies significant problem with noise and error measurement. More, as seen above the efficiency score of each DMU figure out the set of efficient DMUs based on the set of non-dominated solution that doesn't provides to ascertain trends in performance or to observe the persistence of efficiency or inefficiency.

The above empirical results show that some of these critics applies. In fact, it seems very difficult to say if fiscal policy explains technical inefficiency of DMUs in the privatised firms because we are considering complex socio-economics realities whose role is changing both at micro level and macroeconomics scenario, so it is very difficult to conclude for one or another solutions without making further investigations. DEA approach integrates[10] the SF estimation but assuming each DMU is interested in efficiency maximization unfortunately doesn't distinguish between DMUs different objective, so the strategic behaviours are not reflected in the score.

Considering the basic argument of this paper is go beyond the descriptive analysis of performance, focusing on their usefulness for normative and positive analysis, seems the whole framework for performance assessment should imply a greater caution in the choice of tools that given their characteristics can strongly affect the results and the relative analysis. Looking at the recent literature, seems more realistic to use each tools as part of a holistic framework to study performance, therefore its useful has to be evaluated according to the contribution to better understand the generative mechanisms which implies the differences in performance. For these reasons we have to look at other tools, like neural network, multidimensional scaling etc., that seems better consider, using non-linear algorithms, the characteristics of the processes which has generated the data. For these reasons we consider further tools to analyse the data collected with the purpose to compare the output of others non-parametric tools like Neural Networks (NN). This kind of extra analysis should be useful to overcome the limitation of DEA given that NN "offer the possibility to interpreter the results and the estimation production function (e.g. Interpretation of the technology parameters, the form of the production function, the contribution of each production input)"[11].

1.7. Neural Networks as tools for Assessing the Efficiency of DMU

The original inspiration for the structure of the artificial neural networks (ANN) comes from the workings of the brain therefore they are tools for processing sets of input information and associated outputs with the purpose to capture the relationships between input-output. More, NN are useful for handling data with noise and uncertainty and also in the case inputs and outputs are related in non-linear ways or in the case is very difficult to understand in advance the linear equations. Further details can be provided by Hornik et al. (1990) paper, that shows how models can approximate any function and its derivatives to any degree of accuracy.

ANN have performed well compared with other techniques for classification, regression and time series forecasting when the data contains highly non-linear relationships. The beginner who promoted the applicability of artificial neural networks as tools to evaluate performance was Athnassopoulos and Curram in 1996. Then Costa and Markellos in 1997 applied this tools to evaluate public transport efficiency and compared the results of Multilayer Percepton (MLP) with econometric regression and DEA. The main difficulties of this comparison are the determination of comparable efficiency score between the non-linear statistical estimators of neural networks and data envelopment analysis. We overthrow this difficulties following Costa and Markellos (1997) approach. Then considering the technical characteristics of each network, like no a priori assumptions, flexibility, ability to fix the hidden layer, oversize etc.., we use choose to implement a feedforward multilayer neural networks to analyse the efficiency performance of each privatised firm and to investigate if there are non-linearity in the used data set. In fact, in last case it might potentially affect estimations of efficiency obtained by stochastic frontier analysis and data envelopment analysis with variables returns to scale.

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[10] Performing the DEA we conducted a peers analysis, which we do not include in this work for length reasons, to understand the behavior of public and private owned firms in terms of organizational process. The aim of this paper is not to describe and explain these features but an interesting results came out: while not fully efficient public DMU were imitating public and private frontier DMU, private not fully efficient DMU were imitating just private frontier DMU. This means that probably, it is needed a more "private" behaviour of public firms.

[11] Costa and Markellos (1997) p. 306. In addition, they highlight that the considered network do not necessarily overfit the data studied and therefore they can be used for analysisng data and decisions outside the estimation sample.

1.7.1. The feedforward networks

The feedforward networks is composed like in the figure

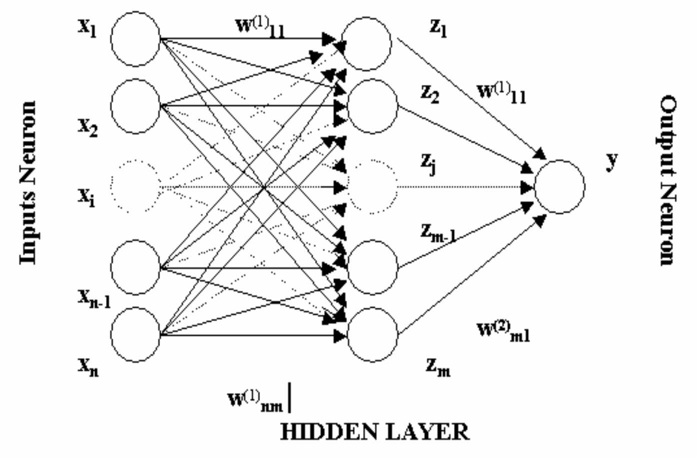

Figure 1 The network structure

by an input layer, hidden layers, and an output layer. The nodes, in the input layer receive the input signals and distribute them forward to the network. In the upper layers, each node receives a signal which is a weighted sum of the outputs of the nodes in the layer below. Each layer connected to the immediately previous layer generally three layers (input, hidden, and output layer) are sufficient for the vast majority of problems; each hidden layers have different activation functions, thus, the output layer is built on the data.

Learning to match a vector of inputs (X) to a vector of outputs (Y) through the interactions among neurons (W), so the learning the function is the following: $\Re^n \xrightarrow{f} \Re^m$, $f(W;X) \sim Y$ where $x(p) \in \Re^n$ is the input vector and $y(p) \in \Re^m$ is the output vector.

$$y_k = f_0\left[\sum_{i \to k} w_{ik} x_i + \sum_{j \to k} w_{jk} f_h\left(\sum_{i \to j} w_{ij} x_i\right)\right]$$ where *i* is the output, *j* is the hidden and *k* the output layer.

The user can define the number of input and output neurons, the number of hidden layers and the number of neurons in each hidden layer, so for our data set we choose to overtrain a overparameterised network to optimise by repeatedly adjusting an initial set of random weights using the backpropagation technique[12] with the purpose to overfit a NN model which loose its ability to generalise over unknown data. The application of this learning rule for the multilayer nets has been done by Rumelhart, McClelland and Williams in 1986, it implies the initial error is backpropagated to the previous layer and the weights are modified following this rule: $w_{ij}(n+1)=w_{ij}(n)+\Delta w_{ij}(n)$. The modified rule of weights between $i \to j$ is $\Delta w_{ij}(n) = \eta\delta_j(n)y_i(n)$. Then by trial-and-error and using the Schwartz information criterion[13] we set the optimal network topology in order to avoid models with more neurons and hidden layers than required.

The characteristics of used data doesn't permit to exclude part of the data in estimating the production frontier, therefore, we use a synthetic sample[14] for training and the cross-validation, then original sample was use on the same nets without learning but just for cross-validation.. The ANN frontier and efficiency measures have been calculate, like in Costa Markellos (1997), using the corrected ordinary least squares (COLS) that estimates the vector of "technology parameter β" by "OLS and then corrects the downward bias in the estimated intercept by shifting it upwards to the point that all corrected residuals are nonpositive and at least one is zero".

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[12] Therefore, the error propagates backwards from the output layer to the hidden layer(s), until it reaches the input layer. Using the method of gradients that converge by a unidimensional progression of {Xk} which converge at the minimum x*= 0 of function verifying the relation for $\forall k \quad \|x_{k+1} - x^*\|_2 \le \left(\frac{\lambda_M}{\lambda_m}\right)^{\frac{1}{2}} \left(\frac{\lambda_M - \lambda_m}{\lambda_M + \lambda_m}\right) \|x_k - x^*\|_2$ where λ_M and λ_m are the maximum and the minimum auto value of Q.

[13] It penalizes the over-parameterised model configuration.

[14] this sample was generated by adding to the original data statistical noise normally distributed. This addition was done 10 times to have a synthetic data available for training.

After designed the optimal network design, the training was stopped at the lowest mean squared error training. The cross validation was done on the 20% of synthetic data. After that the frontier was estimated by using an oversized network to overfit[15] the original data[16]. Considering out set of data with several inputs (Raw Costs, Staff costs, Depreciation costs, Other costs) and one output (Sales), at constant price, the use of the neural network will yield an expected output for each DMU. The expected outputs is compared with the observed in order to calculate the efficiency of each DMU in converting its input levels into output. The choice of an efficiency measurement have been investigated in literature[17], "it is evident that no single approach appears to be overall superior and that the selection must depend on the specific characteristics of the problem underhand" (Costa and Markeollos).

The differences between the models of performance are shown diagrammatically in the Figure 2.

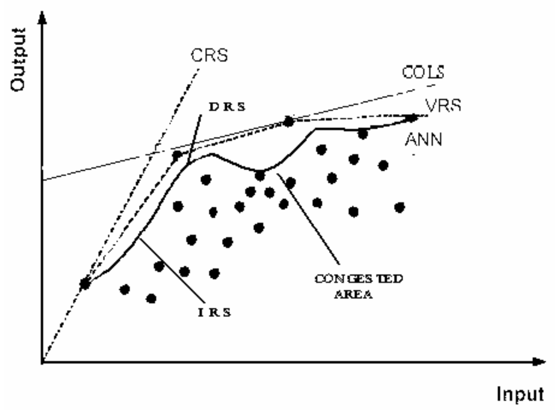

Figure 2 Differences between the models.

From the above characteristics we can observe that techniques, such COLS, SFA frontiers assume production with constant returns to scale whereas DEA results even if are based on global optimum values cannot provide information on the technological progress across activity units, over time and the slope of production function. On the contrary, NN methodology can represent any form of the production function (Increasing Return to Scale IRS, Decreasing Return to Scale DRS, and Congested Area) and employ validation procedures to test the adequacy of the proposed models for unseen Decision Modeling Units. In addition, performance targets are assessed for individual inputs and outputs of each Decision Making Unit that do not have necessarily the same direction of improvement and also allows the use of both continuous value and classification input variables without the modelling enhancements that are necessary in the corresponding DEA models. One of the NN limits is that assessment of efficiency is based on an average production function instead DEA is based on the development of a non-parametric extreme.

However, an econometric approach should always be applied initially then in the case the assumptions[18] are invalid seems better a nonparametric technique; even "if a rather complex approach (NN) has a greater posterior probability than a simpler one, despite a prior beliefs favouring simpler approaches, then it should be selected (given that) favours the combination of different approaches in efficiency measurement problems."

In conclusion seems that the researcher have to be very careful in state what kind of model is better than the other, a good approach light be to implement a new approach that combine the previous or at list, like in our case, to compare the results.

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[15] Assuming "that at that point the model has overfitted the technical inefficiency and not the noise. A signal-to-noise ratio can be calculated as (Deboeck and Cader, 1994) where y; are estimates from the model and a signal-to-noise ratio of 10 implies that the signal is ten times more evident than noise in the data." , Ibidem.

[16] If the model is left to completely overfit the sample then a solution very similar to that of DEA should emerge

[17] Athanassopoulos and Curram (1996) used two alternative transformations to solve the typical problem of this approach (Since the neural network is fitting average performance, the expected outputs will represent average rather than best performance) that allows to convert the difference between the observed and expected outputs into efficiency scores: - Unstandardised efficiencies - standardised efficiencies. The former tends to over-estimate the efficiencies and the latter approach underestimates, however both are appropriate for the single output case.

[18] Costa and Markellos highlight that "when a problem involves measuring efficiency over time (time series or panel data), econometric techniques usually assume that the variables of production are nonstationary and that they move along some deterministic linear time trend. In order to transform to stationarity, they adjust the logarithmic levels of the variables for a linear trend. This is a serious drawback for econometric techniques, since their apparent stochastic nature contradicts their assumptions regarding the existence of deterministic trends. In the case of MLP and DEA, the problem of nonstationarity is less important, and therefore these approaches are more appropriate for analysing efficiency over time."

1.7.2. Empirical Results

The time series reporting Raw Costs, Staff costs, Depreciation costs, Other costs, were selected as inputs of production for each firm and the sales were considered as the single output. As in the previous analysis we use the annual data to perform efficiency analysis. As argued by large part of literature the success or failure of privatization should not only consider the raw output produced but also the improvement in output due to the impact of embodied technical progress. Unfortunately this qualitative information is not available, so in this work is considered just as efficiency changes. The ANN were optimised by using a standard back-propagation algorithm that accelerates the convergence of the model optimisation procedure and a synthetic sample of 1000 input/output vectors was created by adding noise normally distributed. To avoid the danger that the network weights got trapped in a local minimum and select the best ANN design and training condition we use different random weight. To selected as the best model several models with different topologies were trained over-parameterised[19] network on the synthetic data and the original data were used for cross-validation. On the basis the efficiency measures of considered DMUs, that involves comparing their ability to convert input onto output, were created "by correcting the downward bias in the estimated curve by shifting it upwards to the point that at least one of the corrected residuals was zero".

The NN efficiency scores in table Table 13 were estimated in a similar way to the COLS method, no year has an efficiency of 100% given that the function is shifted according to the maximum error of the NN in the synthetic data and not according to the error in the original data (Costa and Markellos 1997). From the NN output of British Aerospace we can the level of efficiency for this firm at least in the initial data was not affected by "investment" or fiscal policy but, looking at the history seems related to "board difficulties". However, the NN output confirm the others results that the company manage was better under private ownership. In this case a larger availability of data, under public ownership, should perform a better the real path of efficiency.

The results obtained for British Gas confirm the previous results with small changes. In this case it had four periods of crisis: the first one between 1979 and 1983, the second in 1986 and 1987, the third since 1991 to 1996 and finally, the level of efficiency drops in 1997. In the years following privatisation the efficiency score shows again a low value but it sign an improvement since the 1988 till 1990.Here we can summarise that two acts of intervention caused serious suffering in the gas industry, the fine tuning of the 1980s and the "take or pay" contract of the end of 1990s. This seems due to the application of new tax rules to the "privatised" firm and to the end of the restructuring program conducted under public ownership. Also the obtained results for British Steel confirm the previous results. They are slightly good in the pre-privatization period since 1983 to 1988, then under the private ownership they decline continuously until the 1993. The analysis could help to understand that also public firms can reach serious improvement in performance thanks a good management that behaves perfectly in a "private" way.

British Aereospace				***British Gas***				***British Steel***				***British Telecom***			
1978	90.190	**1990**	97.792	**1976**	96.121	**1988**	96.759	**1975**	97.838	**1987**	96.026	**1981**	90.937	**1993**	93.851
1979	90.350	**1991**	97.672	**1977**	94.481	**1989**	98.000	**1976**	97.636	**1988**	96.442	**1982**	91.360	**1994**	93.961
1980	91.632	**1992**	95.918	**1978**	94.524	**1990**	97.328	**1977**	97.947	**1989**	96.075	**1983**	91.048	**1995**	93.934
1981	91.075	**1993**	97.679	**1979**	92.765	**1991**	93.306	**1978**	97.766	**1990**	96.669	**1984**	92.710	**1996**	93.977
1982	92.564	**1994**	96.601	**1980**	91.697	**1992**	93.591	**1979**	97.589	**1991**	95.134	**1985**	93.009	**1997**	94.042
1983	93.426	**1995**	95.908	**1981**	90.348	**1993**	92.448	**1980**	96.995	**1992**	94.917	**1986**	93.434	**1998**	94.163
1984	93.542	**1996**	96.227	**1982**	89.305	**1994**	91.222	**1981**	96.539	**1993**	94.507	**1987**	93.832	**1999**	94.115
1985	93.645	**1997**	96.628	**1983**	90.715	**1995**	90.196	**1982**	95.815	**1994**	95.336	**1988**	93.993	**2000**	94.568
1986	94.489	**1998**	95.850	**1984**	94.542	**1996**	92.356	**1983**	96.424	**1995**	95.808	**1989**	94.047		
1987	95.502	**1999**	93.783	**1985**	93.139	**1997**	88.399	**1984**	96.379	**1996**	97.027	**1990**	93.823		
1988	95.029	**2000**	96.830	**1986**	92.175			**1985**	96.562	**1997**	97.035	**1991**	94.274		
1989	97.627			**1987**	92.537			**1986**	96.478	**1998**	96.846	**1992**	94.082		

Table 13 Neural Network output.

For British Telecom we have the lowest efficiency score in 1981 when was separated from the Post Office in 1981 and became a free-standing corporation though still publicly owned. In the period pre and post privatisation, since 1982 to 1990 the efficiency score had very slightly increase. However, it is important to point out that, under public ownership British Telecom was basically a monopolist in the sector, after privatisation the sector has been opened to competition in many services for customer. The small lack in efficiency for 1990 can signal the stronger competition in the market, while in 1991 and 1992 the efficiency slightly improved. After 1992 the firms policy was quite good , so they had continuous increase in efficiency even though there was increased competition in the market. In summary the average of the index under public ownership for British Aerospace it is 90,812% while under private ownership it is 95.549, for British Gas it is 92.76 under public ownership and 93.58 under private ownership, for British Steel it is 96.88 under

[19] The neurons and the hidden layer was modified until the signal-to-noise of each nets was less than 5% on the original data

public ownership and 95.834 under private ownership and finally for British Telecom we have an average of 91.813 under public ownership and 94.006 under private ownership.

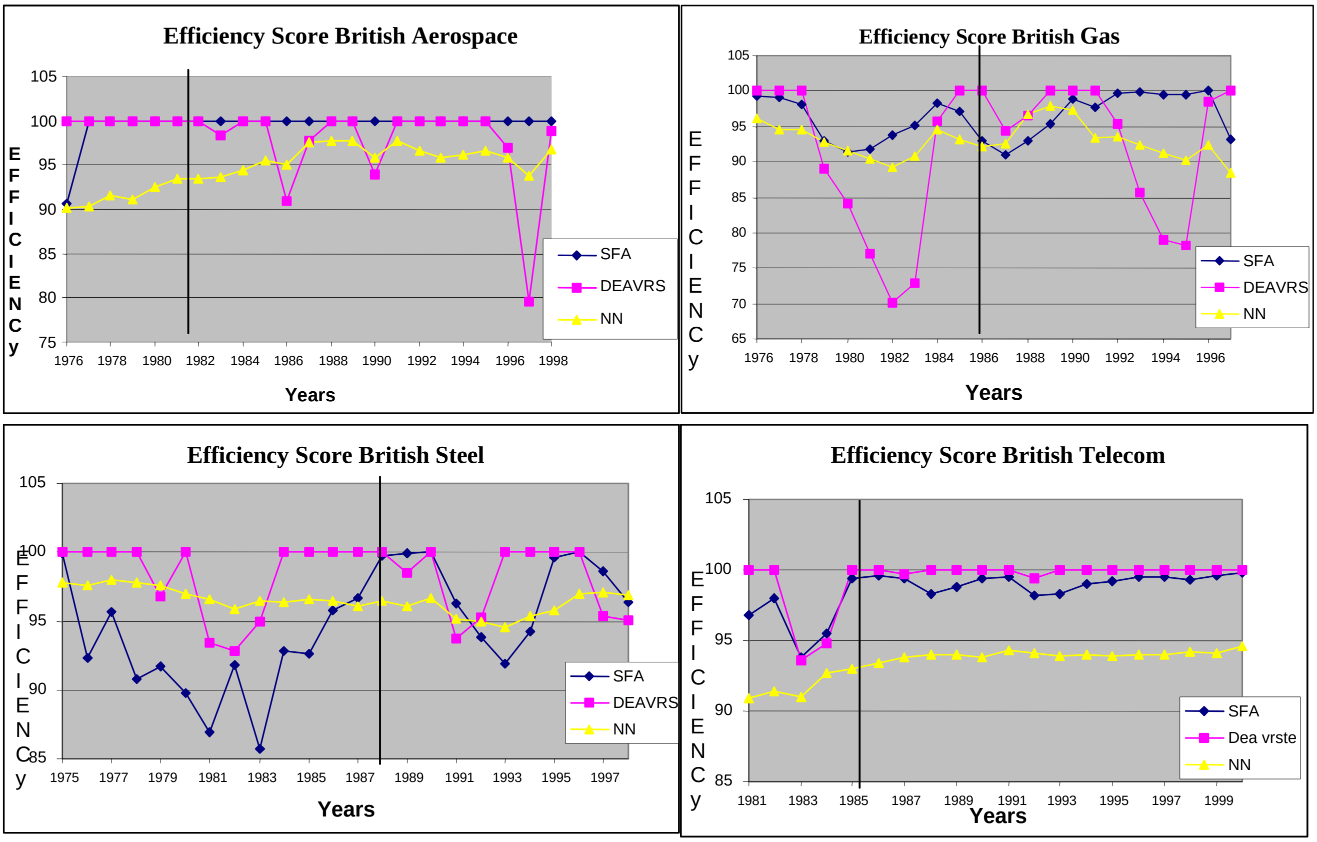

Figure 3 A comparison of three tools: DEA, SF and NN.

As we can see in Figure 3, SFA, DEA and NN approaches identify the changes during the analysed period, more the changes in the organisational structure, present in the second part of data set, highlighted that privatization product some significant modification in the pattern data. The results of the NN are smoother that the efficiency score obtained by SF and DEA, but usually catch the over hill and dale, therefore this means that the Network has a greater ability to process and to adapt the data. These results point out that the NN methodology, like in DEA analysis, the frontier with variable returns over scale gives the technology parameters of a continuous non-linear function of production. Even if this kind of analysis is more complicated than the linear production function frontier, it has the advantage of providing information on the local slopes of the production function. This characteristic implies the obtained results of efficiency analysis which could be used in normative[20] and positive[21] analysis. Hence, the efficiency scores calculate from the production frontiers that are used as frontier levels of production for given inputs in the case of the NN are given by considering the most efficiently combined set of inputs[22]; so production can be seen as productivity gains (arise by the variable returns over and across scales), and, efficiency gains arise by success design and organisation of production). To have a more realistic approach to the optimisation, it must be highlight that this combination is unique, given that the effects of each input are non – separable; therefore the optimal value of some input(s) should be examined for a given level of other inputs.

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[20] "Normative analysis consists of looking at the history of one or several operators and identifying those that were most successful in terms of productive efficiency. Normative analysis also determines the level of output that should have been produced for each historically realised combination of production inputs and these results can be used in drawing conclusions and making decisions about the optimal characteristics of future production." Costa and Markellos (1997).

[21]" Positive analysis is concerned with setting output targets for given combinations of production inputs or input targets for a given level of production." Ibidem.

[22] As said by Costa and Markellos "In economic terms this effect implies that inputs not only have variable returns over scale, but also variable returns across scales."

1.8. Conclusions

The massive interests of economic literature about the privatisation gave a notable impulse to the discussion about this theme in the pre and post privatisation firms performance. In this paper we concentrate the attention on the efficiency measures with the purpose to identify and measure sources of successful performance that can be used in policy planning and allocation of resources. So, we can try to answer a fundamental question: does privatisation increase efficiency?

	British Aerospace	British Gas	British Steel	British Telecom
SF score public	97.63	**97**	93	96
DEA score public	**100**	88.89	**98.3**	97.68
NN score public	90.812	92.764	**96.888**	91.813
SF score private	**99**	95.4	**97**	**99.1**
DEA score private	99.5	**93.95**	98	**99.9**
NN score private	**95.549**	**93.588**	95.834	**94.006**

The general results obtained from the 3 different tools are consistent. In fact, we see that privatization enhanced efficiency in three out of four sample firms. The case of British Telecom does not leave space to any doubt all the tools give the same answer: privatization increases efficiency. Also the magnitude of the increase signalled from the three tools is the same, around 3 percentage points. British Aerospace also shows a better behaviour under private ownership for two out of three tools. The DEA score is just 0.5 percentage point lower under private ownership but this is due to small number of observation related to the public ownership. British Gas also seems to better perform under private ownership for two out of three tools but here we have to note that the difference in the average of efficiency score is not so relevant as in the two previously examined cases. The explanation of this has to be found in the “hostile” competitive behaviour that private British Gas faced. The SF score, that control for investment plans and taxation policies puts in evidence these features. Finally, for British Steel we find the result that under public ownership the firm had a better performance but this is not surprising. In fact, the private behaviour of a public manager as Ian MacGregor strongly enhanced the public performance of BS rescuing the UK steel sector from a deep crisis. In general term we can observe that for the whole data set that physical investment and tax policy influence the performance of the new juridical status of the firms and also that usually privatisation concretise in addition to the extraordinary entrance for public balance also and increased annual entrance deriving from the expansion in tax bases.

From the above consideration we can easily note that the DEA score have a larger standard deviation compared with SF and NN. This is due to the algorithm of DEA that signals in an amplified way the shift from an efficient situation to a period of crisis. The magnitude of variation observed with DEA are not directly connected with percentage values of increase or decrease in efficiency. This because the direct connection between the observed value of he input and the “theoretically achievable” level of inputs it is signalled by the lambda coefficient. So, once we observe a sudden and of a large magnitude shift, the better thing to do is to analyse the lambda parameter. But this was not the main aim of this paper. The SF method seems to better catch some “fine tuning” in efficiency, and this is due to the use of three control variable that help to reduce the resulting production inefficiency by a sensible magnitude. So the smoothness of SF is not surprising even if we observe some large values that, again are not directly correlated to the magnitude of the percentage change in efficiency. To overcome this lack of the two methods, the Neural Network approach was really well performing. In fact, it results are smooth that the which ones obtained by the others tools. These results seem better catch the real change in efficiency score because an over-trained network using a back-propagation algorithm calculate weight that are able to give a more realistic optimisation of combination of input/output, in addition it better consider that the effects of combined inputs given they are non –separable from the whole. Hence, this tools seems better because favours the combination of different approaches in efficiency measurement problems, more it looks both at the history of each operators and identifies those that had a larger weight in terms of productive efficiency and combination of production inputs and to the realised results for drawing the optimal characteristics of future production. However, this work arise many question about the possibility of the parametric approach to individuate initially the model then in the case the assumptions are strong, invalid or unrealistic seems better a nonparametric (including neural) approach that has a greater posterior probability than a simpler one. In conclusion seems that the researcher have to be very careful in the analysis of the economic problem, so a good approach might be to implement combine the characteristics of previous tools with the purpose to understand the processes which has generated the data.

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