Title:

Privatisation, Ownership and Technical Efficiency in the Turkish Electricity Supply Industry using Data Envelopment Analysis

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By

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Dedication

To

my mother and my sisters.

Acknowledgement

This thesis would not come into being without help of several people I received at various stages of my research. I faced serious difficulties at the data collection stage. My aim for investigating efficiency implications of privatisation has received a mixed response in both public electricity institutions, the Turkish Electricity Authority (TEA) and the Ministry of Energy and Natural Resources (MENR), and private electricity companies, Kepez Electric jsc. and Cukurova Electric jsc. The TEA and the MENR were reluctant to disclose any cost data, owing to the still ongoing negotiations with private investors for electricity privatisation. Kepez Electric jsc. and Cukurova Electric jsc. did not want to cooperate because they were facing a take-over bid by a private company, Rumeli Holding.

It took several meetings with a number of officials in the TEA and the MENR, and trips to the headquarters of Kepez and Cukurova, to achieve some cooperation. Eventually, they all agreed to provide data but only for one year (1991), and only for physical inputs and outputs related to electricity production. These were standard inputs and outputs used in the empirical literature reviewed in chapter 5 in this thesis. The least complete data set was for the hydroelectric power plants study (chapter 7); the calculations had to be made without a crucial piece of information: amount of water used in power plants during electricity generation.

First of all I would like to thank all who helped at the data collection stage; among them my special thanks go to Professor Dr. Sadik Kirbas, Professor Dr. Yavuz Tekelioglu, Suphi Goksu, Ziyaittin Demirayak, Yaman Akar, Kazim

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Content

Chapter 1 Introduction

This thesis evaluates the Turkish experience of electricity privatization to date, and investigates the claimed ability of private investors to bring technical and managerial efficiency into the Turkish electricity supply industry. There are two main motives behind this thesis. The first motive is the recent move by many countries towards privatizing their electricity industry. This move is interesting and important because it indicates an extension of privatization applications, which are more commonly seen in industries producing competitively marketable products and services, to the electricity industry which is traditionally protected against market competition due to its natural monopoly cost conditions. The second and more obvious motive for this thesis is the lack of empirical investigation and thus empirical evidence for or against the government's claim that private ownership will enhance economic efficiency in the Turkish electricity industry.

At this point it is important to note that lack of empirical investigation accompanying privatization implementation is a general shortcoming of the Turkish privatization program. Among a long list of review articles about privatization implementation in Turkey, including for instance Gultekin (1993), Patton (1992), Onis (1991a), Karatas (1990), and Leeds (1988) among others, there are very few studies involving rigorous enterprise or plant level performance evaluation of privatization candidates.

One of the first comprehensive studies of privatization in Turkey is the report completed by the Morgan Guarantee Bank (1986), which selected and ranked the candidates for privatization according to "saleability" criterion. The report identified the foreign investors as the foremost important group of buyers, which caused public anger leading the government to withhold the report's implementation.

There followed two exceptional and important studies by Cakmak and Zaim (1992 and 1991), who analysed the efficiency differences between public and private ownership types, using plant level data from the cement industry. They used two popular techniques, stochastic frontier analysis and data envelopment analysis (similar to the one used in this thesis) respectively to investigate the efficiency differences between cement plants in 1984, long before some of the public plants were privatised in 1989; they find no significant difference between ownership types.

A more recent study is by Karatas (1995) who used financial indicators (profit margins and profit-asset ratios) and labour productivity to investigate the performance of privatised public enterprises and public participation in Turkey in the period 1988-1991. The results suggest various degrees of performance improvements, though in the case of public enterprises with monopoly power it was less clear whether that was due to the involvement of private ownership or as a result of exercising their monopoly power by charging higher prices for their products.

Except for these studies, hardly any planned and finalised privatization effort in Turkey was accompanied by rigorous enterprise or plant level performance evaluation other than the usual accounting scrutinies, investigating the candidate's financial viability. This indicates that the government takes the superior performance under private ownership for granted, or is frightened to test it. This perception is supported by the observation that the government is dealing with the question of "what is the best way to privatise?" rather than what must be a prerequisite question of "whether to privatise?"

The former question involves largely practical issues such as drafting legislation, restructuring the candidates, and deciding when, how, and to whom to sell public enterprises at what price. Even on these practical issues the government is said to be unsuccessful, considering the limited progress in actual implementations of privatization. Since the privatization program was initiated in the early 1980s, only a few small and medium size public enterprises were sold to the private sector usually through a block sale; and only a few minority shares of public participation were sold through divestiture. These were easy to handle, and the stake was too small to attract loud public outcry. However, when it came to selling larger and strategically important public enterprises such as Petkim (a large petro-chemical complex), Erdemir (iron and steel), Sumerbank (textile and banking company) and TEK (dominant electric utility and the subject matter of this thesis) the reactions grow louder and stronger, consequently slowing down the preparation efforts, and forcing the government to reconsider its decision or to change its privatization strategy.

Various factors contributed to the slow progress of privatization in Turkey. These factors are common in many privatising developing countries and are similar to those discussed in Price (1994). For the Turkish case, the most important factors may be the weak economic and institutional arrangements, including underdeveloped financial sectors and capital markets, lack of purchasing power amongst domestic investors to pay for candidates of privatization, and perhaps the most influential reason is the inability of the government to explain its privatization plan to the public and to build a coalition in due course between interest groups for privatization (Onis, 1991b).

The overview of privatization implementation in Turkey presented thus far suggests that the government pays less attention to the question of "whether to privatise?", which is precisely the reverse of what we intend to do in this thesis. Naturally this requires empirical investigation of performance differences between public and private firms, where we faced two interrelated difficulties. The first difficulty was to decide which performance indicator to use to analyse privatization effects; and the second difficulty appeared at the data collection point.

According to Cook and Kirkpatrick (1995) the best way to analyse the effects of privatization is to base the investigation on the objectives set for privatization. Another important issue is to focus the analysis on the enterprise level since the process of privatization ultimately involves transferring to the private sector the rights to profit (and naturally costs) incurred from operating the enterprise. This is the change which is expected to have immediate effects on the objectives, incentives for the management, and consequently on the economic efficiency performance of the firm (Vickers and Yarrow, 1988). These issues are discussed in chapter 2.

The most important objective for electricity privatization set by the government is to attract the financial sources and managerial expertise of private investors who are expected to enhance economic efficiency in the Turkish electricity industry. So, this should be the performance indicator to use in the investigation of the effects of electricity privatization in Turkey.

Economic efficiency has a broad definition of performance, and economists usually distinguish between its two main aspects during a performance analysis: productive efficiency and allocative efficiency. Productive efficiency deals with performance within the firm whereas allocative efficiency is concerned with performance of the firm in the market.

Productive or internal efficiency has to do with cost minimisation for a given level of output. It can be separated into two dimensions: technical efficiency and price efficiency. Technical efficiency is related to the minimum quantity of inputs to be consumed to produce a given amount of outputs, whereas price efficiency takes notice of relative prices to ensure that those inputs are consumed at a cost minimising combination. The firm is productively efficient when both technical and price efficiency components are satisfied simultaneously (Farrel, 1957). As shown in chapter 4, there is only one mix of these inputs which is cost minimising, given technological opportunities and relative factor prices.

Allocative efficiency has a broader definition which contains productive efficiency, i.e. allocative efficiency represents productive efficiency but the reverse is not correct (Rees, 1984). Allocative efficiency relates the price of the product paid by the consumers to the costs of its provision. In the most general sense, it has to do with the entire allocation of resources in the economy. One of the most widely used definitions of allocative efficiency is, also know as Pareto efficiency, that it is attained when it is impossible to make a person or group better off while making somebody else worse off by reallocating the resources in the economy.

As we indicated in the acknowledgment the other difficulty appeared at the data collection stage. Data restrictions including lack of input prices did not allow this thesis to pursue a performance analysis based on price and allocative efficiency. With the available data it was only possible to calculate the technical efficiency component of economic efficiency. By definition technical efficiency requires information only on physical inputs and outputs, characterising the production relationship within a firm. The methodology of data envelopment analysis, which is explained in chapter 4, permits technical efficiency calculation without the need to involve input prices in the performance investigation.

Technical efficiency is calculated for the Turkish electricity supply industry, using cross-section data of 1991. We would have used later years' data too if it had been available. In any case, the year 1991 is a significant year because it was then that electricity privatization, which commenced in 1984, really gained momentum in Turkey. First of all, 1991 was the year when two distribution organisations franchised to private companies completed their first full operating year in the liberalised electricity market. Later in the same year the government increased the number of potential distribution organisations to be privatised from fifteen to twenty-one (out of seventy-three), and immediately offered eight more distribution organisations to private investors, which in fact were never privatised.

Then in 1993 the government restructured the dominant public utility, the Turkish Electricity Authority, splitting it into two large joint-stock companies, one responsible for generation plants and transmission network (the TEAS), and another responsible for distribution networks and supply to end-users (the TEDAS). In the same year, each province was defined as a separate distribution area open for tender by private investors, but there has been little further progress in privatising electricity distribution up to 1995. Finally, the government announced its plan to sell four out of sixteen thermoelectric generating plants in 1995. It was emphesized that those plants were selected amongst those most in need of rehabilitation.

There are a number of ways to investigate the impact of privatisation. For instance, the actual or immediate impacts of privatisation can be examined by measuring performance differences of a firm before and after privatisation; or the potential impact of privatisation can be investigated by comparing the performance of a public firm with that of its private counterparts operating in the same industry. When comparison in the same industry is not possible, another option may be to compare the performance of the candidate of privatisation with that of its private counterparts operating in another country.

In the light of the above developments in electricity privatization in Turkey this thesis investigates the immediate effects and the potential effects of privatization on the distribution side and on the generation side, respectively. The immediate effects of privatization are analysed in the distribution organisations study (chapter 6) where the technical efficiency of privatised distribution organisations is compared with that of similar distribution organisations that remained in the public sector; any performance differences in favour of private distribution organisations will be attributed to the privatization process.

Analysing such immediate effects in a year immediately after privatization, however, requires further analyses to find out the causality between performance and the candidates for privatization. This should be directed to provide insight to the issue of whether the candidates were already efficient before privatization, or they became efficient as a result of privatization. The fundamental importance of this investigation arises from the motive that leads a government to select the initial candidates amongst the best performers and presumably the most saleable to give the impression that privatization results in efficient performance, consequently opening and easing the way for future privatization implementation.

The potential effects of privatization are analysed in the hydroelectric power plants study (chapter 7) where the technical efficiency of private power plants is compared with that of public power plants. Superior performance by the private power plants may be taken as evidence for potential improvements achieved by privatization. Thus, the results are expected to indicate for or against potential privatization of hydroelectric power plants. The last empirical study is the thermoelectric power plant study (chapter 8) where a causality analysis similar to the one applied in the distribution organisations study is undertaken to observe whether the government was genuine in its declaration that the immediate candidates of four thermoelectric power plants were selected amongst the group most in need for rehabilitation.

The thesis is organised under nine main chapters including the introductory chapter (chapter 1) and the chapter of conclusion (chapter 9). Chapter 2 contains an economic analysis of electricity privatization, discussing firstly the case for privatization, and then efficiency implications of various scenarios of electricity privatization. Chapter 3 carries the arguments built up in the previous chapter to the Turkish case, and evaluates the developments of the Turkish electricity supply industry and its privatization to date. Chapter 4 explains the methodology of data envelopment analysis and exhibits how the technical efficiency is measured. Chapter 5 reviews the applications of data envelopment analysis to the electricity generation and distribution to select the variables for the empirical studies. The remaining three chapters contain the empirical studies, which are ranked according to the steps taken in the privatization process of the Turkish electricity industry. The privatization started on the distribution side, thus, chapter 6 includes the distribution organisations study. Chapter 7 is the hydroelectric power plants study; and chapter 8 is the thermoelectric power plants study. Chapter 9 gives an overall account of the empirical results and comments on their likely policy implication.

Chapter 2 An Economic Analysis of Electricity Privatisation

2.1 Introduction

This chapter examines electricity privatisation in terms of its likely contribution to economic (allocative and productive) efficiency, firstly discussing the case for privatisation, and then the efficiency implications of various scenarios of electricity privatisation.

Electricity privatisation can be seen as a matter of re-examination of the most cost efficient industrial organisation for electricity production. The ideal industrial organisation will contain possible market abuses, due to natural monopoly conditions; and will ensure a tariff structure that will produce incentives for cost minimisation. The tariff structure should also generate sufficient revenue for renewal and expansion expenditures of the industry.

Economic Theory suggests that when a natural monopoly is left unregulated, it could maximize profit at a price far higher than the marginal cost of production. The deviation of price from marginal costs has serious economic implications showing itself as misallocation of resources, welfare losses and economic inefficiency. Therefore, there are benefits of finding ways of persuading monopolists to set price equal marginal cost. However, due to the declining level of average costs over the relevant output level in naturally monopolistic industries marginal cost pricing (the first-best solution) results in financial losses, and if not recovered somehow, this could force monopolist to retire from the market and the consumers to be deprived of supply.

The conventional way of operating and regulating an electricity industry has been the integrated monopoly often taken with public ownership that is then expected to keep prices, if not equal, at least close to marginal costs of production in order to achieve efficiency in allocation of resources. The financial losses are assumed to be covered by efficiently raised taxes. The alternative but less common way of running an electricity industry has been under private ownership regulated by a quasi-governmental agency, in theory working at an arms-length distance from political interference. In the absence of direct subsidy, the regulatory body imposes restrictions on prices charged by the private owner, aiming that these prices will be enough to cover financial losses and will not yield more than a normal profit. This is average cost pricing (the second-best solution), where normal profit is usually defined as a level that just enough to attract the necessary capital into the industry. This is rate of return regulation that has been practice recently in the USA.

Electricity privatisation often involves a departure from the integrated structure, irrespective of type of ownership, towards a more disintegrated structure facing more competition in the market. This involves separating the potentially competitive parts (electricity generation and electricity supply to large customers) from the naturally monopolistic parts (electricity transmission and distribution networks). Performance of both public ownership and private ownership is criticized for failing to make the most of the economic and technological benefits of integrated structure. Performance of public ownership is, perhaps because it is experienced more, criticized more severely due to its continuous operational and financial inefficiencies. Private ownership under rate of return regulation is criticized for its poor cost reducing performance.

The recent trend is towards privatisation and liberalization in electricity industries. It is argued that owing to recent developments in technologies of plant construction and demand growth, economies of scale in electricity generation are exhausted, and this has significantly reduced the cost benefits of vertical integration in electricity industry. Because of the cost reducing effects of competition, introducing competition for electricity generation, after it is split from the still naturally monopolistic operations of electricity transportation (transmission and distribution), is expected to produce better cost minimising performance than could be achieved under the integrated structure. Privatisation is seen as an important public policy option for introducing competition into the electricity industry, and this also reflects a popular preference for private ownership of the electricity industry. Among other reasons, this move is supported largely by the perception that private ownership is equipped with better incentives than its public counterpart, leading to a relatively better cost minimising performance.

This chapter develops the economic analysis of electricity privatisation under three main sections. The following section presents the economic rationale behind the integrated structure of an electricity industry. The third section investigates whether differences in cost minimising performance can be traced to differences in types of ownership. The fourth section evaluates the examples of electricity privatisation, and suggests possible ways of introducing private elements and competition to the electricity industry. The last section concludes this chapter.

2.2 Integrated Structure for Electricity Industry

One of the most important rationales behind an integrated structure for electricity production is associated with natural monopoly cost conditions arising from a combination of economies of scale, scope, horizontal and vertical integration (Joskow and Schmalensee, 1983). Economic Theory tells us that when natural monopoly occurs, one-firm production is the most cost efficient way of satisfying the entire market demand, and therefore allowing entry into the market results in wasteful duplication of scarce resources.

At this point and before we identify which economies are associated with which economic activities in electricity production, let us give a definition of natural monopoly and discuss its efficiency implications when it is not regulated. Note that we do not aim for a comprehensive presentation but a textbook treatment of the related issues in order to help the discussion throughout this chapter. Detailed treatment of the materials can be found in Sharkey (1982) and Waterson (1988), among many others.

2.2.1 Natural Monopoly and Efficiency

One can mention about traditional and new definition of natural monopoly, and a natural monopoly can be sustainable or unsustainable. The traditional definition suggests that a natural monopoly results from economies of scale in production of one output, or it may arise due to economies of scope in production of more than one output. The new definition of natural monopoly regards both economies of scale and economies of scope as important indicators to identify whether a production process is naturally monopolistic, but it is emphasized that the subadditivity of the cost function over the entire range of output(s) is the essential condition for the existence of a natural monopoly. In other words, a natural monopoly occurs when the total costs of producing output(s) by one firm are not higher than the total costs of any other arrangement of production by more than one firm, given available technological capabilities and demand conditions. This is called a sustainable natural monopoly case.

The duration of natural monopoly status of a firm is largely related to the shape of its average cost curve and the demand pattern for its product(s). Therefore, cost reducing innovations in production technology and demand growth may finalize the firm's natural monopoly status. In this case, the natural monopoly is not sustainable anymore. In theory, unless the firm exercises entry preventive pricing policy (limit or predatory pricing), excess profit attracts new entry into the market until excess profit is eliminated. The new entrants may aim to produce for a particular part of consumer demand if the market is for one product, or a subset of the production if there are more than one product (Weyman-Jones, 1994).

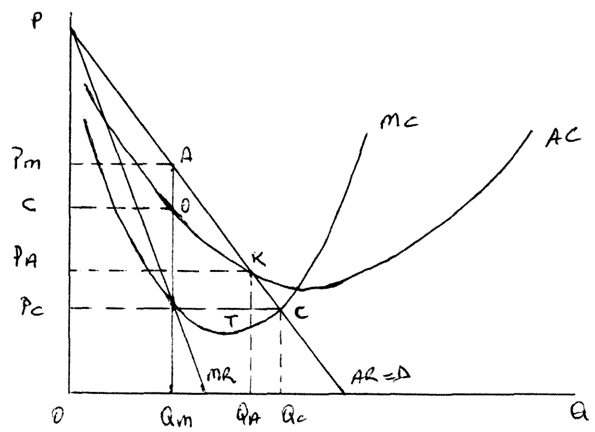


Figure 1 Natural Monopoly and Efficiency

Figure 1 illustrates a naturally monopolistic industry. For the sake of simplicity in illustration, we assume that the industry is producing only one product. The first-best pricing policy is marginal cost pricing (Pc) that leads to maximisation of social welfare and economic efficiency. Social welfare is often associated with the sum of consumers' surplus and producers' surplus, and this is frequently used by economists as a yardstick of economic efficiency. In this sense, the maximisation of economic efficiency is similar to the maximisation of social welfare. Thus, economic efficiency can also be defined as the state of economy where there is no alternative pricing policy that will make one person better off without worsening the well-being of somebody else. This is the basis of Pareto efficiency, and notice that it is similar to the definition of allocative efficiency given in the introductory chapter.

The Theory of Welfare Economics suggests that the three famous Pareto-Optimality conditions should be satisfied for the maximisation of social welfare. Marginal cost pricing satisfies these conditions (Varian, 1987, and Koutsoyiannis, 1979). In other words, the efficient allocation of resources requires an equilibrium where the price (Pc) is set equal to the marginal cost of producing at the Qc output level (Figure 1).

An unregulated monopoly, however, could choose Qm and Pm output and price combination in order to maximize profit. The monopoly profit can be shown by the rectangle area PmAOC. The monopolistic price differs from the marginal cost pricing by an amount equal to PmPc and the efficient level of output differs from the profit-maximising output by QmQc. If marginal cost pricing is followed, however, due to declining level of average cost curve, it will result in financial losses that should be recovered somehow, otherwise the monopolist is forced out of the market.

The subsidization of financial losses when marginal cost pricing is followed in a naturally monopolistic industry provided strong support for public ownership of the industry. The main goal was to solve the natural monopoly issue by ensuring that the monopolist pursues welfare-maximisation, and guarantee adequate investment and security of supply. The financial losses were to be covered through efficiently raised taxes. In principle, an efficiently raised tax is a lump-sum tax that would leave the amount of consumers' surplus and producers' surplus unchanged. According to Price (1977) a poll tax is perhaps the only true example of non-marginal tax which will have no effect on efficiency.

Nonetheless, governments are rarely able to raise tax efficiently. They tend to impose tax on income and sales that are relatively easier to collect. However, these taxes themselves have distorting effects since they affect the trade-off between work and leisure time. Therefore, a second-best solution for natural monopoly pricing problem is usually observed. This is average cost pricing where the monopolist is allowed to deviate from marginal cost pricing in such a way that the new price yields a normal profit just enough to bring the necessary capital and other resources into the production.

In Figure 1, the average cost pricing results in an output level Qa which is less than the first-best solution Qc, but larger than the monopoly solution Qm. This is clearly an improvement in terms of welfare-maximisation, because the dead-weight loss is reduced to KTC. Nevertheless, this is still an inefficient pricing strategy since Pa is still larger than marginal cost pricing. In other words, consumers are still paying more than it costs to produce the last unit of output. The area KTC represents the remaining efficiency losses.

Sharpe (1983) analyses in detail an alternative way suggested by Demsetz (1968) of ensuring that the natural monopoly follows a cost minimising price policy. On the basis of an earlier work of Chadwick (1859), Demsetz suggests that it should be possible to create a competitive environment, for the monopoly rights (franchise) of serving the market, if not in the market due to natural monopoly conditions. The franchise would be given to the bidder who offers to supply the market at the lowest unit price. Provided that the bidding process is competitive, the presence of rivals will put pressure on bidders to offer a price close to the cost of provision of services. Since marginal cost pricing results in financial losses, the competitive bid-price is expected to translate into a price high enough to cover average costs, which will be a better outcome than the much higher monopoly price.

The Demsetz scheme can be related to contestable market theory suggested by Baumol et al (1982) that even the presence of an entry threat is sufficient to keep prices close to marginal cost. Among other assumptions, the absence of sunk costs, that is costless entry and exit into and out of the profitable market is the essential condition for the validity of contestable market theory. As we shall see later in this chapter the electricity industry is an unlikely candidate of contestability due to substantial amount of irrecoverable sunk costs.

Among others, Schmalensee (1979) and Williamson (1976) warn that a Demsetz scheme may run into trouble for a number of practical difficulties. The first difficulty is with ensuring that the bidders are non-collusive. The second difficulty is the complexity of designing comprehensive contracts covering all contingencies may arise between the bid-winner and the auctioning body. The third difficulty is the valuation of the investment already done in the case of contract termination.

Signing a short term contract may solve these problems to a degree, but this may result in the bid-winner choosing to under-invest due to the possibility of being not able to recover all costs of investment during the contract period. Another option then may be the government investing and incurring the fixed costs of investment while leaving the operation of the monopoly to the bid-winner. In any case the difficulties stated above require regulation in order to enforce and monitor the implementation of the contract, which may end up being not too different from the direct regulation under public ownership or indirect regulation under private ownership.

Further improvements in terms of allocative efficiency can be achieved by allowing the monopolist to pursue more complex tariffs, such as two-part tariffs or general nonlinear tariffs, rather than a linear tariff of average cost pricing (Armstrong, Cowan and Vickers, 1994). When a two-part tariff is implemented price need not cover all costs anymore. Consumers pay a fixed charge plus a price equal to the marginal cost of each unit consumed. Nonetheless allocative inefficiency remains in the market since the fixed charge may force out some low-demand consumers from consumption of the good. The remaining allocative inefficiency can be eliminated further by applying general nonlinear tariffs or optional two-part tariffs where consumers with high elasticity of demand are charged a substantial amount of fixed charge plus a price close to marginal cost, while consumers with low elasticity of demand are charged a low or zero fixed charge plus a price above marginal cost. This is an attractive result since fewer consumers are excluded from consumption of the good, and higher allocative efficiency is achieved. The applicability of such discrimination is very much related to the ability of identifying each consumers' elasticity of demand, which is a demanding task and requires large amount of human and other resources.

When natural monopoly produces more than one product and monopoly occurs due to substantial level of economies of scope, marginal cost pricing still results in financial losses that can be recovered through cross-subsidization. This requires charging a higher uniform price to customers with low price elasticity of demand, while charging a price very close to marginal costs to customers with high price elasticity of demand. This is known in the literature as Ramsey pricing which has been suggested as more appropriate for natural monopolistic industries to achieve at least a non-negative profit (Baumol and Bradford, 1970).

These theoretical arguments for solving the pricing problem of natural monopoly in practice have translated into two most usual restrictions that a regulatory body imposes on a regulated utility. These are either by limiting the profit that the utility can earn from the capital invested, or by capping the price that the utility can charge to consumers. The former is known as cost of service or rate of return regulation (ROR) widely practiced in the USA, while the latter is recognized as the Retail Price Index minus X regulation (RPI-X) popularized in the UK.

The standard criticism of ROR is that it encourages over-capitalization (Averch and Johnson, 1962), and produces poor incentives for cost reduction. A regulatory body sets detailed prices for the utility, based on the operating and investment costs, which will yield a normal rate of return, or profit on the utility's capital stock. Rate of return is described as normal when it is just enough to attract funds for the business.

Since the rate is decided according to the amount of capital invested, the utility may be tempted to choose capital intensive production techniques to pad their rate base. This may lead the utility to increase its capital intensity beyond the most efficient input combination, which results in productive inefficiency. Besides that because the condition of price and marginal cost equality is not satisfied the outcome is also allocativelly inefficient.

The other criticism of ROR is that it produces less incentive for cost reduction. In principle, under the ROR either the regulatory body, or, more often, the utility can call for a change in price tariff, as soon as one of them realizes that costs cannot be recovered anymore. The negotiations take place in a court room fashion of lengthy discussion, and cost items are discussed item by item in order to find whether they are justifiable. The utility expects the regulatory body to pass-through the increases in the costs by allowing the utility's prices to increase as well. However, there is always a possibility that following a detailed review of cost items, the regulatory body may find some of them unjustified or uneconomic. This may help to curb the intention of the utility to commit excessive capital expenditure.

RPI-X regulation is a result of a search to eliminate or reduce the need for detailed investigation of cost expenditure, and to promote incentives for the utility to minimize its costs. The dissatisfaction with ROR led the privatised industries in the UK to be regulated in two general ways of RPI-X regulation: average revenue constraint and tariff basket constraint (Bradley and Price, 1989). The tariff basket constraint can give the utility an incentive to charge such prices that may converge to Ramsey pricing (Bradley and Price, 1988).

Under RPI-X regulation the utility is allowed to increase its average prices during a pre specified period, say three to five years, at the rate of inflation in the economy minus a predetermined factor X, representing an expected level of efficiency improvement in the utility. This is said to give an incentive to the utility to reduce costs, since the utility is not punished for reducing its costs by forcing it to reduce its prices as well. The utility may retain the extra profits achieved through cost reduction during the period.

The standard criticism of RPI-X regulation is that it may result in under investment. This may occur if the regulatory body responds to the period of high profits by severe price restrictions. In this case the utility may respond by over investing for the similar reasons shown above under ROR. The problem of under investment is circumvented in the UK type regulation since the regulatory body has a legal duty to guarantee that the utility can self finance itself, and imposes certain minimum quality standards.

Another important issue is the determination of the X factor. It is argued that the only way to determine X is to examine the achieved rate of return of the capital invested, and make periodical adjustments to ensure that the achieved rate of return is justifiable. In this case "...RPI-X is merely a special form of rate-of-return control, embodying no significant net advantage over the US approach on grounds of economic efficiency" (Beesley and Littlechild, 1989).

Both ROR and RPI-X regulation are vulnerable to regulatory capture if the regulatory body relies heavily on cost information from the utility. The utility may distort or hide some costs in order to achieve higher price increases when its prices are reviewed. This problem can be solved to a degree if there are comparable utilities producing the same outputs or services, for instance regional electricity supply companies. Following Shleifer's (1985) solution the information monopoly of a utility can be broken by allowing the utility to increase its price in the line with performance of its similar counterparts. One potential difficulty is to identify a genuinely comparable sample of utilities. The methodology of data envelopment analysis used in this thesis can be very useful due to its ability to compare efficiency of an entity with that of the most similar other entities.

In this section we reviewed the theoretical arguments for one firm production of the entire market demand when there are natural monopoly cost conditions; Then, we suggested the possible ways of tackling with the harmful effects of natural monopoly, leading to efficiency loss. The following section presents the economic characteristics of electricity industry, and in the light of the above arguments, examines the presence of natural monopoly cost conditions in the electricity industry.

2.2.2 Economic Characteristics of Electricity Industry

Economic characteristics and the natural monopoly cost condition of electricity supply industry can be analysed more easily by grouping its economic activities under five vertical stages as suggested by Armstrong, Cowan and Yarrow (1994):

stage 1: supply of energy inputs,
stage 2: generation,
stage 3: transmission,
stage 4: distribution,
stage 5: supply to final customers.

Following these production stages, electricity is generated and delivered to the end users. First of all, various types of energy inputs are consumed in power plants built with various technologies to generate electricity. Then the generated electricity is transmitted in bulk through a national high-voltage network to distribution points, where the voltage level of the electricity is reduced by transformers to required levels demanded by different classes of customers (domestic, commercial, industrial, and others) who will use it for different purposes. After that, the electricity is distributed through low-voltage regional networks to final customers. Altogether these economic activities are identified with market failures due to environmental and various economic externalities which justify direct or indirect government involvement in the electricity supply industry.

The environmental externalities are associated with the most common types of energy sources used in electricity generation. These are fossil fuels (coal, gas and oil), nuclear energy sources, and hydroelectric energy sources. The fossil fuels burning power plants emit carbon dioxides, sulfur dioxides and nitrous oxides to the air, whose harmful effects to the environment are well known. Another environmental concern is related to radioactive and toxic nuclear waste that can not be easily and safely disposed of. Hydroelectric generation is criticized for ecological damage done to the environment during the construction of dams and power plants.

The harmful effects of these environmental externalities can be internalised by imposing an environmental tax, which may give to the utility incentive to switch to environmentally friendlier generation technologies, or to install emission reducing filters to the fossil fuel burning power plants, or to replace cheaper but harmful energy input with its more expensive but less harmful kind (Yaisawarng and Klein, 1994). For instance, recent developments in the new combined cycle gas turbine (CCGT) technology and these environmental concerns have led the way to replace coal burning technology by the CCGT technology.

Moving towards environmentally friendlier electricity generation requires extra investment which may not be easily affordable particularly by developing countries which are still struggling to find new financial sources to invest on the generation side to match the growing energy demand. Therefore, they may distance themselves from incurring extra cost rather than being environmentally conscious! Naturally this requires global as well as country wide enforcement of the measures taken for internalization of environmental externalities.

Economic externalities arise due to the natural monopoly cost conditions in the electricity supply industry which is characterized by technical interdependencies among three main production stages (generation, transmission, and distribution), transaction costs, and asset specific capital investment. Electricity generation and electricity supply to large industrial and commercial customers are regarded as potentially competitive areas. However, there are substantial economies of scale in national transmission and local distribution services, due to large amounts of capital investment in durable and asset specific equipment (which are sunk costs). Although large capital investments and long lead construction periods in power plants make the generation stage naturally monopolistic, recent arguments for liberalization of electricity markets suggest that the natural monopoly situation is largely reduced due to technological innovations in plant construction and also due to demand growth for electricity. Generation plus transmission is a gray area, and it is not clear whether that combination leaves space for competition. In any case, close co-ordination among production stages is essential because electricity is yet to be stored economically; thus for the security of the system, frequently changing electricity demand (according to the time of day and season) is required to be satisfied completely, continuously and at the least possible cost (Vickers and Yarrow, 1991a).

When analysing the natural monopoly cost conditions in the electricity supply industry as a whole, the discussion of economies of scale may be less relevant, because the electricity supply industry produces a bundle of services. For instance, the industry generates electricity in order to match various parts of demand (base-load and peak-load). It also transmits and distributes electricity in various voltage levels to various types of customers. For instance, industrial customers usually are connected directly to the transmission network whereas domestic consumers receive electricity through the distribution networks. The industry also ensures reliability and load stability in the electricity supply system by securing a continuous balance between electricity demand and supply. Each activity can be regarded as a separate product due to different arrangements undertaken to meet each separate demand. Therefore, the electricity supply industry is more like a multiproduct firm where scope economies may define the economic activities rather than scale economies alone.

Vertical integration has traditionally been supported to reap the cost benefits of interdependencies between production stages, to reduce the transaction costs in the decision making process, and to achieve a cost efficient co-ordination for maintenance and future investment related to all stages. Economies of vertical integration represent the case where the total cost of organizing all economic activities in the electricity supply industry under a single firm is less than the total costs had each economic activity been operated independently by a separate firm such as generation firm, transmission firm, and distribution firm. A recent paper by Lee (1995) investigates the vertical integration issue in the electricity supply industry by using the translog production function for 70

US investor owned electric utilities in 1990. The results indicate the exhaustion of economies of scale in the whole electricity supply industry; however due to potential technological efficiency loss in the industry, the disintegration between generation, transmission, and distribution stages is not suggested.

According to Eden et al (1982), in a mixed system the most cost efficient arrangement is by dispatching the plants with low operating costs (nuclear and hydroelectric plants) to run continuously to match base-load demand, and then to run power plants with higher operating costs (gas turbines) to meet peak-load demand. Between those two extremes there are large coal and oil fired power plants with moderate operating costs, which can be called to the system as required.

The cost efficient dispatch requires a considerable amount of information about the vintage, capacity, starting costs, running costs, maintenance costs of the power plants, in addition to the other information about the reliability of the transportation networks and transformation points. In the traditional way, all power plants are integrated and their co-ordination is realized by one firm which has direct access to the relevant information.

Horizontal disintegration represents a shift from the traditional way to the market oriented way of achieving close co-ordination between power plants to meet electricity demand with the least possible costs. Transaction costs are, however, likely to arise from obtaining relevant information under the disintegrated structure from power plants operated by separate owners who possibly will serve individual special interests.

The theoretical debate for horizontal disintegration at the generation stage is based on the claimed exhaustion of economies of scale in electricity generation. It is argued that different generation companies can compete in the wholesale electricity market with each other as well as with new comers, and even with neighbouring countries connected to the electricity supply system to sell electricity to large customers (industrial and large commercial customers) through the transmission network (Yarrow, 1994). Promoting competition in the electricity generation market, therefore is expected to yield a better cost saving result than would be achieved under the integrated structure. This is an attractive proposal indeed, since the generation stage accounts for slightly more than two-thirds of the total cost of electricity delivered to final users (Newbery, 1994); thus, there is a large prospect for cost reduction.

In the debate for horizontal disintegration, an important issue is identifying at which levels are scale economies exhausted: at plant level, or at firm level? If the scale economies are exhausted at the plant level, the aforementioned prospect for cost reduction still exists. However, if scale economies are exhausted at the firm level, this may have wider implications; because for a multi-plant firm the cost benefits of horizontal integration involve economies of scope as well as economies of scale. The firm may have a combination of different types of power plants scheduled to meet base-load demand as well as peak-load demand; therefore, even if the economies of scale are exhausted, the economies of scope may still justify single firm generation.

There is a large body of empirical literature on economies of scale in electricity generation. These are reviewed in Cowing and Smith (1978) and more recently in Pollit (1993). The results from the reviewed literature do not provide a consistent answer to the question of whether, and at what levels are the economies exhausted. The results are different depending on the data and methodology used (Bateson and Swan, 1989).

The inconclusive evidence for economies of scale in electricity generation does not stop the trend towards a liberalized electricity market, which is frequently explained by reference to the contestable market theory. Vickers and Yarrow (1985) examine the contestability of electricity market and conclude that the generation market, with large capital investments and a long lead construction period, is unlikely candidate for contestability, as the asset specific investments are likely to incur suck costs during entry or exit.

More recently, Gegax and Nowatny (1993) discuss the issues of natural monopoly cost conditions in the electricity supply industry, and disagree with the recent trend of disintegration in the electricity supply industry. They argue that if not the economies of scale, then the economies of scope and economies of vertical integration still justify the continuation of the integrated structure in the industry; the main problem in the electricity industry is the regulatory structure.

In this section we presented natural monopoly cost conditions and related them to economic activities in an electricity supply industry. Among the three main options of controlling natural monopoly: public ownership, regulated private ownership, and Demsetz competition, public ownership is the most widely pursued and the most severely criticized option for its poor performance in the electricity industry. It is argued that the poor performance was largely due to constant political interference in the pricing and investment decisions of the electric utility, which led public ownership to fail in producing and enforcing cost effective economic policies that would yield sufficient revenue for renewal and expansion investment in the electricity industry. Operating and financial inefficiency reached a level under public ownership that even a regulated private monopoly structure, despite the problems associated with regulation, is regarded as a better option for the electricity industry in terms of achieving higher cost efficiency. The following section assesses the link between ownership form and cost minimising behaviour; and addresses the following question "what would be the case in the absence of privatisation?"

2.3 Performance Differences between Public and Private Electric Utilities

The interest for both theoretical and empirical investigations of the likely link between ownership and performance has increased recently due to many countries justifying their move towards privatisation by claiming that ownership matters for performance. Many authorities acknowledged the positive effects of more competitive product and capital markets on performance, but they often give only partial or weak support to the relationship of ownership type with performance (Borcherding, Pommerehne and Schneider, 1982). This view is recently challenged by Vining and Boardman (1992) who presented evidence supporting the view that ownership matters even in competitive industries for allocative and technical efficiency; their evidence is in favour of private ownership.

Until the early 1990s, the World Bank, one of the most influential bodies promoting privatisation, particularly in indebted countries, presented a view similar to the former argument. The World Bank defined the key factor determining economic efficiency as the way that the organization was managed (World Bank Report, 1983). Then, in the light of new evidence, the Bank declared that "ownership does matter" and that transferring state industries and services to private ownership in itself improves economic efficiency (Kikeri, Nellis and Shirley, 1992). One of the most recent empirical studies is by Megginson, Nash and Randenborgh (1994) report evidence in support of privatisation.

In contrast to the evidence for superior performance of private ownership in competitive markets, both theory and empirical evidence are less clear to support either public or private ownership in industries where economic activities are characterized with significant market power. In this case the general consensus among authors is the performance will depend on the joint effects of ownership, competition and regulation (Armstrong, Cowan and Vickers, 1994, and see also Vickers and Yarrow, 1988).

In general, the cost differences between public and private electric utilities are perceived to be the result of the differences in their operational objectives, and the incentive structure and monitoring system available to the owner to persuade management and employees to follow those objectives (Prager, 1992, and Vickers and Yarrow, 1991b).

Firstly, the government has direct control on the pricing and investment decisions of the public sector manager (agent) of the electric utility, and it uses this control frequently through the associated minister and bureaucrat (principal) in order to achieve a number of socio-economic objectives where the overriding principle of a private utility, profit maximisation receives a rather low priority. Some of these socio-economic objectives are pursued in order to subsidize a particular consumer group or industry, to promote economic activities in a certain region, or to create or maintain employment (Rees,1984).

Secondly, the shares of the public enterprises are not tradable in the stock market, and therefore unlike the private enterprises case, dissatisfaction with poor performance of management cannot be expressed by share-holders selling their shares, which in the private sector may leave the enterprise vulnerable to a successful take-over bid (Alchian, 1965).

The profit, if any, made by a public utility cannot be kept and directed for new investments or maintenance; it has to be transferred to the Treasury. Poor performance is hardly ever punished, and perhaps unintentionally encouraged by the central budget subsidization of losses. Bankruptcy, particularly in industries like electricity which have a vital importance for an economy, is not possible in public sector; the losses are covered and investments are guaranteed by the government.

Lastly, the management of a public utility is not rewarded for efforts towards cost minimisation: s(he) receives the same salary which is not related to performance improvements in the utility. This may result in the management seeking non-pecuniary benefits from running electric utilities rather than seeking cost minimisation. This type of behaviour is similar to the assumptions made in public choice theory where politicians, bureaucrats and public sector managers are assumed to value their own benefits more highly than public interests. Politicians are vote-maximizers, and in order to be re-elected, they use their influence over bureaucrats and public managers to pursue those aforementioned non-commercial objectives. Since the pay system is not related to performance in the public sector both the appointed bureaucrats and public managers may choose to follow the course set for them by the politicians in order to secure continued employment. In a way this reduces the divergence in the utility function between principal and agent in the public sector. However, there are also some exceptional cases where politicians, bureaucrats and public sector managers value public interests more than theirs, and carry their duties in a 'public spirit' and feel pleasure from getting their duties well-done (Hausman and Neufeld, 1991, and Kelman, 1987).

Ordover, Pittman and Clyde (1994) discuss the performance differences between public and private ownership in a similar fashion as above, but in their case particularly for the post-socialist countries. They conclude that, compared with public ownership, the privately owned company would produce significant improvements in performance as a result of its ability and incentive to raise rates of the tariff, to raise capital, to utilize the efficient mix of inputs, and finally, to its ability to adapt itself to changes in the future.

In the light of the above arguments, electric utilities under public ownership are assumed to be less cost-conscious. They are assumed to compromise efficiency at almost every stage of electricity generation compared with their private counterpart. For instance, in order to achieve the above socio-economic objectives, the government frequently exercises its influence on the public electric utility to buy energy inputs from domestic producers, often protected from international competition, and to pay for these energy inputs more than their market prices.

The decision between, say, coal and lignite may be given in order to cross-subsidize related industries rather than being driven by cost-concerns. This choice will also effect which technology will be used to construct power plants; biased technology selection creates extra inefficiency. The utility may also be forced to employ more labour than needed at the expense of distorting the cost-minimising mix of inputs. Further inefficiency occurs when the government decides to construct power plants in less appropriate locations in order to promote a certain local economy.

Moreover, public electric utilities often have universal supply obligations that they are required to satisfy all electricity demands irrespective of the location of consumers; they have to supply electricity even to those living in remote areas which is more costly to supply.

As indicated in the previous section, the cost-efficient running of an electricity system requires that the power plants are called to the system according to their incremental costs, starting from the least cost plant (merit order scheme). The lack of cost reducing incentives is likely to result in power plants running in an incorrect merit order and at the wrong scale of operation.

Since the priority is given for satisfying all electricity demand, a large part of investments in public utility is often directed to plant construction and therefore transportation networks are usually relatively neglected. Insufficient investment in transportation networks shows its adverse impacts as unreliable and poor quality of supplied electricity and large network losses.

At the last stage of electricity generation, electricity supply to end-users, inefficient performance arises from the tariff structure. Public utility applies a price tariff dictated by the government, which is usually designed to keep prices lower to the most expensive to supply (domestic customers) while charging higher prices to those cheaper to supply (industrial customers). This can be justified on the ground of vote concerns of the government, but it has serious consequences for the growth and competitiveness of the country since electricity becomes an expensive input rising the total costs of production. Additionally, because of poor financial performance revenues become insufficient to match operating expenses without even considering capital expenses and investment expenditures. Lastly, illegal connections to the electricity system, and poor debt collection efforts are two other causes of revenue losses in public electric utilities.

So far we have exhibited the likely causes of cost-inefficient performance of electric utilities under public ownership. Ownership effects of performance are widely examined in the electricity supply industry. The results from the empirical studies however are not consistently favouring either public or private ownership. In their frequently cited paper on ownership and performance, Boardman and Vining (1989) classify fourteen empirical studies of electricity supply industry according to the results on relative efficiency of public and private electric utilities. Only three studies find public ownership better performing while six studies express the superior performance for private ownership. The remaining five studies are classified under the heading of no difference or ambiguous results. A similar but more recent and comprehensive review of these studies can be found in Pollitt (1993).

There are several issues related to the empirical literature of the electricity supply industry that make one cautious in using the results to draw policy conclusions. Firstly, most of the studies did not take into account the multi-output nature of economic activities in electricity generation. Perhaps due to lack of data, even the high number of studies of non-parametric analysis, which is capable of easily handling the multiple-output cases, used one-output and multiple-inputs in calculations of productive efficiency.

Secondly, the majority of the studies used econometric and statistical techniques to observe average relationships in the data and based their analysis on estimating various types of cost functions, e.g. simple, Cobb-Douglas, Translog. Only a few empirical studies used stochastic frontier analysis. For instance, Cote (1989), Kopp and Schmidt (1980) and Hammond (1992) applied the stochastic frontier analysis to examine relative performance on the generation side, while Button and Weyman-Jones (1992) and Burns and Weyman-Jones (1994a) used the same technique to assess the relative performance on the distribution side.

Thirdly, as Pollitt (1993) pointed out, the empirical literature was dominated by the US studies based on data from the early 1970s or before. It is less reliable to draw conclusions from those old studies about the electricity supply industry in the 1980s and 1990s when a rapid advancement occurred in the technology used in electricity industry, and differences in relative performance between alternative types of ownership become a major issue of political discussion.

Fourthly, the studies comparing the ownership impact on performance devoted more attention to the thermoelectric generating plants and utilities, and until recently very little to electricity distribution. There are very few comparison studies of nuclear and non-renewable modes of electricity generation. Our hydroelectric power plants study in chapter 7 is the only comparison study in the published literature known to the author, applying the data envelopment methodology examining the ownership effect on technical efficiency. Comparison studies of the transmission part of the electric activities are almost omitted in the literature of electricity, except Pollitt (1993).

Lastly, most of the empirical studies are cross-sectional, measuring the performance at a particular time point usually in a particular year. However, this trend seems to be changing by recent interest in the Malmquist type of productivity growth measurement. These studies are again largely focusing on the generation side; the examples are by Fare et al. (1990), Hjalmarsson and Forsund (1993), Yaisawarng and Klein (1994), and Fare et al. (1994). There are fewer studies of Malmquist efficiency measurement of the distribution organisations, for instance by Hjalmarsson and Veiderpass (1992a) and Burns and Weyman-Jones (1994b).

In the light of these remarks it is important to resist any temptation to rely on experiences of other countries to draw policy conclusions. Each country has its own special conditions that shape its economic policies. Therefore it is not surprising to see different arrangements, as reviewed by Holmes (1991) and Plewhe and Beckert (1992), in different countries for their electricity supply industry.

Despite the lack of consistent evidence for disintegration, there has been a growing interest among policy-makers in moving away from the integrated structure, at least to some degree (Munasinghe, 1990). The largest efficiency gains are said to come from reduced political interference in daily operations of the utility, exposure to competition in input markets, and increased pressure on management due to fear of take-over and bankruptcy. The following section discusses the possible options of electricity privatisation in terms of their likely effects on cost-minimising behaviour.

2.4 Efficiency Implications of Models of Electricity Privatisation

Electricity privatisation and its likely efficiency implications are well examined in the literature, for instance by Joskow and Schmalensee (1983) and Tenenbaum, Lock and Barker (1992), among others. It is emphasized that the ultimate success through privatisation will come from not only the transfer of ownership but also from the success in regulation in order to introduce and protect competition wherever feasible, and to prevent monopoly exploitation in natural monopoly.

Recall from the previous section that, with the current technologies, market and demand conditions, there is a consensus that electricity transmission and distribution are naturally monopolistic. Electricity distribution to small domestic end-users is a local monopoly. Electricity generation and electricity supply to large industrial and commercial customers are potentially competitive areas. In theory, competitive areas do not need regulation since competition is regarded as the best regulator. However, at the early stages, regulation may still be needed in order to promote and protect competition until sufficient competition dwells at the market. The need for regulation over naturally monopolistic activities is obvious.

Country-based experiences of electricity privatisation are analysed by Plewhe and Beckert (1992) and Holmes (1991). Flavin and Lenssen (1994) include a selected list of countries, stating their industry structure before and after reforms. Four models of electricity privatisation can be identified. Each model differs according to the degree of disintegration and competition introduced at privatisation of the publicly owned electric utility. A number of issues are expected to influence which model will be chosen. These are the privatizing countries' economic conditions, intellectual and technological endowments, and political climate towards privatisation.

The first model is transferring public utility to private sector without any disintegration. This is the easiest model to apply, and the most attractive for private investors since the utility is transferred with its monopoly power attached. Privatisation is not accompanied by competition, therefore it has the worst incentive for productive efficiency. The economic activities of the private owners should be regulated by either ROR or RPI-X regulation. This may be easier to handle than a more disintegrated structure since now only the final price of the utility will be a matter of regulation; transactions between production stages within the utility are ignored.

The second model involves liberalization of the wholesale electricity market while still keeping the integrated structure of public monopoly. This is a partial but quite attractive privatisation strategy, in particular for countries such as Turkey, which face financial constraints for expansion expenditures in the energy sector, and prefer to experience privatisation in a limited way without losing ownership of electrical equipment.

In this model domestic and foreign investors are allowed to bid for constructing new generating capacity under the built-operate and transfer (BOT) scheme. The BOT scheme works as follows: A private investor (domestic or foreign) or consortia of private investors bring the capital needed to construct power plants, and get it back during the operation of the power plants with an extra return on the capital invested. At the end of contract period the private investor returns the plants to the government according to the contract signed and without any claims of compensation. The BOT scheme has been a very popular way to finance infrastructural expansion by private capital, as described and illustrated by Sirtaine (1994). Alternative to the BOT scheme is the built-operate and own (BOO) scheme where the private investor retains ownership of the newly constructed power plant.

Demsetz competition may occur at the bidding stage for plant construction, however other than that a competitive outcome is less likely to materialize. Because the bid-winner will often insist on selling electricity to the public utility under a long-term contract which specifies ex ante and ex post price and price escalation clauses as well as minimum sales and performance standards in order to reduce the risks of uncertainties about various contingencies that may arise during the contract period.

Demsetz competition can also be promoted for the franchise of distribution services. Either the BOT or the BOO schemes can be followed for the renewal and construction of distribution networks. Or, the government may choose to bear the sunk costs of capital investment and transfer only the management of distribution organization. In that case, the physical assets of electrical equipment are not transferred to private investors, but the rights to the residual profits arising from the operations of the distribution organization are transferred. In a broader sense this also constitutes a form of privatisation, although it does not involve asset transfer (Vickers and Yarrow, 1991b).

At the extreme case, the government may sell individual power plants to private investors.

Demsetz competition will still require regulation in order to ensure that the bidding stage is genuinely competitive, and in order to enforce and monitor the implementations of the contract conditions.

The third model involves a change in the integrated structure of public utility. The distribution part is isolated from the generation and transmission part, and each part is organised under a separate company. The companies then organize their relationship through contracts. After that, the companies can be divested to the private sector as regulated monopolies. This model does not provide extra incentive for cost effective behaviour since competition is not introduced to the potentially competitive areas.

The third model is very similar to the current structure of the dominant public utility (the TEA) after it was split into two companies: the TEAS and the TEDAS. As explained in the following chapter, the former became responsible for power plants and transmission network, while the latter became responsible for local distribution networks and electricity supply to end-users. These companies have not been privatised yet.

The last model is the British (England and Wales) model which represents the most radical structure for an electricity supply industry among the models presented in this section. The British model involves "1. vertical separation between generation and transmission, 2. horizontal breakup and liberalization of generation, 3. a regional structure for distribution and retail supply, 4. phased liberalization of retail electricity." (Armstrong, Cowan and Vickers, 1994, p.279).

Before privatisation the publicly owned electricity supply industry in England and Wales was separated into two parts. The Central Electricity Generating Board (CEGB) was responsible for electricity generation and transmission, while electricity distribution and supply to end-users were undertaken by twelve area boards.

In March 1990, The CEGB was vertically and horizontally disintegrated. The fossil-fuel burning power plants of the CEGB were distributed between two new generation companies: National Power and PowerGen, while the nuclear power plants were inherited by Nuclear Electric. Sixty percent of the former two companies were privatised on March 1991, but the latter is still publicly owned in 1995, but being prepared for sale.

The Electricity transmission was transformed to another private company, National Grid Company (NGC) which was initially jointly owned by, and expected to work at arm's length from, the newly created twelve regional electricity companies (RECs). NGC is now being sold by the RECs to become a separate company.

Electricity transmission, distribution and supply to customers with demand less than 1MW was franchised as a local monopoly and regulated. The limit for monopoly electricity supply to customers was further reduced to 100kW in 1994, and due to be abolished in 1998. That is electricity supply is gradually opening for competition. The type of regulation is RPI-X regulation where the constraint is imposed on average revenue per KWh. At the electricity supply cost pass through is allowed. Costs of power purchase, transmission, and distribution, fossil fuel levy are allowed to be reflected in the electricity price to end-users.

Electricity generation is not regulated; actual competition between the new generators as well as potential competition from the new comers, and imports from Scotland and France are expected to lead to lower electricity prices. NGC plays an important role in the new industry structure. It is responsible for scheduling of power plants, maintaining the system stability, and coordinating the electricity transaction from Scotland and France. NGC is also the pool manager, the newly created spot market for bulk electricity supply, and acts as a maestro buying electricity from the power companies and selling to large customers and distribution companies at a minimum cost possible.

The pool electricity price is determined in the bulk supply market as follows: Each generator informs for the next day in which half-hour slot which plants will be available to run for what price. The pool ranks the available plants starting from the cheapest bid-price to more expensive untii they are sufficient to meet demand forecast. Aii piants which are run in the next day are paid the most expensive bid-price among the running power plants. However, since the pool prices vary widely according to demand at time of day and year, the parties are usuaily entering into contracts in order to hedge the risks that may occur from volatile price fluctuations.

Newbery (1994, p.303) comments on the effects privatisation had on efficiency in the British electricity supply industry. He analyses the impact of privatisation on efficiency in the short run in terms of whether electricity is transmitted to its end users at least cost (merit order dispatch); in the medium run in terms of whether the inputs are selected and used correctly; and in the long run in terms of whether sufficient amounts of investments are made at least cost, by using the best technology, and in the correct place.

Newbery reports the concerns about the damaging ability of National Power and PowerGen to manipulate the pool-price by not declaring capacity which in fact can be made available. Significant increases in labour productivity were observed. The short run efficiency in general increased but since electricity prices did not decrease fast, that result in large profits to the generators. Charges for electricity transmission were not adequately related to energy losses, thus it was not clear whether the whole system was operating at the least possible cost. Another concern was that the NGC appeared to be less effective in influencing the location decisions of new plant construction. However, under the new structure it seems that both the costs and construction time of power plants are reduced by about 50%.

2.5 Conclusion

This chapter has discussed the recent departure from the integrated structure in electricity supply industries. A more disintegrated and competitive, preferably privately owned, electricity supply industry was claimed to be a better arrangement for a better cost minimising result. Nevertheless, these claims are not supported by consistent and clear cut empirical evidence, and there is a strong feeling for the continuation of the integrated structure in the electricity supply industry, if not for economies of scale, for benefits from economies of scope, horizontal and vertical integration. However, the lack of consistent evidence for disintegration does not stop the move by a growing number of countries towards a partial or complete privatisation.

The more obvious motive for electricity privatisation, particularly in indebted countries, may be continuous dissatisfaction with perceived poor operational and financial performance of a publicly owned electricity supply industry. Investments in electricity supply industry are capital intensive, and, under public ownership, they are usually met by the government which also allocates financial resources to other sectors of economy. Many indebted countries suffer from an acute budget deficit, and its capital intensive nature makes the electricity supply industry one of the largest contributors to the central budget deficit. This led many governments to recognize privatisation as an attractive option for finding the needed financial resources.

The World Bank played an important role in promoting and encouraging electricity privatisation, in particular in indebted countries. This can be observed from the policy change in the World Bank towards financing energy projects. After the Second World War, the Bank encouraged the capital-poor countries to establish and develop their energy infrastructure in the public sector by borrowing directly from international banks and agencies. Then it was easier to borrow with favorable conditions. However, after the oil shocks in 1973 and 1978, the indebted countries experienced severe macroeconomic crises, increasing their foreign debt and leaving the majority of them financially insolvent. Under these conditions further borrowings from domestic or international financial markets by sovereign governments would only worsen the already serious debt problem (see Barnett, 1993).

The World Bank then proposed that indebted countries free their public institutions to shop around for their own financial needs (Oliveira and MacKerron, 1992). To help the implementation the Bank extended "Energy Sector Loans" as a part of "Structural Adjustment Loans" to a number of indebted countries, including Turkey, under the condition that they reform and improve the productivity of public institutions operating in energy sector. In the light of these developments, the following chapter analyses the Turkish experience of electricity privatisation.

Chapter 3 Electricity Privatisation in Turkey

3.1 Introduction

This chapter evaluates the development of the Turkish electricity supply industry, and its privatisation to date. Two related motives are driving electricity privatisation in Turkey. The first motive is the financial and operating inefficiencies in the dominant public utility, the Turkish Electricity Authority (TEA); while the second motive is the inability of the government to finance the TEA's investment anymore owing to the outstanding budget deficit and national debt. During the 1970s, the TEA, like the other large state-owned enterprises, was used by successive governments to satisfy their socio-economic objectives similar to those discussed in the previous chapter, which resulted in over employment, incorrect investment decisions, misplaced power plants, and continuous budget deficits. The TEA is one of the largest state-owned enterprises in Turkey employing about 70 000 people, and has one of the worst financial records among other public utilities, its contribution to the national debt reaching about $600 million at the end of 1990 (Plehwe and Beckert, 1992).

Electricity privatisation started with the announcement of the electricity liberalisation law in 1984, by freeing the entry into wholesale supply and local distribution markets. This was in fact to comply with the condition that was imposed on Turkey by the World Bank for "Energy Sector Loans." The government expects private investors to improve financial, operational, and managerial efficiency in the electricity supply industry. Initially, a partial privatisation policy was pursued, attracting private investors to undertake renewal and expansion of electricity infrastructure by the BOT scheme, without transfer of property rights. This is similar to the second industry structure in the previous chapter. The BOT scheme tried and failed to attract private investors. Now, the government is forced to compromise on the issue of property rights of electrical equipment to find the much needed financial resources. For that, the TEA was restructured by separating distribution from generation and transmission in 1993 as a preparation for future privatisation. This is the third industry structure of the previous chapter. After that, recently, the government announced its plan to sell four out of sixteen thermoelectric power plants in 1995.

Privatisation of the TEA can be seen as the reversal of the efforts put for nationalisation of the electricity supply industry which ended with the creation of the TEA in 1970. The shift from nationalisation to privatisation in the Turkish electricity supply industry can be analysed under three transitory periods. The following section analyses the developments until the establishment of TEA in 1970. The third section discusses the developments during the monopoly period of the TEA. The fourth section evaluates the implications of the Liberalisation Law of 1984, and implementation of electricity privatisation to date. The fifth section concludes the chapter.

3.2 The Early Years of the Turkish Electricity Industry

This period coincides with the early years of the Republic of Turkey founded in 1923. The period can be identified with efforts to rebuilt the war-torn country, by establishing state-owned enterprises undertaking economic activities in almost every sector of economy (Canevi, 1994). Untii the beginning of the 1950s, the government could not transfer enough capital to develop its own electricity supply system, thus it had to continue with the privileged company's system adopted from the Ottoman Empire time. Under this system, private companies, usuaily with a large foreign partner(s), were given concessions to supply electricity to a predefined area by constructing and operating power piants (Toktas, 1993).

The earliest examples of this system can be traced back to 1902 when a Swiss and Italian partnership was given the concession to construct and operate a power plant to supply eiectricity to Tarsus. Another example is the Ottoman Electric Company, a joint partnership of Hungarian Gant joint-stock company (jsc), Banque Generale de Credit, and Banque de Bruxellese, which was to construct the Silahtaraga power plant and supply electricity to Istanbul in 1914. These examples can be regarded as fore-runners of the BOT scheme that the government tried to revitalise by the Liberalisation Law of 1984.

Several private companies then were given concessions to construct, operate and supply electricity to a number of large cities such as Ankara, Adana, Bursa, Antep, and Tekirdag. Due to strong pressure to eliminate foreign ownership in Turkey all these companies had been nationalised at various times by 1945. The nationalised power plants were run by the Minlstry of Public Works until they were transferred to the municipalities which were then given an important role in their local electricity business by the Law no.4483 of 1943.

As the economy developed and demand for electricity energy increased, the government moved towards a more organised way of constructing power plants and running the electricity supply system. To undertake this mission a number of public institutions were established in 1935 such as the General Directorate of Electrical Works Study and Research Administration (EWSRA), the Mineral Research and Exploration Institute (MREI), and the Etibank. In 1945 the Provincesbank and in 1953 the State Hydraulic Works (SHW) were established. The most important of these institutions were Etibank, the SHW, the Provincesbank, and municipalities. Each institute dealt with different aspects of power plant construction and nation-wide electrification, supposedly with close co-ordination with and support for each other.

Inspite of nationalisation and efforts by the aforementioned public institutions to construct power piants and satisfy electricity demand, some private companies continued to seek a place in the electricity supply industry. For instance, an attempt was made to establish the Northwest Anatolia Electrification Partnership, but this failed in 1952. In 1953, the Aegean Electric jsc was established, but subsequently failed to stay in the market. In the same year, the Cukurova Electric jsc, and in 1956 the Kepez and Antalya Environs Electric jsc were established, and have managed successfully to survive in the market to date. The World Bank played a crucial advisory role in the foundation of the last two private companies.

Both companies have been recognised as privileged companies by the MENR until 2002, which was extended later in 1988 for another 70 year ending in 2058. The privilege status gives them a monopoly to generate, transmit, distribute, and sell electricity to mainly large industrial, commercial and other customers in their defined service areas. Cukurova Electric jsc serves in three provinces namely Adana, Icel and Hatay, while Kepez Electric jsc serves in only one province namely Antalya. These provinces were also served by public distribution organisations. The relationship between these companies and the

TEA and the Ministry of Energy and Natural Resources (MENR) are discussed later.

Until the foundation of the TEA in 1970, the electricity supply industry exhibited a very segregated structure. The national grid was not completed, and there were challenges and often delaying disagreements between the public institutions about the way to deal with different aspects of electrification of the country. This led to a growing consensus for standardising and administering the electricity supply system by one institution, the TEA.

The foundation of the TEA first came into the agenda as early as 1957. The TEA was to takeover all electrical equipment of municipalities. Members of parliament representing big cities were enjoying great political benefits through the electricity operations of municipalities. Fearing for the disappearance of their political influence, they lobbied and opposed strongly the bill for the foundation of the TEA, eventually gaining its withdrawal by the government. Later, there were several unsuccessful attempts by proponents of the establishment of the TEA, which had to wait for realisalisation until 1970.

Eventually in 1968, the bill was presented to the National Assembly for discussion, with great support and persuasion of the World Bank. Interestingly the same World Bank is now proposing the privatisation of the TEA. In 1970, the TEA was established under the Foundation Law no.1312, by inheriting all electric facilities, power plants, and transmission networks belong to the Etibank, the Provincesbank, and the SHW. Later the municipalities transferred their power plants to the TEA, but the operations of the local distribution networks remained in the hands of local administrations until the public distribution organisations were established by the TEA, one for each province, in 1982.

3.3 The Monopoly of the TEA

The TEA was given the responsibility of organising the electricity generation, transmission, distribution and supply throughout the country. As the economy developed and energy demand increased, the TEA undertook an ambitious electric power development programme financed by internal and external financial resources to overcome the shortages in electricity generation.

Table 3.1 shows the development of the installed generation capacity according to energy sources used between 1970 and 1991. During the first three operational years of the TEA, the total installed capacity reached 3192.5 MW of which 79% was thermoelectric generation capacity. The installed capacity of oil-fired power plants accounted for the largest share (47.0%) in the total installed capacity, which was partly due to relatively cheap oil prices and low construction costs of thermoelectric power plants during the 1960s.

However, after the first oil shock in 1973, oil prices increased sharply, leading the TEA to import electricity from Bulgaria and Russia to cover shortages, to switch to alternative energy sources such as lignite, and to explore its hydroelectric generating potential (Kolars, 1986), which is about (gross) 112 TWh/yr (Tasdemir, 1988). The starting of the Southern Anatolia Development Project (SADP) coincides with this period, which has been financed solely by internal financial sources (Kolars and Mitchell, 1991), and still swallows large amount of capital daily. The SADP includes the construction of fifteen hydroelectric power plants with about 7600 MW capacity at the Euphrates and Tigris rivers.

Table 3.1 the installed capacity according to the energy sources in Megawatts (1970-1991)

Year	Hard Coal	(%)	Lignite	(%)	Fuel-Oil	(%)	Natural Gas	(%)	Geo-thermal	(%)	Other	Thermo Total	(%)	Hydro Total	(%)	Overall Total	(%)
1970	350.3	16.0	306.6	16.7	655.9	27.1	-		-		5.2	1509.5	64.8	725.4	35.2	2234.9	100.0
1971	350.3	14.8	306.6	15.6	848.1	39.8	-		-		5.2	1706.3	73.3	871.6	26.7	2577.9	100.0
1972	350.3	12.7	308.6	13.3	854.7	43.1	-		-		12.4	1818.7	71.5	892.6	28.5	2711.3	100.0
1973	350.3	12.1	608.6	14.0	906.0	47.0	-		-		12.4	2207.1	79.0	985.4	21.0	3192.5	100.0
1974	350.3	11.3	608.6	17.5	906.1	39.9	-		-		12.4	2282.9	75.1	1449.2	24.9	3732.1	100.0
1975	350.3	9.1	608.6	17.2	966.1	30.1	-		-		12.4	2407.0	62.2	1779.6	37.8	4186.6	100.0
1976	350.3	7.4	608.6	16.3	984.3	25.5	-		-		12.4	2491.6	54.2	1872.6	45.8	4364.2	100.0
1977	350.3	6.2	908.8	17.6	1047.3	26.9	-		-		12.4	2854.6	58.3	1872.6	41.7	4727.2	100.0
1978	323.3	5.6	1069.1	20.1	1047.3	26.1	-		-		12.4	2987.9	57.0	1880.8	43.0	4868.7	100.0
1979	323.3	4.7	1069.1	23.9	1047.3	22.7	-		-		12.4	2987.9	54.3	2130.8	45.7	5118.7	100.0
1980	323.3	3.9	1069.1	21.7	1047.3	22.4	-		-		12.4	2987.9	51.2	2130.8	48.8	5118.7	100.0
1981	323.3	3.6	1234.1	21.3	1057.8	21.1	-		-		12.4	3181.3	48.9	2356.3	51.1	5537.6	100.0
1982	232.3	3.4	1621.5	20.8	1057.8	20.0	-		-		-	3465.3	46.6	3082.3	53.4	6547.6	100.0
1983	245.9	2.9	1825.8	28.5	1057.8	23.2	-		-		-	3695.8	58.5	3239.3	41.5	6935.1	100.0
1984	219.9	2.3	2381.4	30.7	1340.7	21.9	-		15.0	0.1	-	4584.3	56.1	3874.8	43.9	8459.1	100.0
1985	219.9	2.1	2886.4	41.8	1395.7	20.5	100.0	0.2	15.0	0.1	-	5244.3	64.8	3874.8	35.2	9119.1	100.0
1986	197.7	2.0	3601.4	47.0	1395.7	17.5	400.0	3.4	15.0	0.1	-	6235.2	70.1	3877.5	29.9	10112.7	100.0
1987	181.6	1.4	4456.4	38.4	1492.6	12.2	800.0	5.7	15.0	0.1	-	7489.3	58.0	5003.3	42.0	12492.6	100.0
1988	181.6	0.7	4456.4	25.3	1547.6	6.8	1555.2	6.7	15.0	0.1	-	8299.8	39.7	6218.3	60.3	14518.1	100.0
1989	331.6	0.6	4735.8	38.3	1544.6	8.1	2035.8	18.3	15.0	0.1	-	9208.4	65.5	6597.3	34.5	15805.7	100.0
1990	331.6	1.1	4896.2	34.0	1552.4	6.8	2210.0	17.7	15.0	0.1	-	9550.8	59.8	6764.3	40.2	16315.1	100.0
1991	352.6	2.0	5071.8	29.4	1552.4	9.0	2555.4	14.9	15.0	0.2	-	10092.8	58.5	7113.6	41.5	17206.4	100.0

Source:The Summary of Turkish Electricity Statistics, APK-351, August-1991, p.2 and p.38.

By 1982, the share of Hydroelectric installed generation capacity reached 53.4% of the total installed capacity. Then, in 1986, it decreased almost to its previous level in 1972 (29.9%). This was due to the connections of newly built lignite-fired power piants into the system, which increased the thermoelectric generation capacity to 70.1% of the total generation capacity. Until 1989, several thermoelectric and hydroelectric power piants were connected to the national system. In 1991, about 59% of the total installed generation capacity was provided by the thermoelectric power plants.

Between 1970 and 1991, the main changes in the total installed capacity originated from the capacity increases by the TEA. As seen from Table 3.2, Cukurova Electric jsc had 166.0 MW (106.0 MW thermoelectric, and 60.0 MW hydroelectric) total installed capacity in 1970. By 1974, its installed hydroelectric generation capacity increased to 192.0 MW, increasing its total installed capacity to 298.0 MW. Cukurova Electric jsc's total capacity remained the same untii 1991. Kepez Electric jsc's total hydroelectric generation capacity was 26.4 MW until 1985, which then increased to 30.4 MW in 1986 and later to 80.4 MW in 1987. The auto-producers operated thermoelectric and hydroelectric power plants during the period. Their total installed generation capacity increased from 347.2 MW in 1970 to 1193.7 MW in 1991, which makes 7% of the total generation capacity.

Cukurova Electric jsc and Kepez Electric jsc retained their places in the eiectricity market. However, their ambition to extend their share in the market was prevented by the monopoly power of the TEA. The foundation Law no.1312 defined the TEA as the ultimate statutory monopoly to organise construction of power plants. When needed, the TEA did not hesitate to exercise that power. For instance, at the time when the market needed new

Table 3.2 The installed capacity according to the generation companies in Megawatts (1970-1991)

	TEA			CEAS			Kepez		Outo-	produ	cers	Man	ucipa	lities	Turkey		
Year	Thermo	Hydro	Total	Thermo	Hydro	Total	Hydro	Total	Thermo	Hydro	Total	Thermo	Hydro	Total	Thermo	Hydro	Total
1970	904.7	534.3	1439.0	106.0	60.0	166.0	26.4	26.4	347.2	12.2	359.4	151.6	43.6	195.2	1509.5	725.4	2234.9
1971	1094.7	669.6	1764.3	106.0	130.0	236.0	26.4	26.4	389.9	12.2	402.1	115.7	32.0	147.7	1706.3	871.6	2577.9
1972	1188.3	689.8	1878.1	106.0	136.0	242.0	26.4	26.4	409.2	12.2	421.4	115.2	26.8	142.0	1818.7	892.6	2711.3
1973	1568.3	782.1	2350.4	106.0	136.0	242.0	26.4	26.4	414.3	12.2	426.5	118.5	27.3	145.8	2207.1	985.4	3192.5
1974	1643.3	1190.3	2833.6	106.0	192.0	298.0	26.4	26.4	415.0	12.2	427.2	118.6	26.9	145.5	2282.9	1449.2	3732.1
1975	1708.5	1520.7	3229.2	106.0	192.0	298.0	26.4	26.4	475.0	12.2	487.2	117.5	26.9	144.4	2407.0	1779.6	4186.6
1976	1771.1	1613.8	3384.9	106.0	192.0	298.0	26.4	26.4	496.2	12.2	508.4	118.3	26.8	145.1	2491.6	1872.6	4364.2
1977	2071.1	1613.8	3684.9	106.0	192.0	298.0	26.4	26.4	559.2	12.2	571.4	118.3	26.8	145.1	2854.6	1872.6	4727.2
1978	2178.8	1622.0	3800.8	106.0	192.0	298.0	26.4	26.4	584.8	12.2	597.0	118.3	26.8	145.1	2987.9	1880.8	4868.7
1979	2178.8	1872.0	4050.8	106.0	192.0	298.0	26.4	26.4	584.8	12.2	597.0	118.3	26.8	145.1	2987.9	2130.8	5118.7
1980	2178.8	1872.0	4050.8	106.0	192.0	298.0	26.4	26.4	584.8	12.2	597.0	118.3	26.8	145.1	2987.9	2130.8	5118.7
1981	2344.7	2097.5	4442.2	106.0	192.0	298.0	26.4	26.4	613.2	12.2	625.4	117.4	26.8	144.2	3181.3	2356.3	5537.6
1982	2719.7	2823.5	5543.2	106.0	192.0	298.0	26.4	26.4	613.2	12.2	625.4	117.4	26.8	144.2	3556.3	3082.3	6638.6
1983	2937.6	2998.5	5936.1	106.0	192.0	298.0	26.4	26.4	625.2	12.2	637.4	27.0	10.2	37.2	3695.8	3239.3	6935.1
1984	3542.9	3644.2	7187.1	106.0	192.0	298.0	26.4	26.4	935.4	12.2	947.6	-	-	-	4584.3	3874.8	8459.1
1985	4147.9	3644.2	7792.1	106.0	192.0	298.0	26.4	26.4	990.4	12.2	1002.6	-	-	-	5244.3	3874.8	9119.1
1986	5141.8	3644.2	8786.0	106.0	192.0	298.0	30.4	30.4	987.4	10.9	998.3	-	-	-	6235.2	3877.5	10112.7
1987	6290.9	4720.1	11011.0	106.0	192.0	298.0	80.4	80.4	1092.4	10.8	1103.2	-	-	-	7489.3	5003.3	12492.6
1988	7046.4	5935.1	12981.5	106.0	192.0	298.0	80.4	80.4	1147.4	10.8	1158.2	-	-	-	8299.8	6218.3	14518.1
1989	7939.0	6298.1	14237.1	106.0	192.0	298.0	80.4	80.4	1163.4	10.8	1174.2	-	-	-	9208.4	6597.3	15805.7
1990	8261.7	6465.1	14726.8	106.0	192.0	298.0	80.4	80.4	1183.1	10.8	1193.9	-	-	-	9550.8	6764.3	16315.1
1991	8793.1	6521.5	15314.6	106.0	192.0	298.0	80.4	80.4	1193.7	10.8	1204.5	-	-	-	10092.8	7113.6	17206.4

Source:The Summary of Turkish Electricity Statistics, APK-351, August-1991, p.3, and APK-354, p.4.

investment for new power capacity, Cukurova Electric jsc volunteered to construct new hydroelectric power plants.

In 1976, the Council of Ministers approved the request for permission by that company. However, the TEA insisted on its monopoly in construction of power plants and reacted swiftly by applying to the Council of State for cancellation of the permission. The Council of State recognised the TEA's monopoly in co-ordination of any electrical expansion, and cancelled the permission. Nevertheless, the TEA could not meet the increasing electricity demand by investing in new generation capacity, which led to the announcement of the Electricity Liberalisation Law of 1984.

3.4 The Liberalisation Law of 1984 and Privatisation to Date

Several countries including Turkey suffered severe macroeconomic crises following the oil shocks in 1973 and 1978, increasing their foreign debt and leaving the majority of them financially insolvent. That made it very difficult for the indebted countries to carry on with budget-financing of infrastructure development project. The World Bank then proposed that Turkey and several other indebted countries seek for methods of financing these projects through extra-budgetary resources. That included freeing their public institutions to shop around for their own financial needs. Privatisation was shown as an important and useful way of reducing the financial burden of energy utilities on the Treasury. To help the implementations the World Bank offered "Energy Sector Loans" as a part of "Structural Adjustment Loans (SAL)" under the condition of reforming and improving the productivity of public institutions operating in the energy sector.

Turkey is one of the rare countries which received five successive structural adjustment loans between 1980 and 1984. Freeing the loans was conditional on meeting some specific policy changes in four key areas: trade policy involving measures to promote exports and liberalise imports; reforms of the capital market and financial sector; reform of the state-owned enterprises; and sectoral reform directed particularly towards energy sector (Kirkpatrick and Onis, 1991).

To comply with the conditionality of the SAL V offered by the World Bank, Turkey prepared its energy sector plan in 1984, and joined the wave of electricity privatisation by announcing the Electricity Liberalisation Law (no.3096), which abolished the legal monopoly rights of the TEA in the electricity market. Later to support the implementation, the World Bank extended an extra energy sector loan of $375 million in 1987.

By the Liberalisation Law, the government introduced a partial privatisation policy, financing the expansion and renewal investments of the electrical infrastructure under the Built-Operate and Transfer (BOT) scheme, without giving up the property rights of the electrical equipment. As indicated in the second section the idea of the BOT scheme was not new for Turkey.

In fact the first step for liberalisation of the electricity market was taken in 1982 by the Law no.2705, which gave the rights to private investors to construct power plants and sell their electricity to the TEA. This can be regarded as an example of Built-Operate and Own (BOO) scheme. The Yurttaslar jsc was first to come forward to take advantage of the BOO scheme. Its application to construct the Tohma hydroelectric power plant (13 MW) was first accepted, but later cancelled as the company failed to complete the required project and financial conditions.

The Law no.3096 laid down the conditions by which the private investors can, for a predefined time period, construct power plants to generate, transmit, distribute, and trade electricity, and also can operate power plants belonging to the TEA. The same Law stated the type, duration, tariff structure and ending condition of the entrustment contract to be signed by the private investors. Since then, there have been many amendments and contributions to the Electricity Liberalisation Law of 1984.

At the time when the ability of Turkey to borrow at all was in question, the government regarded the BOT scheme and franchising monopoly rights of local distribution as attractive alternatives to central budget financing of infrastructural projects by attracting financial support from private investors. Securing overdue payments through franchised distribution organisations was seen as another way to recap financial losses for the government which is deeply concerned with not upsetting its voters.

Augenblick and Custer (1990) give early examples of the BOT arrangements in Turkey. Power plants are usually built by a joint venture company on an equity-debt basis (usually 30% equity and 70% debt), and run long enough to pay back all financing put in place. Generated electricity is purchased by the TEA on a take-or-pay basis. The price of electricity is paid in a basket of convertible currencies, where dominant currency varies between projects. The payment is made by the TEA and guaranteed by the government. The lenders have no recourse for repayment of the debt to either the government or the share-holders of joint-venture company. At the end of the agreed period, the power plant is transferred to the TEA. The renewal investments of the distribution network are undertaken by a similar arrangement.

At the beginning, the MENR negotiated with private investors a cost plus profit type of tariff which consists of capital charge, operating charge (operating costs, administrating costs, insurance costs, maintenance costs), and dividend-a return on equity sufficient to provide an internal rate-of-return for the investor's equity so investors would commit the capital expenditures. This is very similar to the tariff structure under rate-of-return regulation examined in chapter 2. This type of negotiation took a long time, thus the MENR switched to a simpler way which is similar to RPI-X regulation, negotiating the sale price of electricity only. The government stili guarantees that the TEA buys the agreed amount of eiectricity at an agreed sale price.

Since the announcement of the Eiectricity Liberalisation Law, there have been many applications by private investors to the MENR, which controls the energy sector and its privatisation, to take part in the newly liberalised electricity market. However, the pace of electricity privatisation and liberalisation has been very slow, and rather disappointing for the government. Most of the negotiations for power plant construction were directed to exploit the hydroelectric generation resources of the country. Besides that, there were also a small number of thermoelectric power projects, though with larger capacity, under negotiation. In 1993, the total installed generation capacity of hydroelectric and thermoelectric power plants which the implementation contracts were signed and which were under examination reached 1495 MW and 2350 MW, respectively (Aybar, 1993).

So far only three small hydroelectric power plants namely Aksu-caykoy (10 MW), Hasanlar (9.5 MW), and Kisik (9.5 MW) were constructed, and another one Mudurnu (33.15 MW) is under construction by private investors under the BOT scheme. Table 3.3 lists a number of hydroelectric plant projects to be constructed under the BOT scheme. The list represents developments until 29 August 1991.

Table 3.3. Hydroelectric plants to be constructed under the BOT scheme

List of the Hydroelectric Plants which only the construction contract signed

Plant	Installed Capacity (MW)	Applicant	Construction Area	Date of Contract
ASLANCIK	90	CUKUROVA-DOGUS	GIRESUN	18 June 1987
BERDAN	10	ENERJI TESIS	MERSIN	17 April 1987
LAMAS	1.6	EVDILEK	ICEL	28January 1988
TORTUM-2	11	NURTEK	ERZURUM	18 August 1988
PORSUK	2	GUNDES	ESKISEHIR	30 November 1988
SOLAKLI	380	MAPA-NORENDEL	TRABZON	14 March 1989
BIRECIK	672	BIRECIK	S.URFA	25 April 1989
KONAKTEPE	210	KPP	TUNCELI	15 May 1989
GUROLUK	135	BM MUHENDISLIK	RIZE	14June 1989
BEGENDIK	20	BAHCESARAY	SIIRT	11 January 1990
GURCE	10.5	GURCE	ANTALYA	30 January 1990
KOVADA III	6.8	GOKDERE	ISPARTA	30 January 1990
GOKSU	6.5	GOKSU	ISPARTA	30 January 1990
GOMBE	11.5	KAVALA	ANTALYA	13 August 1990
AHIKOY I-II	4.2	PELKA	SIVAS	13August 1990
ESENKOY	1.97	ENERJI-SU	MUGLA	13 August 1990
SUTCULER	2	SUTCULER	ISPARTA	14 June 1991

List of the plants which their construction contract is ready to be signed

Plant	Installed Capacity (MW)	Applicant	Construction Area
DUZCE	43.1	KAVALA	BOLU
LAMAS III-IV	41	TGT	ICEL

List of Hydroelectric Plants which their fisibility reports are under examination

Plant	Installed Capacity (MW)	Applicant	Construction Area
YAMULA	100	KAYSERI	KAYSERI
BAYRAMHACILI	30	KAYSERI	KAYSERI
ESEN I-II	90	TEMELSU	MUGLA
ESEN III	13.5	FETES	MUGLA
TOHMA	11.5	SEPTAS	MALATYA

List of Plants which their fisibility reports are under discussion

Plant	Installed Capacity (MW)	Applicant	Construction Area
TOZKOY	140.0	SWEDISH HYDRO POWER GROUP	RIZE
DEREKOY	105	GRASETTO CONS.	RIZE
KALKANDERE	34	GRASETTO CONS.	RIZE
CEVIZLIK	90	GRASETTO CONS.	RIZE
CEVIZLIK	90	NORENDEL	RIZE
DUTLUDERE	30	GENIS	CORUM
LAMAS I-II	26	TGT	ICEL
GULNAR ILISU	20	TISAN	ICEL
FETHIYE	16.5	AGE	MUGLA
CILDIR II	8.7	IPA	KARS
DINAR II	3	ACK	AFYON
AKSU ANAMAS	2	OZ	ISPARTA

The majority of foreign investors were interested in construction projects of relatively larger thermoelectric power plants. For instance, a consortium led by Trinity Partnership International Inc. (USA) signed the implementation contract in 1992 to construct Cankiri-Orta thermoelectric power plant (250 MW). In the same year, another consortium of Enron Power Holding C.V. (Holland), Wing International Inc. (USA), Midland Generation (UK), and Gama (Turkish) was negotiating with the MENR to construct thermoelectric plants in Marmara-Ereglisi (400 MW), Gebze (1000 MW), and Izmir-Aliaga (700 MW). Unit

International Inc. was also negotiating to construct three natural gas burning power plants in the same areas. A consortium led by Japanese EPDC and an Australian company (SEAPAC) was waiting for site selection to construct Aliaga coal fired power plant (1000 MW) and Gazi coal fired power plant (1600 MW), respectively (Aybar, 1993). Another group of British investors came forward as partners of Karadeniz Electric jsc.

The construction of the power piants has not started yet due to disagreements about financial guarantees between the government and private, particularly foreign, investors (Plehwe and Beckert, 1992). The government resisted giving repayment guarantees to private investors; if such guarantees had been given the method of financing these power plants would not be much different than financing them by the budget. There have been many meetings to clear the differences with foreign partners, but no progress has been achieved yet. Another cause for delay was due to frequently changing legislation, sometimes during the negotiations, and difficulties in passing the amended bills through the National Assembly.

During the 1970s, the TEA was largely concerned with expansion of electricity generation and the distribution side was relatively neglected, and so needed to be rehabilitated. Perhaps for that reason electricity privatisation has started from the distribution side. In 1985, the boundaries of fifteen distribution areas to be franchised to private companies were defined. In 1989, by the recommendation of the MENR, the Council of Ministers defined Cukurova Electric jsc, Kepez Electric jsc, Kayseri Electric jsc, and Aktas Electric jsc as entrusted distribution companies.

The first two companies were to take-over the publicly owned electrical equipment and thus to combine their own operations with that of their public counterparts operating in their service areas. However, they found the conditions of the agreement too unfavourable and did not sign the agreements, maintaining separate distribution systems within the same area as previously.

The last two companies however have signed the entrustment Agreement with the MENR, and the Electrical Equipment and Management Rights Transfer Agreement with the TEA. Kayseri Electric jsc has taken over the public distribution organisation in the province of Kayseri while Aktas Electric jsc has replaced the Anatolian part of operations of public distribution organisation in the province of Istanbul. Both companies commenced service in their corresponding distribution areas in 1990.

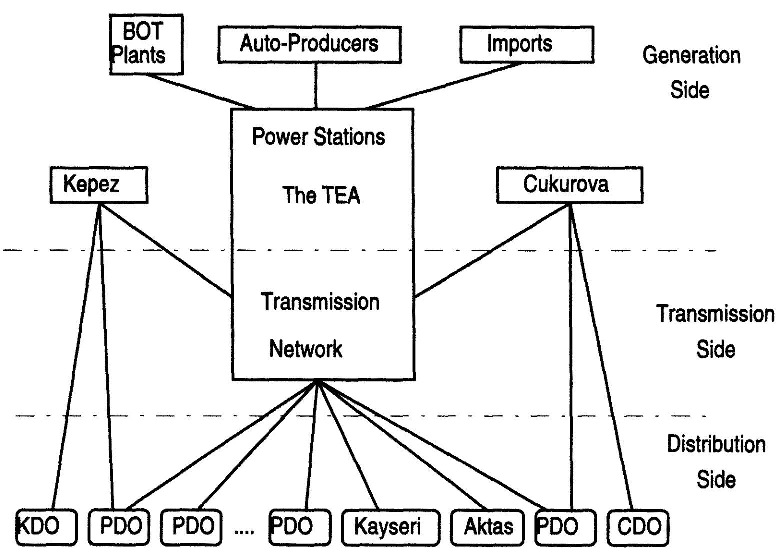
Table 3.4 List of twenty-one distribution areas defined in 1991.

(If not stated otherwise, the area is defined by the provincial boundary).
1. Adana, Mersin, Hatay and Kucuksir, Yesildere, Kisirli villages of province of Kahramanmaras.
2. Antalya, and the lake area of the Karacaoren I, II, III Dams and Hydroelectric stations.
3. Artvin. ***4.*** Aydin, Denizli, and Mugla. ***5.*** Canakkale. ***6.*** Isparta.
7. Eskisehir and Bilecik. ***8.*** Kastamonu. ***9.*** Kirsehir.
10. Kayseri and the villages of Tekmen, Egerci, Agcasar, Arpaozu, Sizir, Dendil, Esikii and Cat of Sivas.
11. Balikesir. ***12.*** Sivas. ***13.*** Tekirdag. ***14.*** Van. ***15.*** Zonguldak.
16. The Anatolian part of Istanbul surrounded by from the West Bosphorous, from the North the Black Sea, from the East the Istanbul-Izmit provincial border, and from the South the Marmara Sea. Also, the islands of Buyukada, Heybeli, Burgaz, Kinali and Sedef.
17. Samsun. ***18.*** Izmir. ***19.*** Afyon. ***20.*** Manisa. ***21.*** Usak.

Following a number of amendments of the boundaries and the addition of some more areas, the Council of Ministers increased the number of distribution areas to twenty-one as shown in Table 3.4 in 1991. Five more private distribution companies were immediately entrusted to operate in five distribution areas shown in Table 3.5 with the franchise of exclusive monopoly rights and accompanying obligations for thirty years.

Table 3.5. List of companies granted a franchise

1- AYDEM Southwest Anatolia Energy Industry and Trade j.s.c. in the fourth entrustment area.
2- GOKDERE Electric j.s.c. in the sixth entrustment area.
3- TEKTAR Electric Generation, Transmission, Distribution and Trade j.s.c in the seventh entrustment area.
4- BEST Balikesir Energy Industry and Trade j.s.c. in the eleventh entrustment area.
5- SENKOM Energy Communication, Generation, Transmission, Distribution, Industry and Trade j.s.c. in the eighteenth entrustment area.



* KDO=Kepez Electric jsc's distribution organisation
PDO=Public distribution organisation
CDO=Cukurova Electric jsc's distribution organisation

Figure 3.1 The structure of the Turkish electricity industry in 1991.

Apparently the government by-passed creating a competitive environment at the bidding stage, by negotiating with only one candidate for the local monopoly rights of one distribution area. In any case, the five companies did not sign the agreements because they were not satisfied with the conditions of the agreements, and were asking for more provision of repayment guarantees. Therefore, the five distribution areas are still serviced by public distribution organisations. At this point it may be useful to present the industry structure in 1991, since the three empirical studies of this thesis use 1991 data.

Figure 3.1 shows the structure of the Turkish electricity supply industry in 1991, which changed little between the foundation of the TEA in 1970 and its restructuring in 1993. The TEA is the vertically integrated dominant public utility accounting for about 89.0% of the total installed capacity (17206.4 MW) of Turkey in 1991.

Cukurova Electric jsc and Kepez Electric jsc are long standing vertically integrated private suppliers in the electricity industry with a tiny share (about 4%) of the total installed capacity. This is insufficient to satisfy local electricity demand in their area, and so both companies purchase electricity heavily from the national system run by the TEA. Recall that these companies have their own distribution networks which are used to serve mainly industrial and commercial customers by Cukurova Electric jsc in three provinces: Adana, Icel, and Hatay; and by Kepez Electric jsc in only one province: Antalya. The remaining customers in each of these provinces are supplied by a separate public distribution organisation which receives its electricity from the national system. The other public distribution organisations obtain electricity from the national system, and are obliged to distribute and supply it in their corresponding distribution area, usually a province, to all domestic, commercial, industrial, and other types of customers.

The slow progress with the BOT arrangements appears to be forcing the government to change its approach towards electricity privatisation. As a sign of that, the government restructured the TEA, splitting it into two separate large companies: the TEAS and the TEDAS in 1993. The present structure of the Turkish electricity supply industry is shown in Figure 3.2. The TEAS inherited all the power plants and transmission network from the TEA while the TEDAS become responsible from the local distribution networks and supply to end-users. Another development is the announcement of the government its plan to sell four out of sixteen thermoelectric power plants immediately in 1995. The government emphasized that the candidates were selected amongst the most in need for rehabilitation.

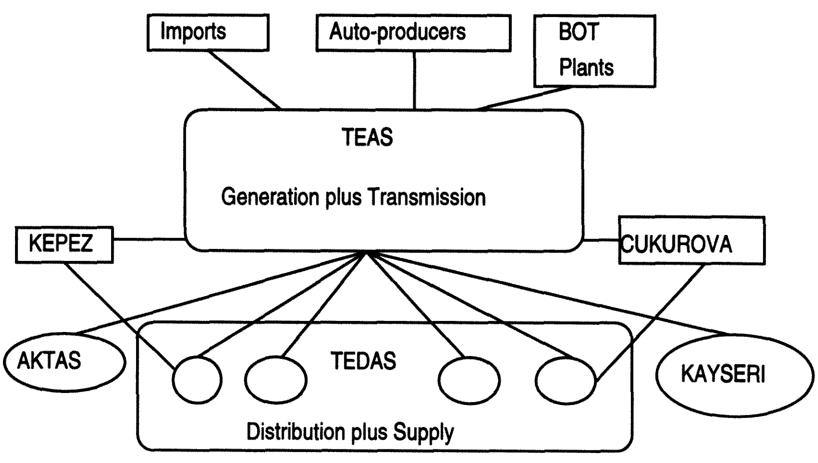


Figure 3.2. The Structure of Turkish Electricity Supply Industry in 1993

The split indicates that the government shifted its interest from internal co-ordination to market-based contractual relationships in the electricity supply industry. However, there is no evidence that the split was undertaken as a result of exhaustion of the benefits of centralised production, nor it is likely to observe any competition under the new structure of the Turkish electricity supply industry. Because, the potentially competitive electricity generation is still vertically integrated with the naturally monopolistic transmission system. The three BOT power plants are obliged to sell electricity through the TEAS, rather than selling it directly to large end-users or to distribution organisations including the newly franchised companies. The electricity generated by the BOT plants are guaranteed to be purchased by the TEAS at an agreed price tariff under a long-term contract.

Formally, the TEAS and the TEDAS now have their own accounting and managerial targets, however, they still have no say on electricity prices. The price decisions are extremely centralised and are decided under the political influence of the MENR. Thus it is very difficult to comment on whether the price tariff reflects the genuine cost of supplying electricity.

3.5 Conclusion

One of the most important motives behind electricity privatisation in Turkey is identified as the need for improvement of financial and operational inefficiencies in the TEA. Failure to bring the necessary capital for the expansion of electrical infrastructure under the BOT scheme has forced the government to undertake more radical internal reforms in the TEA by splitting it into two large companies. The government announced that the split was in order to prepare the TEA for a likely privatisation in the future.

The steps taken by the government towards electricity privatisation so far have not accompanied by empirical investigation, suggesting benefits from leaving economic activities to private sector. That is, there is no empirical evidence supporting either the recent disintegration of the TEA, or that of the franchise of the two distribution organisations to private sector. Therefore, there are clear benefits from investigating the government's claims for privatisation.

A useful way to investigate the impact of privatisation is by pursuing a cost-benefit methodology, similar to the one explained in Jones, Tandon, and Vogelsang (1990). This methodology has recently applied by Gelal, Jones, Tandon, and Vogelsang (1992); Their findings are in favour of privatisation. Green and Price (1993) employ the same methodology to analyse the relationship between privatisation, and steps to increase competition in previously monopolised industries in the UK.

Applying such a methodology however requires a large amount of information which was very difficult in our case to obtain. As we indicated before, during our research we ran into difficulties in obtaining enough data to get a reasonably good picture of performance differences between public and private firms. Cost data was not made available by the TEA and the MENR for our research. Had these data made available, cost differences between public and private firms would be analysed in the Turkish electricity supply industry.

The lack of data led us to ignore the allocative or price efficiency aspects of economic efficiency and concentrate on technical efficiency issue in the Turkish electricity supply industry. The methodology of data envelopment analysis is followed, since it requires data only for physical outputs and inputs for technical efficiency measurement. The following chapter shows how technical efficiency calculated for the three empirical studies of this thesis.

Chapter 4 Methodology of the Data Envelopment Analysis

4.1 Introduction

This chapter explains the methodology of data envelopment analysis (DEA) and exhibits how the technical efficiency is measured. A detailed explanation of the DEA procedure is given in Charnes and Cooper (1985), Silkman (1986), Ahn, Charnes, and Cooper (1988), and Seiford and Thrall (1990), among others.

The DEA was initiated by Charnes, Cooper, and Rhodes (1978) (CCR-Model) by generalising Farrell's (1957) productive efficiency measurement to accommodate multiple output characteristics of a production process. They developed the DEA to evaluate the performance of non-profit and public organisations, where price data usually do not exist or are unreliable. The entity under examination is called as decision making unit (DMU).

The CCR-Model calculates an overall measure of technical efficiency which shows pure technical and scale efficiency of a DMU altogether. Banker, Charnes, and Cooper (1984) (BCC-Model) revised the CCR-Model to allow for flexible scale assumptions as varying returns to scale (VRS) observable by calculating the pure technical efficiency of a DMU for its given scale of operation.

Both the CCR-Model and BCC-Model are used in this thesis to calculate overall and pure technical efficiency scores for distribution organisations and power plants in Turkey in 1991. Since they are extensions of the seminal work of Farrell (1957), the following section gives an overview of Farrell's efficiency measurement. The third section introduces the CCR and BCC models. The fourth section gives a basic graphical illustration of alternative technology frontiers and explains the corresponding ways of calculating technical efficiency scores against them. The fifth section concludes the chapter.

4.2 An Overview of Farrell's Efficiency Measurement

Farrell employed the definition of technical efficiency given by Koopmans and Debreu's coefficient of resource utilisation to show how overall (productive) efficiency can be decomposed into its two multiplicative parts: the technical efficiency part and price efficiency part.

Farrell developed the technical efficiency measure for a one-output, multiple input case, and under two main assumptions: the first assumption is strong disposability of inputs which implies that consuming more of some input(s) while the others are kept constant does not reduce output; and the second assumption is constant returns to scale technology which represents operation at the minimum range of the long-run average cost curve.

The efficiency analysis involves constructing the technology frontier and calculating the technical efficiency score in terms of how far the observation lies from the frontier. The technical efficiency measurement can be directed to show the maximum output level which can be achieved by a given level of input (output-based technical efficiency), or to show the minimum input level needed to produce a chosen level of output (input-based technical efficiency), or finally to show how much input must be reduced and output increased simultaneously, to achieve a unit score of technical efficiency.

The technical efficiency measures of the Turkish distribution organisations and power plants are calculated against the input-based technology frontier since the TEA decides which plants will be called to the system and how much electricity each plant will generate under the merit order scheme. The TEA also informs its own and private distribution organisations how much electricity they will supply. In that sense, each distribution organisation or power plant is assumed to be facing a predetermined objective in the presence of limited resources. Thus, the performance of each distribution organisation or power plant will be judged in terms of its ability to perform the given task by consuming minimum inputs.

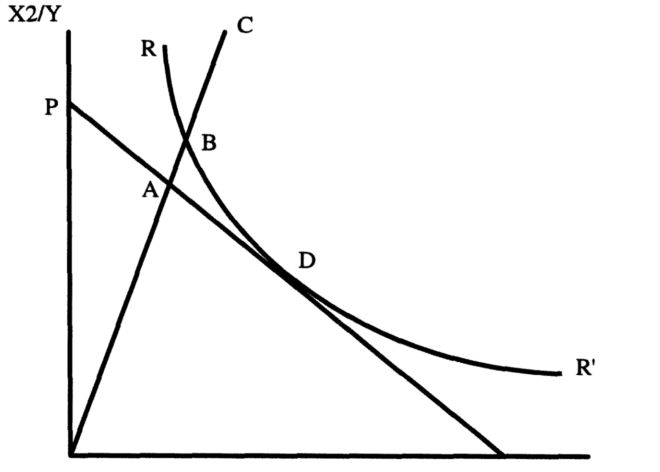


Figure 4.1 Farrell's Input Efficiency Measurement

Therefore, the focus will be on the input-based technical efficiency. Farrell (1957) defined a firm's technical (input) efficiency as the ratio of efficient input consumption to the firm's observed input consumption. This measure can be easily comprehended by referring to Figure 4.1.

Farrell's efficiency measure is based on a production possibility set consisting of the conical hull of observed input-output vectors. Each component of overall efficiency is identified in terms of a production frontier as a ratio of efficient to observed performance. Farrell assumed strong disposability of inputs and required the production function, i.e. $y=f(x_1, x_2)$, to be homogeneous of the degree of one, where y represents output produced by consuming two inputs, x_1 and x_2, respectively. Accordingly, the production function can be rewritten as $1=f(x_1/y, x_2/y)$ so that the efficiency frontier can be identified by the unit isoquant RR' in figure 4.1.

Overall efficiency is attained when both technical and price efficiencies are achieved simultaneously at point D. Point C represents a DMU producing unit output by more input than needed. The level of its input over utilisation is the ratio of efficient to observed input utilisation. This is a radial measure and represented by (OB/OC), which is less than unity. As the performance of C improves, that is, input utilisation reduces, its efficiency ratios get closer in value to unity. In general then,

$$0 \leq \text{Technical Efficiency} \leq 1$$

The measure of price efficiency is also radial. At point B, price efficiency is represented by the ratio (OA/OB), where PP' represents the isocost line defined by the ratio of factor prices.

From this useful efficiency measurement by Farrell, two general approaches to frontier analysis have been developed. A parametric or stochastic approach generally associated with estimating frontier production or cost functions, and a non-parametric or linear programming approach as the one used in this thesis. The methodology behind estimating the stochastic efficiency frontier is reviewed in Bauer (1990).

There are several reasons why this thesis employed the non-parametric rather than the parametric approach. First of all, the non-parametric approach uses linear programming techniques, calculating the efficiency frontier by running a series of optimisations, one for each observation. The efficiency frontier is constructed empirically by observing the efficient subset of the entire data set. This allows the identification of sources of inefficient performance at the individual observation level.

The parametric approach uses econometric techniques, estimating the efficiency frontier by a single optimisation across the entire data set, and without differentiating between efficient and inefficient observations. The non-parametric approach is also a non-statistical methodology since it is directed to relative efficiency measurement rather than estimating parameters of an arbitrarily selected functional relationship. In that sense the parametric approach usually allows any hypothesis or estimates to be tested statistically.

On the other hand, the non-parametric approach searches for observations with unusual input and output combinations, thus the efficiency frontier may be sensitive to outliers. The stochastic noise in the data may also have distorting effects on the efficiency frontier. The parametric approach can easily handle the stochastic noise but only at the expense of imposing restrictive distributional assumptions on the composite error term. The composite error term consists of two parts, the stochastic error term and the efficiency term. The probabilistic distribution of the efficiency term depends on its computational tractability.

Furthermore, the discriminatory power of the non-parametric approach is sensitive to the number of variables in the calculations. The efficiency score of a particular DMU does not reduce with the addition of a new variable into the calculation, and the number of efficient DMU tends to increase as the number of variables gets closer to the number of observations, because in that case there are more facets on which a given set of DMUs can be efficient. To achieve a reasonable level of discriminatory power in the calculations, the literature of DEA suggests that the number of variables should be no more than one-third of the number of observations. This requires a proper a priori selection of variables in any non-parametric efficiency calculation.

Finally, the parametric approach requires an expert knowledge of selecting one output amongst several other potential output variables, or computing fixed weights reflecting the importance of each output in costs and volumes. The non-parametric approach handles the multiple output issue more easily by calculating these weights during the computations of technical efficiency. The following section explains how these weights are selected.

4.3 Non-Parametric Efficiency Measurement

The non-parametric efficiency measurement involves constructing the technical efficiency frontier and calculating the relative technical efficiency scores which signify the ability of each DMU at converting multiple inputs to multiple outputs. Charnes, Cooper and Rhodes (1978) calculate the technical efficiency of a DMU by solving the fractional programming problem (1). Due to the problem setting in (1) the CCR-Model is also known as the Ratio-Model. Table 4.1 gives the definitions of the variables.

Table 4.1 The definition of variables

θ= DEA efficiency score.
o= A specific distribution organisation (plant) to be measured ($1 \leq o \leq n$).
i= the subscript of inputs (i=1,2,...,m).
j= the subscript of distribution organisation (plant) (j=1,2,...,n).
r= the subscript of outputs (r=1,2,...,s).
x_{ij}= the ith input of the jth distribution organisation (plant).
y_{rj}= the rth output of the jth distribution organisation (plant).
v_i= the weighting variable for the ith input.
u_r= the weighting variable for the rth output.
s_i^- = the slack variable for the ith input.
s_r^+ = the slack variable for the rth output.
λ_j= a non negative value related to the jth distribution organisation (plant).
The vector $\lambda=(\lambda_1,\lambda_2,...,\lambda_n)^T$ is used to construct a hull that covers all the data points.

The CCR-Model

$$\textit{Maximise} \quad h_o = \frac{\sum_{r=1}^{s} u_{ro} y_{ro}}{\sum_{i=1}^{m} v_{io} x_{io}}$$

Subject to (1)

$$\frac{\sum_{r=1}^{s} u_{ro} y_{rj}}{\sum_{i=1}^{m} v_{io} x_{ij}} \leq 1$$

$$u_r, v_i \geq 0$$

$$j = 1,2,....,n; r = 1,2,....,s; i = 1,2,....,m.$$

The objective of the problem (1) is to search for output weights and input weights that will maximise the ratio of total weighted outputs to total weighted inputs, i.e. the technical efficiency ratio (ho) of DMU under investigation. The maximisation is pursued subject to the constraint that no other DMU in the sample could score more than unit efficiency by using the same weights.

The important point here is that these weights are treated as unknown, and their values are determined during the analysis and as a result of comparing the DMU's output and input vectors with the other DMU's output and input vectors. The value of weights may vary from DMU to DMU, and they are not the values of inputs and outputs in any economic sense.

The optimal (*) values of the weights have 'shadow prices' interpretation and indicate the marginal effect each input and each output has on the technical efficiency score. Examination of these values provides information on the relative importance of inputs and outputs in the efficiency evaluation. They enable one to calculate marginal rates of substitution between inputs and marginal rates of transformation between outputs. The marginal rate of substitution is the rate at which one input can be reduced while another input is increased and still produce the same level of outputs. Similarly, the marginal rate of transformation is the rate at which one output can be decreased while another output is increased and still consume the same amount of inputs.

The fractional linear programming problem in (1) has intractable non-linear and non-convex properties that present difficulties as it stands, and so it needs to be linearised. For the input-based technical efficiency measurement, the problem setting (1) can be linearised by restricting the denominator of the objective function to unity, and adding it as another constraint to the problem. In this way, the original problem in (1) is transformed to a problem of maximising the total weighted outputs in the presence of normalised total weighted inputs plus the remaining constraints in (2).

Primal

$$\begin{aligned}
&\textit{Maximise} \quad h_o = \sum_{r=1}^{s} u_{ro} y_{ro} \\
&\textit{Subject to} \qquad\qquad\qquad\qquad\qquad (2) \\
&\sum_{i=1}^{m} v_{io} x_{io} = 1 \\
&\sum_{r=1}^{s} u_{ro} y_{rj} - \sum_{i=1}^{m} v_{io} x_{ij} \leq 0 \\
&u_r, v_i \geq 0 \\
&j = 1,2,\ldots,n; r = 1,2,\ldots,s; i = 1,2,\ldots,m.
\end{aligned}$$

Dual

$$\begin{aligned}
&\textit{Minimise} \quad h_o = \theta_o \\
&\textit{Subject to} \qquad\qquad\qquad\qquad\qquad (3) \\
&\sum_{j=1}^{n} x_{ij} \lambda_j + s_i^- = \theta_o x_{io} \\
&\sum_{j=1}^{n} y_{rj} \lambda_j - s_r^+ = y_{ro} \\
&\lambda_j, s_i^-, s_r^+ \geq 0; \\
&j = 1,2,\ldots,n; r = 1,2,\ldots,s; i = 1,2,\ldots,m.
\end{aligned}$$

Either (2) or its dual companion (3) can be solved to obtain the technical efficiency scores. It can be easily observed that the number of variables in (2) is equal to the number of constraints in (3). In (2) the constraints are indexed on the number of observations, whilst in (3) they are indexed on the number of inputs and outputs. Since the number of observations is usually considerably larger than the number of inputs and outputs, and computational efficiency of simplex method reduces with increases in the size of constraints set, the dual form (3) with only (m+s) number of constraints in inputs and outputs is more easy and less time consuming to compute then the primal (2). Thus, the dual form (3) is used in the technical efficiency calculations reported in chapter 6-8.

When the dual form (3) is used the 'shadow prices' interpretation of the weights is not applicable anymore. However, the dual form (3) now searches for values of the weights λ_j to construct a composite DMU with outputs $\sum\lambda_j y_{rj}$ and inputs $\sum\lambda_j x_{ij}$ which outperforms the inefficient DMU under examination. In each run a different DMU is treated as one under investigation, and the dual form (3) searches for the minimised physical inputs subject to the constraint that the level of each output be at least as large as the DMU under investigation, i.e. $y_{ro} \leq \sum_{j=1}^{n} y_{rj}\lambda_j$, and another constraint that the level of each input be at least as little as the amount consumed by the DMU, i.e. $\theta_o x_{io} \geq \sum_{j=1}^{n} x_{ij}\lambda_j$. In this way, the received optimal solution (=*) will bound the outputs of DMUo from above by the former constraints, and similarly will bound the inputs from below by the latter constraints. This envelopment process gives its name to the data envelopment analysis.

The optimal values of λ_j identify the DMUs with similar input or output mix and operating characteristics as the DMU being evaluated. If all slacks are zero, and θ_o^* is equal to one, the DMU is deemed technically efficient. That is in comparison to the efficient DMUs identified by λ_j values for the DMU being evaluated, there is no evidence of inefficiency in the consumption of any input, or production of any output. In other words, it is not possible to improve some observed values of input or output for the DMU being evaluated without worsening other input or output values. The λ_j values for the efficient DMUs which the efficient DMU is being evaluated against will be zero.

The DMU is regarded as technically inefficient if it has an efficiency score less than one and/or positive slack variables. This implies that there is at least one or a linear combination of more than one DMUs which can score unit efficiency by using the same weights. The optimal values of λ_j form a composite (hypothetical) DMU which outperforms and presents a target for the DMU being evaluated. The values of λ_j show the percentage contribution of each efficient DMU to the construction of the hypothetical DMU against which an inefficient DMU is compared. For instance, under the constant returns to scale technology, the technical (input) efficiency score of less than unity, say 75%, means that the DMU being evaluated can save 25% of its input consumption and maintain its current output levels. Since the technical (input) efficiency score is a composite of pure technical (managerial) and scale efficiency, from the policy making point of view, it is important to identify each component's share on the technical inefficiency.

Banker, Charnes, and Cooper (1984) showed how overall technical (input) efficiency can be separated into its pure technical and scale efficiency components. This can be achieved simply by adding another constraint into the dual form (3). The newly added constraint $\Sigma\lambda_j=1$ requires the frontier to be constructed as convex combinations of the efficient DMU, and allows for varying returns to scale, i.e. increasing, constant, and decreasing returns to scale.

The BCC-Model

$$\textit{Minimise} \quad h_o = \theta_o$$

$$\textit{Subject to} \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_o x_{io} \qquad (4)$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad j = 1,2,....,n;$$

$$\lambda_j, s_i^-, s_r^+ \geq 0; r = 1,2,....,s; i = 1,2,....,m.$$

The problem setting (4) calculates the pure technical (input) efficiency for a DMU given its current scale of operation. Scale efficiency measures the degree of deviation from the optimal scale and can be defined as TE_{CRS} /TE_{VRS}.

The value of scale efficiency ranges between zero and one, representing the distance between the CRS and VRS frontiers at the observed DMU's output level. One minus scale efficiency score measures the proportional decrease in input consumption which could occur had the pure technically efficient DMU operated at the optimal scale, i.e. constant returns to scale. If scale inefficiency is present, it is crucial to determine whether this is the result of operating in an increasing or decreasing returns region.

To identify the type of scale inefficiency a third technology frontier must be calculated. This technology frontier permits only the non-increasing returns to scale (NIRS), i.e. the technology exhibits only constant and decreasing returns to scale. The type of scale inefficiency can be determined by comparing the results of VRS technology to the results of NIRS technology. The NIRS frontier is constructed by restricting the intensity factor λ_j to be less than or equal to one.

The NIRS-Model

$$\begin{aligned} &\text{Minimise} && h_o = \theta_o \\ &\text{Subject to} && \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_o x_{io} \qquad (5) \\ & && \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro} \\ & && \sum_{j=1}^{n} \lambda_j \le 1 \qquad j = 1,2,....,n; \end{aligned}$$

$$\lambda_j, s_i^-, s_r^+ \ge 0; r = 1,2,....,s; i = 1,2,....,m.$$

The efficiency scores at the NIRS technology are calculated by solving the linear programming problem (5). If SE≠1 and $TE_{nirs}=TE_{vrs}$, then the DMU is operating in the decreasing returns region and should reduce its scale of operation to become scale efficient. If SE≠1 and $TE_{nirs}<TE_{vrs}$, then the DMU is operating in the increasing returns region and should increase its scale of operation to achieve scale efficiency. Banker (1984) suggested an alternative way of identifying the type of scale inefficiency by summing the optimal solution of λ_j in the problem setting (3). If $\Sigma\lambda_j=1$, the DMU is operating at the most productive scale size. If $\Sigma\lambda_j>1$, the DMU is operating in the decreasing returns region. If $\Sigma\lambda_j<1$, the DMU is operating in the increasing returns region.

The non-parametric efficiency analysis does not only identify the most and least efficient DMUs but also shows the possible amount of input which can be saved at the present output level. Ways of improving the inefficient DMU can also be suggested. For each inefficient DMU, the data envelopment analysis identifies one or a group of efficient DMUs which have similar input and output combinations and operating characteristics as the DMU being evaluated. These efficient DMUs create a target performance level that the inefficient DMU should adopt to become efficient. For instance, when the dual form (3) is employed for the non-parametric analysis, the inefficient DMU will have the following input and output targets to become efficient:

$$x_{io}^{target} = \theta_o^* x_{io} - s_i^{-*}$$
$$y_{ro}^{target} = y_{ro}^* + s_r^{+*}$$

where the main changes are to the input levels. Each efficient DMU's contribution to the target performance can be identified from the corresponding λ_j values. For the efficient DMU the λ values for the efficient DMUs making its reference set are zero, only the DMU being evaluated has the λ value of one. The number of times that an efficient DMU appears in the reference set of inefficient DMUs reveals whether that DMU is a self evaluator or an evaluator of the other DMUs. If the count is high relative to the number of DMUs under examination, the operations of DMU can be regarded as a reference to be followed by inefficient DMUs. The values of slack variables give an indication of particular inputs that the inefficient DMU may have difficulty to save, or of particular outputs that it may have difficulty to augment.

4.4 Graphical Representation

The technical efficiency measurement under the alternative assumptions of technology of CRS, VRS, and NIRS can be easily understood by referring to Figure 4.2. Consider five power plants who are consuming the same input, say capital (K), producing the same output, electricity (E), but in varying quantities. Their input-output combinations are represented by P_t, and t=1,.....,5.

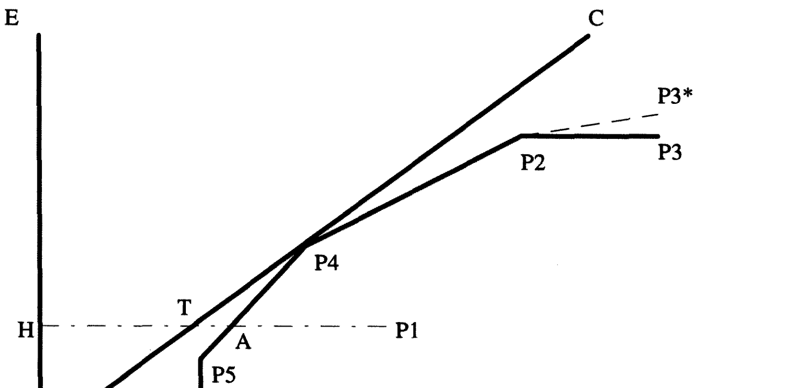


Figure 4.2 Alternative Frontier Technologies

When the CRS technology is assumed the efficiency frontier is an unbounded ray starting from the origin and passing through the linear combinations of the efficient plants, as represented by OC. For P1 the measure of technical (input) efficiency is (HT/HP1). One minus the value of (HT/HP1) measures the proportional reduction in input consumption that can be achieved and still maintain the same level of output. The λs represent the weights attributed to each plant which determine the frontier.

To break the overall technical (input) efficiency into pure technical and scale efficiency, one should assume varying returns to scale technology. In this case the efficiency frontier is not unbounded linear anymore, but a convex combination of the efficient plants, as represented by the supporting segments of S-P5-P4-P2-P3.

The new efficiency frontier may accommodate scale inefficient plants such as P2 (operating in the decreasing returns region) and P5 (operating in the increasing returns region), where both P2 and P5 are pure technically efficient for their current level of scale operation. The pure technical (input) efficiency of P1 is (HA/HP1). The scale efficiency can be calculated for P1 as (HT/HA). The value 1-(HT/HA) measures the proportional reduction in input consumption which can be achieved if P1 was scale efficient, i.e. operating at constant returns to scale.

P1 lies inside both technology frontiers and therefore is neither pure technically efficient nor scale efficient. This implies that for the same level of electricity generated by P1, it is possible to find another plant or a linear combination of other plants which are using less of the input than used by P1 and generating the same level of electricity. For P1 these plants will be P4 and P5. The efficiency score of P1 can be used to adjust its existing consumption of input and suggest a target point on the efficiency frontier which will improve P1's current performance such that it is not dominated by the efficiency frontier anymore. The target point for input-based analysis is T at the CRS frontier and A at the VRS frontier. For instance, P1 can adjust its input and output level to reach the target point A as follows:

$$\theta_1^* < 1$$

Input target: $(K_1\theta_1^* - s_k^{-*}) = \{(K_4\lambda_4^*) + (K_5\lambda_5^*)\}$

Output target: $(E_1 + s_e^{+*}) = \{(E_4\lambda_4^*) + (E_5\lambda_5^*)\}$

The target performance for P1, for the one-input (K), one-output (E) case, is clearly equal to the linear combination of performance of P4 and P5, where $\lambda_4^*, \lambda_5^* > 0$. The input target suggests a radial (equiproportionate) reduction in input plus any further reduction in input suggested by a non-zero input slack variable (s_k^{-*}). For the input-based measurement, the output target does not require a radial (equiproportionate) adjustment to output, but only augmentation of output suggested by the amount of a non-zero output slack variable.

Summing the values of λ_4^* and λ_5^* as suggested by Banker (1984) is one way of spotting the type of operation i.e. decreasing returns or increasing returns, that caused the scale inefficiency of P1. For P1 in Figure 4.2 $(\lambda_4^* + \lambda_5^*) < 1$, so its scale inefficiency is due to operating in the increasing returns region, and it should expand its activities until it reaches the optimal scale of operation, i.e. constant returns to scale. An alternative way of identifying the type of scale inefficiency is to calculate a third technology frontier called the NIRS. In Figure 4.2, the NIRS is represented by OP4P2P3. Comparing the efficiency scores between the VRS and NIRS technologies confirms that P1 is operating in increasing returns region.

P3 in Figure 4.2 lies on the boundary but not on the efficient part of the efficiency frontier since it has input slack while it scores unit efficiency. P3 is dominated by P2 since both generate the same level of electricity, i.e. $E_2=E_3$, but P3 uses more input than P2, i.e. $K_3>K_2$. That is, the performance of P3 can be still enhanced as it moves towards P2 by reducing its input further. To avoid the non-parametric analysis attributing unit efficiency score to a DMU with non-zero slack, Charnes, Cooper, and Rhodes (1979) introduced a non-Archimedean or infinitesimal (ε) imposing strict positivity on the weights in problem setting (1). ε is an arbitrarily selected small but non-zero number which creates a lower bound constraint to prohibit the efficiency frontier from having any vertical or horizontal segments. Hypothetically, ε shifts the portion of P3 upwards to point such as P3* in Figure 4.2. Conceptually, the positivity requirement is useful, however there are some reason why it can be ignored in actual computations. Firstly, there is no standard way of deciding about the value of ε, and different values of ε produce different efficiency results. Secondly, the inclusion of ε may generate a difficulty in relating the efficiency results to the original definition of Farrell's efficiency analysis (Chang and Sueyoshi, 1991). Finally, its inclusion unnecessarily complicates the efficiency analysis without providing much real benefit (Sexton, 1986). Therefore, we chose not to include ε in our calculations.

4.5 Conclusion

Under both the CCR and BCC models, the efficiency scores range between zero and one. In general, an efficiency comparison under the CRS technology gives the most exact measure of performance since a DMU has to be both technically and scale efficient to qualify for a unit efficiency score. Under the

VRS technology, however, scale inefficient performance may take a unit score of technical efficiency. Thus,

$$TE_{i,CRS} \leq TE_{i,VRS}$$

i.e. for the same DMU, say i, the technical efficiency score under CRS technology may be lower than under the VRS technology. When these two efficiency technologies coincide the technical efficiency scores will be the same.

In general than, the CRS technology can be regarded as a the 'lower bound' and the VRS technology as the 'upper bound' measure of efficiency. As shown above, the NIRS technology overlaps the VRS technology along the facet P4-P2-P3, and the CRS technology along the facet 0P4. As Grosskopf (1986) suggests, these three alternative reference technologies may have the following order of efficiency scores:

$$TE_{i,CRS} \leq TE_{i,NIRS} \leq TE_{i,VRS}.$$

Other things being equal, the VRS technology gives the highest efficiency score for a given DMU, while its CRS counterpart gives the most exacting measure of performance.

Chapter 5 Previous DEA Studies of Electricity Generation and Distribution

5.1 Introduction

This chapter reviews the DEA applications of previous studies of electricity generation and distribution to help select the variables for our empirical studies. The DEA studies of electricity generation are dominated by studies using US-data, while most of the DEA studies of electricity distribution use UK-data. Since one of the contributions of this thesis is to add to the rather small amount of empirical literature of non-US and non-UK DEA studies of electricity generation and distribution, the review sections are arranged accordingly. The review particularly takes notice of the type and period of the sample data, definitions of the variables, assumptions and orientations of the frontier technology, and finally sources of observed inefficiency. The following section reviews the DEA studies of electricity generation, while the third section reviews the DEA studies of electricity distribution. The last section concludes the chapter.

5.2 DEA Studies of Electricity Generation

This section reviews twelve non-parametric studies of electricity generation. Of the twelve, seven studies are US studies and are reviewed under the sub-section of the US studies of electricity generation. The remaining five studies include one country specific study on Israel and four cross-country comparison studies. These studies are reviewed under the subsection of non-US studies of electricity generation. All these studies are directed to measure various types of efficiency in thermoelectric generation.

5.2.1 US Studies of Electricity Generation

Until the early 1980s, the empirical literature of electricity generation was dominated by the parametric (econometric and statistical) applications. This was partly due to the fact that many economists regarded the assumption of constant returns to scale in the non-parametric methodology as too restrictive. Fare, Grosskopf, and Logan (1983) and Banker, Charnes, and Cooper (1984) relaxed the constant returns to scale assumption to allow for local varying returns to scale technologies, i.e. decreasing and increasing returns to scale. This boosted the number of non-parametric applications of efficiency analysis in public organisations as well as in private organisations. Seiford (1990) contains around 400 studies that applied the DEA methodology since it was first introduced in 1978.

In electricity generation, Fare, Grosskopf and their co-authors take the lead by publishing a series of papers which are reviewed in this sub-section. The first three studies reviewed are Fare, Grosskopf, and Logan (1983, 1985, and 1987) have common assumptions imposed on their calculations. These studies calculated the output-based efficiency measures for electricity utilities against the frontier technology constructed under the alternative assumptions of constant and varying returns to scale; and strong and weak disposability of inputs. Output was treated as strongly disposable. The calculations were for one-output, multiple-input case.

Fare, Grosskopf, and Logan (1983) showed how Farrell's famous measure of overall technical efficiency can be broken into three mutually exclusive and exhaustive parts namely a measure of pure technical efficiency, a measure of input congestion (over utilisation of some inputs), and a measure of scale efficiency. They calculated these measures for a sample of privately owned, regulated coal-fired Illinois electric utilities in the USA. The data were collected for five years between 1975 and 1979. The variables contained one output defined as net electricity generation (measured in millions of kilowatt-hours), and three inputs: labour (measured by annual number of employees), capital (measured by installed generating capacity in megawatts), and fuel (measured in 10^10 Btu's). The technical efficiency and its related three components were calculated against an output-based technology frontier, that is the utilities were analysed according to their ability to generate maximum electricity by the given levels of inputs. The efficiency scores were calculated under the alternative assumptions of scale namely constant and varying returns. The inputs were treated as strongly and weakly disposable in turn. The output was assumed to be strongly disposable. Between the periods none of the plants received unit efficiency score consistently. The main sources of inefficiency were due to managerial incompetence (pure technical inefficiency) and lack of free disposability of inputs (congestion). They did not identify a trend of improvement in the efficiency during the period, and therefore they suggest that the plants were not regulated effectively by the regulator.

Fare, Grosskopf and Logan (1985) used Atkinson and Halvorsen's (1984) data to calculate six different efficiency measures: overall economic, allocative (or price), technical, pure technical, congestion, and scale efficiency measures. Atkinson and Halvorsen (1984) employed parametric techniques, analysing the efficiency differences between private and public electricity utilities by estimating a cost function. They found no evidence of significant difference in allocative efficiency between private and public utilities. The sample contained a cross-section of 123 private regulated and 30 public electric utilities operating in the USA in 1970. The data contained one output, electricity generation (measured as millions of kilowatt-hours), and three inputs: labour (measured as full time equivalent employees), capital (measured as installed generating capacity in megawatts), and fuel (measured in Btu's). Factor prices were used in calculating the overall economic and allocative efficiency measures. The results showed that the average overall economic efficiency was very low for the whole sample, and there was no evidence of significant difference in overall economic efficiency between public and private utilities; this is consistent with the findings of Atkinson and Halvorsen (1984). The difference between ownership types was tested by a number of non-parametric tests, including a test of central tendency (median test), and several other tests (Krukal-Wallis, Van der Waerden, and Savage) that compare the distribution of the efficiency measures between the ownership types. There was no significant difference in price (allocative) or overall technical efficiency between private and public utilities. Public utilities were pure technically more efficient than private utilities. However, a higher number of private utilities (9) appeared to be operating at the optimal scale, and uncongested. Finally the main source of inefficiency for both ownership types was price inefficiency.

Fare, Grosskopf, and Logan (1987) calculated the technical and its related components for a sample of 22 coal-fired plants operating in the Western States of the USA during 1977-1979. The data contained one output (measured in millions of kilowatt-hours of net generation), and three inputs: labour (measured as annual average number of employees), capital(measured as installed generating capacity in megawatt), and fuel (measured as billions of Btu's). The results showed that the plants received high overall technical efficiency scores. The pure technical, congestion, and scale components of overall technical efficiency contributed differently to the technical inefficiency between the plants, the utilities and the years.

Fare, Grosskopf, and Pasurka (1986) is one of the earliest example of non-parametric measurement in electricity generation that used multiple outputs in the calculations. The study examined the impacts of environmental regulations on the relative efficiency of a cross-section of randomly selected 11 public and 89 private steam electric utilities operating in the USA in 1975. The calculations were output-based, and the technology frontier was constructed assuming varying returns to scale. The data contained five outputs and five inputs. The outputs are net electricity generation (measured as million kilowatt-hours) and four measures aof pollution: three measures of air pollution emission namely particulate matter, sulphur dioxide, and nitrogen oxides (all measured in 1,000 tons), and a measure of heat discharge in the water used in the plant. The inputs were labour (measured as average number of employees), capital (measured as installed generating capacity in megawatts), and three types of fuel used by the plants: coal (1,000 tons), oil (1,000 bbls), and gas (million cubic feet). 78% of the plants in the sample were multi-fuel plants, and fuel substitutability was allowed in the calculations. Amongst the outputs, net generation was regarded as desirable product whilst the four measures of pollution were treated as undesirable products that were to reduce by the plants according to environmental regulations. To examine the impact of environmental regulations, the output-based technology measures were calculated under the assumptions of weak and strong disposability of outputs. When the outputs are weakly disposable, the pollution measures are not freely disposable whereas strong disposability means all output variables are freely disposable by the plants. By weak disposability, one output is no longer necessarily freely disposable. Rather, the disposal of an undesirable output imposes a cost in the sense that it is achieved by reducing the other outputs proportionately. The indirect impact of environmental regulations on relative output efficiency is determined by comparing output efficiencies between the weak and strong disposability technologies. Weakly disposable technology would represent the regulated technology whilst strongly disposable technology would represent the unregulated technology. F(x,u) captures deviations from efficiency in the regulated environment and W(x,u) captures deviations in efficiency in the unregulated environment. C(x,u)=[W(x,u)/F(x,u)], then, measures the loss of output efficiency due to environmental regulations. That is, C(x,u) measures the radial difference between F(x,u) and W(x,u) frontiers, i.e. output loss due to lack of disposability. The results show that the environmental regulations imposed costs on the regulated plants in terms of lost output due to lack of disposability of outputs. In 1975 there was a loss of approximately 1,622 million kilowatt-hours due to the environmental regulations.

Fare, Grosskopf, and Pasurka (1989) like the previous study analysed the effects of the environmental regulations on the efficiency of electric utilities, but this time, the performance of the utilities compared between two years: 1969 versus 1975. The sample includes 23 coal-fired steam electric utilities which installed precipitators by the end of 1975.The output-based technology frontier is constructed to calculate the overall technical efficiency and its related components. The data contained one output as net electricity generation (measured in million kilowatt-hours), and four inputs: labour (measured as the average number of employees), capital (measured as the installed generating capacity in megawatts), fuel (measured as the total Btu's (1,000)), and finally precipitators (measured as the installation cost in $1,000). At first, the efficiency measures were calculated with one output and three inputs, excluding the cost of installing precipitator between the years. These results showed no significant difference in any of the efficiency measures between 1969 and 1975. Then the efficiency measures were calculated by including the variable of precipitator in 1975. The overall technical efficiency decreased, though not significantly, between the years, indicating that environmental regulation effected the efficiency at the plant level. The main source of the efficiency loss was due to congestion and scale inefficiency.

Hausman and Neufeld (1991) used the oldest data set amongst the reviewed papers, examining efficiency affects of ownership between public and private US electric utilities subsequent to rate-of-return regulation in 1897/1898. Public ownership was represented by municipal ownership. The sample contained 97 municipal and 218 private plants. The input-based technology frontier was constructed under the alternative assumptions of constant and varying returns to scale. The inputs were assumed to be strongly disposable. Productive, price, technical, pure technical, and scale efficiency measures were calculated, using three outputs and six inputs. The output variables were the electricity generated to use in incandescent lighting, arc lighting, and stationary motors. The largest share (two-thirds) of the total system load was used for the incandescent lighting which was usually priced according to the number of lights installed, number of rooms, or size of the dwelling. Thus, the output of incandescent lighting was measured as the total connected load in candlepower. The arc lighting was used for lighting the open public areas, such as streets or large stores. These lights were on while the generators were running, and the electric utilities kept the record of how many hours their generators run. By the size of the connected load, the arc light was measured in kilowatt-hours. The electricity used in the stationary motors was measured as the total horsepower of the motors connected to the system. The inputs were capital, fuel and labour. The capital was measured by three different types of generating capacity: alternating current, direct current constant voltage, and direct current constant amperage (used for the arc lighting), all measured in kilowatts. Fuel was measured as the amount of coal consumed (in 1,000 lbs). Two labour variables were measured as the number of waged and salaried employees. Input prices for capital, coal, and labour variables were used in calculation of the productive and price efficiencies. The results showed that considering all types of efficiency measures, the municipal electric utilities were significantly more efficient than the private electric utilities.

Yaisawarng and Klein (1994) is the last US study to review in this sub-section. They used the non-parametric methodology to analyse the effects of environmental (sulphur dioxide) control on productivity change in the coal-fired electric plants for the years' 1985-1989. The input-based technology frontier was calculated under the alternative assumptions of scale technologies, and output and input disposability. Then, by using the calculated efficiency measures, a cumulative Malmquist productivity index was derived to observe the productivity change. The sample was an unbalanced panel including 61 coal-fired plants for the years' 1985-1987 and 1989, and 60 plants for the year 1988. The data contained two outputs and four inputs. The plants generated electricity by burning coal which realises SO2 emissions, and they had two options, both costly, to comply with the imposed environmental regulation. One option was buying more expensive low sulphur coal, and the other was purchasing high sulphur coal and installing pollution reducing equipment. Thus the amount of SO2 pollution emission was included as an undesirable output whereas the amount of sulphur in the coal was treated as an undesirable input. In this setting, each plant was producing two outputs: net electricity generation, a desirable output (measured in 10^6 kilowatt-hours), and SO2 emission, an undesirable output (measured in tons), by consuming four inputs: labour, fuel, capital, and sulphur. Labour was measured as the number of employees, fuel includes all types of fuel used namely coal, oil and/or gas, and measured in

10^{12} Btu's. Both labour and fuel were desirable inputs. Capital was measured in 10^{3}dollars at 1973 prices, and treated as a desirable fixed input. Finally, Sulphur was measured as the percentage of sulphur content of fuel by weight, adjusted by the sample minimum. This variable was treated as undesirable input. The results suggested that on average, the plants had relatively high and stable efficiency values during the period. The majority (62%) of the plants were operating in the increasing returns region. Over the period these plants produced the largest share (47.4%) of the net generation. The shares of the plants operating in the decreasing and constant returns regions were 27.4% and 25.2%, respectively. The plants operating in the increasing returns region were consistently more pure technically efficient than the plants operating the decreasing returns region. This may be due to the ability of larger, multi-unit plants to better manage load, and use only their most efficient units during periods of low demand. Comparing the productivity changes in the period against the year 1985, the result showed that there was productivity slowdown in 1986 and 1987, productivity recovery in 1988, and finally, productivity growth in 1989.

5.2.2 Non-US Studies of Electricity Generation

This section reviews the non-parametric studies that were not using the US-data and were not particularly examining the efficiency of the plants in the US electricity industry. There are five studies to review. The first is a country-specific study on Israel by Golany, Roll, and Rybak (1994), and the remainder are cross-country performance comparison studies, one by Hjalmarsson and Forsund (1993), and the other three by Pollitt (1993).

The study by Golany, Roll, and Rybak (1994) is the only country-specific study using non-US data in measuring the efficiency of electricity generating plants by applying the non-parametric (DEA) methodology. This very recent study has similarities with our thermoelectric plant study in Chapter 8, as both studies measure and evaluate the technical efficiency of power plants owned by a single public institution. In our case it is the Turkish Electricity Authority while in their case it is the Israeli Electric Corporation (IEC). Unlike us, Golany, Roll, and Rybak were fortunate enough to have a list of potential input and output variables to choose from. We managed only to collect information about the standard variables used in most of the empirical studies of electricity generation. Golany, Roll, and Rybak added a time dimension to their efficiency calculations by using quarterly data for almost seven years between 1981 and 1987. Precisely, there were 25 quarters from September 1981 to November 1987, and after dropping the periods with missing data, the final number of observations was 87. The list of 58 variables was eventually reduced to seven variables to include to the analysis, following three stage examination processes of these variables. Seven variables were selected after a preliminary judgmental process, regression analysis, and preliminary DEA analysis. The seven variables included four output measures and three input measures. The four outputs were defined as generated power (measured in gross megawatt-hours), operational availability (measured as the proportion of time in which units in the site were operational-excluding planned maintenance), deviation from operational parameters (each load level was related to a set of optimal operational parameters, and was measured as the times the plant deviated from those optimal parameters), and finally SO2 emission (measured as the number of times pollutants exceed specified limits). The three inputs were defined as installed capacity (measured by the installed capacity of all units in a site), fuel consumption (measured as physical quantities of fuel consumed per period), and finally manpower (measured in man-hours). The output-based technology frontier was constructed under the alternative assumptions of constant and varying returns to scale. The constant returns to scale technology frontier was used in variable selection whereas modified versions (by Rousseau and Semple, 1993) of varying returns to scale technology frontier were utilised in actual efficiency calculations. Special attention was given to differences in plant size and to the presence of a categorical variable (SO2 emission). The results suggested that the mean efficiency score across seven years was very stable, with a small upward trend in the last half of the seven years period. The ratio of efficient observations to the total number of observations in each year ranged between 33.3% to 50.0%, with no observable trend. This implied that the various productivity improvement measures taken by the IEC did not result in observable enhancement in the overall operations of the generating plants during the period.

Hjalmarsson and Forsund (1993) is one of the first cross-country comparisons study of productivity analysis applying the non-parametric (DEA) methodology. Their study also focused on the total factor productivity differences and the total factor productivity growth by calculating a Malmquist index. The sample included 10 electricity generating companies, most of them from South Asia. The sample was an unbalanced panel, the countries and available years were as follows: Thailand (1979-90), Hong Kong (1983-87), Pakistan (1983-85), Malaysia (1982-87), Taiwan (1981-87), the Republic of Korea (1983-87), Philippines (1983-89), Australia (1981-90), Singapore (1983-87), and Indonesia (1983-87). The input-based technology frontier was constructed under the alternative assumptions of constant and varying returns to scale, and strong disposability of inputs. The data contained three outputs and five inputs. The outputs were total generation (Y1) measured in gigawatt-hours, peak demand (Y2) measured in megawatts, and the total number of retail customers served directly or indirectly (Y3). The inputs were the total number of employees employed as full time in a year (L1) in generation, transmission, and distribution, the total number of employees employed as full time employees in a year (L2) in generation and high voltage transmission, the total value of fuel used in a year in fixed prices (F), the total installed capacity (C) measured in megawatts, and finally the length of the high voltage lines, 400-60kV (M) measured in kilometres. Four models were arranged by selecting different combinations of the variables. Table 5.2.2.1 shows the variables included in each model.

Table 5.2.2.1 Survey of the models applied in cross-country comparison

	Outputs			Inputs				
MODEL	Y1	Y2	Y3	L1	L2	F	C	M
1	*	*			*	*	*	*
2	*				*	*	*	*
3	*	*	*	*		*	*	*
4	*	*			*			

Model 1 was treated as the main model while the other models are calculated as sensitivity analyses. Model 2 was the standard application in most of the empirical studies of electricity generation. L2 was replaced by L1 in Model 3 since the majority of the companies were vertically integrated, and there was no precise information in some instances for the allocation of employees between generation-transmission and distribution. Model 4 focused on the partial productivity of labour. Calculating the partial labour productivity in this way is confusing. We would rather include the variables of F, C, and M and treat them as fixed as shown in Banker and Morey (1986), and then calculate the partial productivity. The technical efficiency measures were calculated after pooling all companies in all years in one data set, where the relative efficiency was obtained against one frontier for the entire time period. For the majority of companies, the relative technical efficiency scores were similar between Model

1, Model 2, and Model 3, whereas Model 4 gave very low labour efficiency scores in several companies (only one company was on the reference frontier). There were two identifiable groups, one with companies with low scores, and the other with companies with high labour efficiency scores. A Malmqulst index was constructed to identify the differences in the total factor productivity between the companies. The index was calculated only for the years 1986 and 1987 due to lack of comparable data during the other years. Similar results to the above findings were obtained with an observable distinction between a high productivity group and a low productivity group of companies. Another Malmquist index was constructed to identify the productivity growth in a few selected companies, including all years available. The results suggested that there was technical progress in most years, though in varying degrees of productivity change over time.

The following three cross-country comparison studies are from the thesis by Pollitt (1993). The first study was directed to analyse the effect of ownership on the productive efficiency of electric utilities, employing two different methodologies which were those used by Atkinson and Holverson (1986), the parametric technique, and by Fare, Grosskopf, and Logan (1985), the non-parametric technique. Pollitt explains the significance of using these two techniques as firstly they were the most recently developed techniques in both parametric and the non-parametric approaches to the testing of the effects of ownership on productive efficiency; and secondly both studies used the same data set in their calculations. Pollitt's sample contains information from 95 electric utilities operating in 9 countries in 1986.These countries were the USA (73), Australia (5), Japan (9), the UK (3), France (1), Italy (1), Denmark (1), Canada (1), and Ireland (1). The data contained information on thermoelectric generating utilities. A utility was assumed producing one output electricity (measured as millions of kilowatt-hours) by consuming three standard inputs:

labour (measured as the number of employees employed at power plants), capital (measured as nameplate gross capacity in megawatts), and fuel (measured in TBTU(10^12 BTU's)). The input prices were also used when calculating overall and allocative efficiencies. The results suggested that after allowing for the differences in technology for the two methodologies, there was no significant difference in the productive efficiency between the alternative types of ownership. The results from the parametric approach could not reject the null hypothesis of no difference in overall, allocative or technical efficiency between private and public ownership. The results from the non-parametric approach, however, presented only weak evidence of the private utilities outperforming the public utilities in terms of overall efficiency and overall technical efficiency.

In his second study, Pollitt broadens the cross-country utility level analyses to examine the technical efficiency of a wider sample of 768 thermoelectric generating plants operating in 14 countries in 1989. The countries were the USA (606), Denmark (2), Germany (4), Japan (24), Taiwan (7), Australia (20), Canada (20), Hong Kong (1), Ireland (6), Greece (8), New Zealand (3), South Africa (13), Thailand (6), and the UK (48). The full sample was divided into four sub samples according to the plants' load factors (LF) to obtain more meaningful comparison across the plants. The sub samples were divided into three groups: base, LF>60%, (213 plants); simple and double shift (mid-merit) 60%>LF>30% (318 plants) and 30%>LF>15% (129 plants); and peaking plants LF<15% (108 plants). Four different approaches to calculate the technical efficiencies were applied: the data envelopment analysis (DEA), parametric programming approach (PPA), deterministic statistical frontier analysis (DSA), and stochastic frontier method (SFM). For details of these approaches, the reference was given as Lovell and Schmidt (1988). One of the distinct features of Pollitt's study is applying these four methodologies to the same data set.

The data included one output as the net electricity generation (measured in millions of kilowatt-hours), and three inputs: labour (measured as the number of employees employed at the plant level), capital (measured in nameplate capacity in megawatts), and fuel (measured in TBTU(10^12 BTU's)). The results exhibited similar findings as the previous study; there was no significant difference in technical efficiency at the plant level between private and public ownership. This finding was valid between the sub samples and the methods.

In the last study of electricity generation reviewed in this chapter, Pollitt used only the base load plants of the previous study to examine the overall and allocative efficiency measures of 213 plants operating in 12 countries in 1989. The overall and allocative efficiency measures were calculated by the four methodologies mentioned above. This study calculated five measures of overall productive efficiency and three measures of allocative efficiency. The five measures of overall efficiency were calculated applying the DEA (assumes constant returns to scale technology), PPA, SFM, and two applications of DSA methodologies. The first DSA methodology assumed that the underlying production function has a Cobb-Douglas functional form. This allowed the separate calculation of overall and allocative efficiencies by the cost minimisation method. The second DSA methodology assumed a translog functional form for the cost function that allows only direct calculation of the overall efficiency. The SMF assumed a translog cost function which allows the calculation of overall efficiency measure. The DEA, PPA and the first DSA methodologies used all 213 plants to model the production frontier whereas the second DSA methodology and the SFM used only 164 plants operating in 8 countries which have input price data to estimate the cost frontier. The data contained one output as the net electricity generation (measured in million kilowatt-hours) and three inputs: labour (measured as the number of employees), capital (nameplate capacity in megawatts), and fuel (measured in

TBTU). The input price data contained the historical and current price of capital, the price of labour, and the price of fuel. The results suggested that private plants were allocatively more efficient than their public counterparts in the sample. The evidence from the overall efficiency results presented similar, but weaker, support for the superior performance of private utilities over the public utilities.

5.3 DEA Studies of Electricity Distribution

The previous section reviewed the non-parametric applications of electricity generation. This section is to review the non-parametric studies of electricity distribution. Until recently, there were fewer studies of electricity distribution, the majority used US-data, employing parametric (econometric and statistical) techniques to estimate various types of cost functions and focusing on the average relationship in the data. Since the beginning of the 1990s, however, the published studies of electricity distribution have increased. These studies used the non-parametric (DEA) technique, using non-US data and measuring the performance at the individual distribution board level by taking the multiple output nature of distribution activities into account.

A comprehensive and recent review of parametric and non-parametric studies can be found in Pollitt (1993). This section reviews only the non-parametric studies of electricity distribution. The studies are by Weyman-Jones (1991), Doble and Weyman-Jones (1991), Button and Weyman-Jones (1992), Weyman-Jones (1992), Milliotis (1992), Hjalmarsson and Veiderpass (1992b), and finally Pollitt (1993). Weyman-Jones (1991) and Milliotis (1992) were not reviewed in Pollitt (1993). The studies by Weyman-Jones and his co-authors used UK-data in their calculations. Milliotis (1992) and Hjalmarsson and Veiderpass (1992b) analysed the performance of distribution boards in Greece and Sweden, respectively. Pollitt (1993) is the only study of cross-country comparison between the UK and the US distribution boards. The review is undertaken under two subsections, one reviewing the UK studies, and the other reviewing the rest of the studies. Our study of the distribution organisations in Turkey in Chapter 6 contributes to the non-US and non-UK empirical literature of distribution studies which are so far very few.

5.3.1 UK Studies of Electricity Distribution

All the studies reviewed in this section calculated the technical efficiency in publicly owned, non-competitive electricity distribution boards operating in England and Wales prior to their privatisation in 1990. Weyman-Jones (1991) is the first UK study applying the non-parametric methodology to the technical efficiency of twelve Area Electricity Boards in England and Wales in 1986/1987 prior to their privatisation in 1990. The efficiency frontier was assumed to show constant returns to scale technology. The input-based technical efficiency measure for each board was computed, assuming the board consumes two inputs, labour and capital, to distribute electricity to three groups of customers, domestic, commercial, and industrial (output was measured in annual kilowatt-hours sold by each area board). Labour was measured as the number of employees. Two definitions of capital were used in the calculations in turn. The first definition of capital, the total values of area board assets, was found inadequate since it presented problems of using accounting data which "include valuations put on land and buildings that have little or no effect on the technical efficiency with which electricity is distributed" (p.119). The second definition of capital, the amount of mains distributions in service (measured in kilometres) was used. Board level technical efficiency scores were reasonably high, ranging between 79% and 100%. Five out of twelve area boards were technically efficient and operating at the optimal scale.

Doble and Weyman-Jones (1991), unlike the above study, incorporated a time dimension in the technical efficiency measurement of the twelve area electricity boards of England and Wales for a period of twenty years from 1970 to 1989. The input-based efficiency frontier was calculated under the alternative assumptions of constant and varying returns to scale technology. The strong disposability of inputs was also assumed. The data contained four outputs and three inputs. Three of four outputs were electricity supplied to domestic, commercial, and industrial customers (all measured in kilowatt-hours). The forth output was maximum demand (measured in kilowatts), capturing the peakiness of the electricity demand. Three inputs included labour (measured as employees per area board), and two definitions of capital: firstly, the distribution mains (measured in circuit kilometres); and secondly, the transformer capacity (measured in MVA). The results showed high scores of scale efficiency, suggesting that scale inefficiency was not the main source of overall technical inefficiency. The average values of technical efficiency fluctuated over the twenty year period. The changes in the efficiency scores were closely related to the regional cycle of economic activities.

Button and Weyman-Jones (1992) applied the two main approaches, parametric and non-parametric, to the efficiency frontier analysis to identify the amount of X-inefficiency (Lelbenstein, 1966) in the UK electricity distribution industry and to examine its evolution under the process of regulatory change. Following Neuberg's (1977) study of US electric distribution, they estimated a stochastic frontier composed error model of a cost function for a pooled data of twelve area electricity boards operating during 1971-1987 in England and Wales. The data included one output, the number of customers, one input, the number of employees, and environmental variables, network size (measured in mains kilometres), transformer capacity (measured in MVA), electricity distribution services proportional to annual load, peak load (measured in kilowatts), population density, and industrial share. The environmental variables described the area board's operating environs, but were regarded as exogenous to the board. Thus the calculations were short run. The price of labour services and the user cost of capital were used as input prices. The results of the short run stochastic cost frontier showed hardly any evidence of X-inefficiency, and the causes of different performances between the boards were attributed to the random factors of lack, i.e., environmental variables. Then the same variables were used to calculate the overall efficiency scores for the area boards. The full sample was divided into two sub samples, the first covering the pre-privatisation period: 1971/2, 1976/7, 1981/2, and 1986/7 with the last year representing the period when there was greater attention to financial discipline and efficiency monitoring in the area boards. The second period covered 1976/7, 1981/2, 1986/7, and 1988/9 which replaces the earliest nationalisation data with the latest available data before privatisation. During both overlapping samples, there was an important amount of relative X-inefficiency, ranging in some boards between 50-60% compared to the efficient boards. The X-efficiency level improved and the variance of efficiency fell as the distribution industry got closer to privatisation.

Lastly, Weyman-Jones (1992) used a very similar variable set to the one used in the previous study, calculating the technical efficiency measures of the twelve area electricity boards over the period 1971-1989. The efficiency frontier was constructed assuming the presence of varying returns to scale technology. The input-based technical efficiency was calculated for two studies. Study A contains four outputs, domestic sale, commercial sale, and industrial sale (all measured in kilowatt-hours), and maximum demand (measured in kilowatt), and three inputs, manpower (measured as the total number of employees per area board), network size (measured in kilometres), and transformers (measured in MVA). The results provided evidence supporting the previous two studies' conclusion by Doble and Weyman-Jones (1991) and Button and Weyman-Jones (1992). The results indicated the presence of technical inefficiency amongst the area boards during the period, which was closely related to the regional cycle of economic activities of the corresponding area board. Study B was arranged following Neuberg's (1977) input and output characterisation. The data contained one output, the number of customers, one input, manpower, and six environmental variables characterising the (given) working environs of each area boards. The environmental variables were the network size, transformer capacity, total sales, maximum demand, density, and industrial share. The full sample was divided into two overlapping samples and reached the same results as Button and Weyman-Jones (1992): efficiency improved and the variance of efficiency declined as the boards approached privatisation.

5.3.2 Non-UK Studies of Electricity Distribution

This section reviews two country-specific non-UK studies by Miliotls (1992) and Hjalmarsson and Velderpass (1992b), and one cross-country comparison study by Pollitt (1993).

Miliotls (1992) applied the non-parametric (DEA) methodology, investigating the relative technical efficiency in 45 distribution districts of the Greek Public

Power Corporation (PPC). By the linear programming problem setting in Miliotis's paper, we assume the efficiency frontier was constructed under the constant returns to scale technology, and directed to input-based efficiency analysis. The data contained the following variables shown in Table 5.3.2.1:

Table 5.3.2.1 The variables used by Miliotis (1992)

	VARIABLES	MEASURE
Q1:	Network	Total length (km)
Q2:	Capacity of installed transformation points	(KVA)
Q3:	General expenses	monetary units (Drs)
Q4:	Administrative labour	(hrs)
Q5:	Technical labour	(hrs)
Q6:	Number of customers	
Q7:	Energy supplied	(kWhs)
Q8:	Total area	(km^2)

The technical efficiency measures were calculated for four different arrangements of variable set. Case 1 included Q1-Q5 as five inputs used to produce two outputs, Q6 and Q7. This was reported as the main study, reflecting the efficiency of the design of the supply system. Case 2 included the same variables except that this time Q1 and Q2 were treated as outputs. Miliotis justified this by arguing that the technical labour (Q5) required for each distribution district was assumed to be proportional to the number of customers (Q6) as well as to the total length of network (Q1) and to the total size of transformers (Q2). The output and input combination of Case 2 aimed to capture a more accurate picture of labour productivity. Treating two conventional variables of inputs, Q1 and Q2, of electricity distribution as outputs is confusing. We would prefer to treat them as input variables, and calculate a partial labour productivity measure by controlling Q1, Q2, and Q3 as fixed variables on the input side. Then Q3 could be treated as variable rather than fixed to observe the operating as well as the labour productivity.

Case 3 included the same variable set as in Case 1 to calculate the technical efficiency by distinguishing between big urban and small centres. Case 4 included one extra output variable, the total area (Q8) and used the same input variables as in Case 1, to take into account the sparsity of the grid. The technical efficiency scores were compared with simple productivity indices reported by the PPC and with the efficiency results obtained by estimating an econometric frontier and average functions. There were four simple productivity indices defined as follows:

D1: the number of customers/personnel total,

D2: kWh/kVA,

D3: the network length/technical personnel, and

D4: kWh/personnel total.

These were regarded by Milliotis as simple unweighted ratios of one output to one input, showing only one aspect of a more comprehensive picture which the DEA was expected to show. This suggested that DEA results were more reliable than the results from the simple indices. The econometric frontier and average functions were estimated, using the number of customers as output produced by two inputs, labour and capital. The alternative proxies of capital input, the network length and transformation capacity were included in the estimation separately. The results of comparing the DEA measures between Case1-4 exhibited that the low technical efficiency scores could be due to mismanagement of the controllable inputs, the design of the supply system, or the environmental reasons that were not explicitly incorporated into the calculations.

Hjalmarsson and Veiderpass (1992b) used the DEA technique to calculate the technical efficiency measures in 285 Swedish local retail electricity distributors in 1985. The input-based efficiency frontier was constructed under the alternative assumptions of constant and varying returns to scale technologies. The performance of each distributor was analysed according to its ability to provide given amounts of four types of outputs by minimum consumption of four inputs. The definition of the variables is given in Table 5.3.2.2.

Table 5.3.2.2 The variables used by Hjalmarsson and Veiderpass (1992)

OUTPUT		MEASURE
Y1:	Low voltage electricity received by customers	(Mwh)
Y2:	High voltage electricity received by customers	(MWh)
Y3:	Number of low voltage electricity customers	
Y4:	Number of high voltage electricity customers	
INPUT		
L:	Hours worked by all employees	
K1:	Low voltage power lines	(Km)
K2:	High voltage power lines	(Km)
K3:	Total transformer capacity	(KVA)

The full sample was divided into three sub samples for sensitivity analysis. The number of distributors varies between 142 and 143 due to missing data. The first sub-sample contained all the variables listed in the table and included 142 distributors. The second sub-sample included all inputs but only the first two outputs, Y1 and Y2, and 143 distributors. The last sub-sample included again all inputs but this time only the last two outputs, Y3 and Y4, and 142 distributors. The technical efficiency measures were used to identify differences in performance between different types of ownership (municipal utilities, private companies, and economic organisations) operating in different service areas (urban versus rural). The results suggested that there were very small differences in pure technical efficiency between different types of ownership. After accounting for the scale differences, the urban and rural areas showed similar average technical efficiency scores.

The last study reviewed in this chapter is by Pollitt (1993). Pollitt (1993) is the first DEA approach applied to international data from the USA and the UK to compare the technical efficiency of distribution systems in 1990. The full sample contained 145 distribution utilities from the US (136) and the UK (9). The data set included information on 119 privately owned and 26 publicly owned utilities. Pollitt divided the full sample into three sub-samples according to the number of employees (L) as L>1000 (65 utilities), 1000>L>300 (50 utilities), and L<300 (30 utilities) to identify the size of utilities as large, medium, and small, respectively. The data contained three inputs, producing five outputs. The three inputs were the number of employees, transformer capacity (measured in MVA), and network size(measured in circuit kilometres). The five outputs were the number of customers, residential sales (measured in million kilowatt-hours), non-residential sales (measured in million kilowatt-hours), service area (measured in square kilometres), and maximum demand (measured in megawatts). The efficiency frontier was constructed assuming constant and varying returns to scale in turn. The overall technical, pure technical, congestion, and scale efficiency measures were calculated for the distribution utilities in each sub-sample. Then, four environmental measures were also calculated by assuming some variables as environmental variables. Firstly, the circuit km and service area were assumed as environmental variables. Then the maximum demand was treated as environmental variable. Thirdly, the transformer capacity was an environmental variable. Lastly, all variables were considered as environmental variables, except the number of customers and the number of employees. The results indicated that there was no significant difference in technical efficiency between alternative types of ownership. An estimation of average cost function exhibited similar result.

5.4 Conclusion

This chapter reviewed twelve empirical studies of electricity generation and seven studies of electricity distribution, all using the non-parametric DEA methodology. This chapter is a bridge between Chapter 4 and our empirical chapters (6-8). In chapter 4 we presented how technical efficiency can be calculated by using the DEA methodology. Then, in chapter 5 we reviewed the applications of the DEA methodology to electricity generation and distribution. Chapter 5 is particularly useful since it presents, besides the results from the previous studies, the definition of variables, assumptions and orientations of the frontier technology.

The following three chapters investigate the immediate and the potential impact of privatisation in the Turkish electricity supply industry. The immediate impact of privatisation is examined in chapter 6, through comparison of technical efficiency of public distribution organisations with that of private distribution organisations. The potential impact of privatisation is examined in chapter 7 and chapter 8. This is done in chapter 7, through comparison of technical efficiency of public hydroelectric power plants with that of private hydroelectric power plants. Chapter 8 is targeted to investigate whether the four thermoelectric power plants to be sold to private investors were really selected among the most in need of rehabilitation.

Recall that, in our empirical studies, the efficiency frontier is input-based and calculated under the alternative assumptions of constant and varying returns to scale technologies. The inputs are assumed as strongly disposable. We calculated an input-based technical efficiency, since how much electricity will be generated and distributed is given to both public and private operators.

That is, we are not examining whether more electricity can be generated and distributed by consuming given levels of inputs. We are rather interested in the differences between public and private operators in terms of their ability to generate and distribute electricity by consuming as few resources as possible. In order to test the significance of differences between groups we used a powerful non-parametric test, Mann-Whitney test. The Mann-Whitney test is a useful alternative to the parametric t-test, particularly when one wants to avoid the assumptions of parametric tests (Siegel and Castellan, 1988). In each occasion the test is one-sided.

Chapter 6 Distribution Organisations Study[1]

6.1 Introduction

This chapter investigates the immediate effects of electricity privatisation on the distribution side by comparing the technical efficiency performance of private distribution organisations to that of similar distribution organisations remaining in the public sector. The performence differences in favour of private distribution organisations will be attributed to the privatisation process.

The following section discusses what the government has expected to achieve by introducing private elements on the distribution side of electricity supply industry in Turkey. The third section presents the data and variables. The fourth section evaluates the results; and the last section concludes the chapter.

6.2 Retail Electricity Distribution in Turkey

Recall from chapter 3 that the public distribution organisations were founded one for each province (sixty-seven in total) in 1982, following the transfer of

[1]The results of this chapter will appear in Bagdadioglu et al (1996).

distribution facilities and obligations of municipalities and other local administrations to the TEA's ownership. The newly created distribution organisations were to undertake local distribution services, including general lighting, and to operate subject to private law like any private company, though with different objectives. The general perception has been that the public distribution organisations do not perform particularly efficiently since they are not subjected to adequate regulation to reduce network and operating losses. Therefore the cost of distribution services has increased, the quality of service has fallen, and electricity prices have risen.

Some critics link poor performance of distribution organisations to the political interference that existed even more severely at the time of municipality ownership. There is no published empirical study, or evidence substantiating that claim. It would be interesting to investigate whether the transfer led to an improvement in performance of distribution organisations, using data for period before and after the transfer. Unfortunately this can not be done due to lack of data related to that period.

Each public distribution organisation is administered by a public manager appointed by the TEA, who is responsible for realising predetermined distribution activities including supplying given amount of electricity, billing and collecting overdue payments. Each distribution organisation is inspected routinely once a year by the TEA's own inspectors. However, the inspection is usually limited to examination of the accounting sheets. The manager is not encouraged by any extra incentives to cut costs or work more efficiently: s(he) receives the same salary regardless of outcome. The manager has little say on electricity tariff which is determined by the TEA, and with close co-ordination from the MENR. The manager informs the central office about requirements to carry on with the distribution services, and these requirements are usually satisfied. The working environment of the public manager is similar to those specified in chapter 2, where we argued that the constant political involvement makes it difficult for a public organisation to imitate a private organisation's behaviour.

In 1984, the government liberalised entry *for* the monopoly rights of local distribution, hoping that private investors would bring much needed financial and operational efficiency into the electricity distribution market. As indicated in chapter 3, there have been many applications made to the MENR by private investors to take part in local electricity distribution market. The pace however has been very slow and disappointing for the government. The main dispute between the government and private investors was about repayment guarantees for the capital invested.

In 1985, the boundaries of fifteen distribution areas were defined and offered to private investors for bidding. In 1989, the Council of Ministers pronounced Cukurova Electric jsc, Kepez Electric jsc, Aktas Electric jsc, and Kayseri Electric jsc as entrusted distribution companies; only the last two companies have taken over the local distribution services in 1990, by replacing their public counterparts in the Anatolia part of the province of Istanbul and the province of Kayseri, respectively.

The newly franchised distribution companies are expected to speed up the process of extraction of overdue payments, to increase the operating and financial efficiencies and service quality, to reduce network losses and to renew the distribution network. Each franchised company takes over control of the TEA's electrical equipment in its distribution area, and under the supervision of the MENR, it finances the renewal investments on an equity-debt basis.

The franchised companies operate subject to a fixed Electricity Energy Tariff and can keep the profits which can be increased by reducing the operating expenditures and running the distribution system more efficiently. At the end of the thirty year contract period, the franchised company returns all electrical equipment, including any newly built equipment, to the TEA without any further compensation.

It was impossible to obtain a copy of the entrustment and the transfer agreements signed between the parties at the time this research was undertaken. Our request was turned down both by the TEA and by the MENR on the basis of confidentiality of still ongoing negotiations. Therefore the details and type of enforcement of the agreements, and the nature of penalties imposed on the companies in the case of failure to meet the contract conditions are unknown to us. However, recent disputes between Aktas Electric jsc and its customers proved that there was lack of control, regulation, and enforcement of the conditions of the agreements. Finally, the MENR responded to the growing complaints by the former customers of the TEA by threatening to cancel its entrustment agreement with Aktas Electric jsc.

Following a number of amendments of the boundaries and addition of some more areas, the Council of Ministers increased the number of distribution areas to twenty-one in 1991 (Table 3.4 in chapter 3). Five more private distribution companies listed in Table 3.5 in chapter 3 were immediately entrusted to operate in five distribution areas with the franchise of exclusive monopoly rights and accompanying obligations. Apparently, the government by-passed to create a Demsetz type of competition at the bidding stage, by negotiating with only one candidate for only one distribution area. It may be noteworthy that the previously franchised two companies were former private subcontractors of the TEA. The five companies did not sign the agreements because they were not satisfied with the conditions of the agreements and were asking for more provisions of repayment guarantees. Thus, the five distribution areas are still served by public distribution organisations. In 1993 each province (total of 73) was defined as separate distribution area open for tender by private investors but there has been little further progress in privatising electricity distribution up to 1995.

6.3 Data and Variables

The technical efficiency is calculated for the Turkish electricity distribution organisations in 1991 when the two newly franchised private distribution companies had completed their first operational year in the liberalised electricity industry. The technical efficiency is calculated for the alternative assumptions of constant and varying returns to scale technologies. Each distribution organisation is assumed to be aiming to distribute electricity and meet peak demand by consuming as few of inputs as possible. The calculations and interpretation of the results are the same as shown in chapter 4.

In 1991, there were 73 provinces and 76 retail distribution organisations. Of these, 72 were publicly operated, 2 were privately operated, and 2 were the distribution activities of the 2 private generators. For the public distribution organisations information on maximum demand was not readily available and had to be derived for each public distribution organisation from the projections for 1990 and 1995. Six publicly operated distribution organisations did not have maximum demand projections, and therefore were dropped from the sample leaving the final number of observations at 70.

Table 6.1. Definition of the variables

Outputs(Y) and Inputs(X)		Measure
Y1	Number of customers	
Y2	Electricity supplied	MWh
Y3	Maximum demand	MW
Y4	Service area	Km^2
X1	Manpower	Number of employees
X2	Transformer capacity	MVA
X3	Network size	Km
X4	General expenses	Turkish Lira (10^6)
X5	Network losses	MWh

Table 6.1 lists the variables with their definition. The ultimate outputs are defined as the amount of electricity supplied and the number of customers. The maximum demand is also included. The service area identifies the operating territory of each distribution organisation, and with the number of customers should reflect customer density. An alternative approach may be to define the customer density as the number of customers per square kilometre (Y1/Y4). An extra DEA run is carried out to observe the effect of including either of these definitions. Each distribution organisation is considered as producing these outputs by using inputs of labour and different types of capital. The labour is measured as the number of employees per organisation, the best classification which was available. Following the arguments by Weyman-Jones (1991), only physical measures of capital, namely the transformer capacity and network size, are used. General expenses are included as an additional input variable, since these may be the most directly controllable costs by the manager of the distribution organisation. Network losses reflect the quality of the network system in terms of how much power was lost in the transformers

and during distribution, and how much power may be uncounted for other reasons such as illegal usage.

As seen from Table 6.2, the technical efficiency scores are calculated for each distribution organisation for five studies. The main study is Study 1 which includes all output and input variables. The other four studies are calculated as a sensitivity analysis and to capture different aspects of technical efficiency. The Spearman correlation coefficients are calculated to assess the impact of individual variables left out of the results obtained from Study 1 under the CCR model. A Spearman correlation coefficient of 100% indicates the dropped variable has no significant effect on the results obtained from the main study.

Table 6.2. Sensitivity analysis on Study 1

	Study 1	Study 2	Study 3	Study 4	Study 5
Outputs					
Y1: Customer number	***		***	***	***
Y2: Electricity supplied	***	***	***	***	***
Y3: Maximum demand	***	***	***	***	***
Y4: Service area	***				
D=(Y1/Y4)		***			
Inputs					
X1: Manpower	***	***	***	***	***
X2: Transformer capacity	***	***	***	***	Fixed
X3: Network size	***	***	***	***	Fixed
X4: General expenses	***	***	***		Fixed
X5: Network losses	***	***	***	***	Fixed
SCC with Study 1		0.45	0.85	0.80	0.62
Mean Efficiency Score	0.90	0.67	0.86	0.80	0.64
Minimum Efficiency Score	0.53	0.15	0.40	0.39	0.08
Number of Efficient DOs	29	12	21	18	22

+All correlation coefficients are significant at a level of significance = 0.0001;
SCC=Spearman Correlation Coefficients; DOs=Distribution Organisations

Study 2 is calculated to observe the impact of the alternative definition of customer density on the results. The (low) correlation coefficient of 45% suggests that the new definition has a noticeable effect on the results. Dropping the service area itself from the calculation has a less important effect on the results, indicated by the correlation coefficient of 85% in Study 3. Study 4 is calculated by excluding general expenses, which is the only variable measured in money value. Study 4 may also reflect the design efficiency of the electricity supply system. The correlation coefficient of 80% suggests that excluding the general expenses from the calculation has a relatively small effect on the results. Finally, Study 5 is calculated to find out whether overstaffing is an important cause of technical inefficiency. For that, Study 5 assumes the variables X2, X3, X4, and X5 are exogeneously fixed as shown in Banker and Morey (1986), and so calculates the partial labour productivity. Fixing the input variables has a larger impact on the results, indicated by the lower correlation coefficient with Study 1 of 62%.

Between Study 1 and Study 5 the mean and minimum technical efficiency scores and the number of efficient distribution organisations tend to decrease. However, the decline may be not surprising since, as indicated in chapter 4, in the DEA technical efficiency is likely to decline as variables are excluded from the calculation. For diagnostic purposes, Study 1 is used for the evaluation of the technical and scale efficiency in the following section.

6.4 Results

Table 6.3 shows the descriptive statistics of the efficiency scores for the full sample as well as separately for each group of ownership. The individual efficiency scores and the returns to scale measures are given in Table 6.4. Considering the whole sample in Table 6.3, the mean scale efficiency score is quite high (96%) suggesting that the scale inefficiency is unlikely to be the main source of overall inefficiency. The mean efficiency scores of the public distribution organisations are very close to the sample mean while all four private distribution organisations are technically and scale efficient. To test the significance of these findings a non-parametric test, the Mann-Whitney test, is calculated. The null hypothesis is that there is no significant difference in the efficiency scores between public and private distribution organisations. This null hypothesis is tested against the alternative hypothesis that the private distribution organisations have higher efficiency scores than the public distribution organisations.

Table 6.3. Descriptive statistics of the efficiency scores for the DOs

Study 1	Number of DOs	Mean	Standard Deviation	Minimum Value	Maximum Value
All DOs					
OTE	70	0.90307	0.11443	0.52507	1.00
PTE	70	0.93836	0.09621	0.57185	1.00
SE	70	0.96188	0.06365	0.74021	1.00
Public DOs					
OTE	66	0.89720	0.11527	0.52507	1.00
PTE	66	0.93463	0.09786	0.57185	1.00
SE	66	0.95957	0.06486	0.74021	1.00
Private DOs					
OTE	4	1.00	0.00	1.00	1.00
PTE	4	1.00	0.00	1.00	1.00
SE	4	1.00	0.00	1.00	1.00

SE=OTE/PTE; DOs=Distribution Organisations

Table 6.4 The individual efficiency scores and scale measures for DOs

DOs	OTE	PTE	SE=(OTE/PTE)	Scale Type(1)
DO1#	1.000000	1.000000	1.000000	CRS
DO2#	1.000000	1.000000	1.000000	CRS
DO3+	1.000000	1.000000	1.000000	CRS
DO4	0.852451	0.895632	0.951787	IRS
DO5+	0.889313	0.889514	0.999774	IRS
DO6	1.000000	1.000000	1.000000	CRS
DO7	0.690068	0.727428	0.948640	IRS
DO8	0.759302	1.000000	0.759302	DRS
DO9+	0.983943	1.000000	0.983943	DRS
DO10+	0.842660	0.967561	0.870911	IRS
DO11+*	1.000000	1.000000	1.000000	CRS
DO12+*	1.000000	1.000000	1.000000	CRS
DO13+*	1.000000	1.000000	1.000000	CRS
DO14	1.000000	1.000000	1.000000	CRS
DO15	0.643806	0.816585	0.788412	IRS
DO16	0.821596	0.824664	0.996279	IRS
DO17	1.000000	1.000000	1.000000	CRS
DO18	0.932389	0.935904	0.996244	IRS
DO19+	0.928267	0.933265	0.994644	IRS
DO20	1.000000	1.000000	1.000000	CRS
DO21	1.000000	1.000000	1.000000	CRS
DO22+*	0.880903	0.896211	0.982919	DRS
DO23	0.764513	0.850928	0.898446	DRS
DO24	0.819223	0.913339	0.896953	IRS
DO25	1.000000	1.000000	1.000000	CRS
DO26	0.996073	1.000000	0.996073	DRS
DO27	0.878574	1.000000	0.878574	DRS
DO28+*	0.692075	0.696221	0.994044	IRS
DO29	0.900364	0.902371	0.997775	DRS
DO30	0.964497	0.971031	0.993271	IRS
DO31	0.839945	1.000000	0.839945	IRS
DO32	1.000000	1.000000	1.000000	CRS
DO33+	1.000000	1.000000	1.000000	CRS
DO34+*	0.990160	0.998597	0.991551	DRS
DO35+	1.000000	1.000000	1.000000	CRS
DO36	0.740206	1.000000	0.740206	DRS

continued...

DOs	OTE	PTE	SE=(OTE/PTE)	Scale Type(1)
DO37+*	1.000000	1.000000	1.000000	CRS
DO38	0.882552	1.000000	0.882552	DRS
DO39+	0.872207	0.888302	0.981881	DRS
DO40#+	1.000000	1.000000	1.000000	CRS
DO41	0.782191	0.860768	0.908712	IRS
DO42+	0.780626	0.876528	0.890588	IRS
DO43	1.000000	1.000000	1.000000	CRS
DO44	1.000000	1.000000	1.000000	CRS
DO45	1.000000	1.000000	1.000000	CRS
DO46	0.744373	0.745772	0.998124	DRS
DO47+	1.000000	1.000000	1.000000	CRS
DO48	0.932404	0.967678	0.963547	DRS
DO49	0.700676	0.701764	0.998449	DRS
DO50+*	0.870265	0.879200	0.989837	IRS
DO51	1.000000	1.000000	1.000000	CRS
DO52	0.702174	0.772665	0.908769	IRS
DO53	0.885140	1.000000	0.885140	IRS
DO54	0.881010	0.908091	0.970178	DRS
DO55	0.879818	0.983182	0.894867	IRS
DO56	0.724815	0.730549	0.992151	DRS
DO57+	1.000000	1.000000	1.000000	CRS
DO58	1.000000	1.000000	1.000000	CRS
DO59	0.827966	0.900957	0.918985	IRS
DO60+	1.000000	1.000000	1.000000	CRS
DO61+	0.793908	0.805268	0.985892	IRS
DO62	0.999238	1.000000	0.999238	DRS
DO63	0.920355	0.965504	0.953237	DRS
DO64	1.000000	1.000000	1.000000	CRS
DO65	0.525066	0.571854	0.918181	DRS
DO66+	1.000000	1.000000	1.000000	CRS
DO67+	0.794232	1.000000	0.794232	DRS
DO68	0.905857	0.908090	0.997540	DRS
DO69+	1.000000	1.000000	1.000000	CRS
DO70#+	1.000000	1.000000	1.000000	CRS

Notes: (DOs)=Distribution Organisations; (OTE)=Overall Technical Efficiency calculated by running the CRS model; (PTE)=Pure Technical Efficiency calculated by running the NCRS model; (1) Determined by running the Non-increasing Returns to Scale model; (#) The privately operated distribution organisations; (+) 21 Distribution Areas approved in 1991. Distribution Organisations in brackets are defined as one distribution area: [DO3, DO33, DO35], [DO11, DO22, DO50], and [DO13, DO28]; (*) 5 Distribution Areas where the five private companies were granted the franchise but did not take over the operation. Distribution Organisations in brackets are defined as one distribution area: [DO11, DO22, DO50], [DO13, DO28].

For large sample sizes (n>10) the test generates a z-value the significance of which may be determined by referring to tables of the standardised normal distribution. Table 6.5 shows the observed z-values and their probabilities (*p*-values) for corresponding efficiency scores. *P*-values are measures of the credibility of the null hypothesis. If *p*-values fall below the significance level chosen, then the null hypothesis is rejected. At the 5% significance level, the null hypothesis is rejected in favour of the alternative hypothesis that the private distribution organisations have higher efficiency scores. Nonetheless, taking into account the very small number of private distribution organisations (4), the test results should be treated with caution.

Table 6.5. The Mann-Whitney test results for 66 public DOs vs 4 private DOs

Efficiency scores	OTE	PTE	SE
z-values	2.1527	1.7249	2.1527
p-values (probabilities)	(0.0158)	(0.04227)	(0.0158)

OTE=Overall Technical Efficiency; PTE=Pure Technical Efficiency; SE=Scale Efficiency; DOs=Distribution Organisations

Furthermore, analysing the performance of the two franchised companies immediately a year after they take over of distribution organisations requires further investigation to observe whether the public distribution organisations they replaced were already efficient, or they became efficient as a result of take-over. This is worth to investigate because the government might have chosen the best performers to give the impression that private investors improve performance, consequently opening the road for easier privatisation in the future.

To explore whether this might be the case, Table 6.6 shows the descriptive statistics of the efficiency scores of the 10 distribution organisations which were originally offered to private investors.

Table 6.6. Descriptive statistics of the efficiency scores of 10 DOs identified as candidates for privatisation (in 7 DAs) and 58 public DOs not so identified.*

	Number of DOs	Mean	Standard Deviation	Minimum Value	Maximum Value
All DOs					
OTE	68	0.90022	0.11488	0.52507	1.00
PTE	68	0.93655	0.09703	0.57185	1.00
SE	68	0.96076	0.06425	0.74021	1.00
Public DOs					
OTE	58	0.89279	0.11612	0.52507	1.00
PTE	58	0.93474	0.097327	0.57185	1.00
SE	58	0.95471	0.06777	0.74021	1.00
Franchised DOs					
OTE	10	0.94334	0.10210	0.69207	1.00
PTE	10	0.94702	0.09977	0.69622	1.00
SE	10	0.99584	0.00604	0.98292	1.00

SE=OTE/PTE; DOs=Distribution organisations; DAs=Distribution Areas.

*Distribution operations of Cukurova Electric jsc and Kepez Electric jsc are excluded from the table, thus the total number of distribution organisations is now 68.

The 10 distribution organisations offered for private franchise have higher average efficiency scores than those of the other 58 distribution organisations. To test the significance of the difference between the two groups the Mann-Whitney test is calculated. The null hypothesis is that there is no significant difference in the efficiency scores between the 10 distribution organisations in the franchised areas and the remaining distribution organisations. The alternative hypothesis is that the 10 distribution organisations in the franchised areas have higher efficiency scores than the remaining distribution organisations.

Table 6.7 shows the observed z-values and their probability values for corresponding efficiency scores. The probability values are quite large for the overall technical and pure technical efficiency scores, so the null hypothesis is not rejected at a significance level of 0.05. The null hypothesis is rejected only for the scale efficiency scores, suggesting that the franchised organisations have significantly better scale efficiency than the rest of the public distribution organisations.

Table 6.7. The Mann-Whitney test results for 10 DOs identified as candidates for privatisation (in 7 DAs) vs 58 public DOs not so identified.

Efficiency scores	OTE	PTE	SE
z-values	1.3592	0.3781	1.6990
p-values (probabilities)	(0.0885)	(0.3557)	(0.0455)

OTE=Overall Technical Efficiency; PTE=Pure Technical Efficiency; SE=Scale Efficiency; DOs=Distribution Organisations; DAs=Distribution Areas

Although the test results suggest that there was no significant difference of overall technical and pure technical efficiency between the 10 distribution organisations for which the Government offered franchises and the rest of the public distribution organisations, as seen in Table 6.4 the majority of them (6) scored unit overall efficiency scores. The lowest efficiency score is 69%. This finding may support the intuition that the Government will offer to sell its most efficient organisation(s) first. Therefore, it is not surprising that the previous two transfers concluded were among the most efficient candidates.

As seen from Table 6.4, there are 25 public distribution organisations with a unit overall technical efficiency score. The rest of the 41 public distribution organisations are overall technically inefficient. The number of efficient public distribution organisations increases to 35 under the NCRS technology, suggesting that ten publicly operated organisations are measured as technically inefficient solely because of scale inefficiency. Table 6.8 exhibits the sources of scale inefficiency in the public distribution organisations. 20 distribution organisations appear scale inefficient due to operating in the increasing returns region while 21 distribution organisations are scale inefficient as a result of operating in the decreasing returns region.

Table 6.8. The sources of scale inefficiency in the public DOs

CRS	IRS	DRS
25	20	21

CRS=Constant returns to scale; IRS=Increasing returns to scale; DRS=Decreasing returns to scale; DOs=Distribution Organisations

Each of the 41 overall technically inefficient public distribution organisations can become overall efficient by adjusting its operation to the associated target point determined by the efficient distribution organisations which define its reference frontier. As shown in chapter 4, the DEA produces diagnostic information about the sources of inefficiency for each organisation with respect to the variables included in the calculations. The efficiency scores and the disaggregated results suggest a target point on the efficiency frontier that the inefficient organisation can reach by adjusting its input and output levels. Appendix 1a and 1b exhibit these target levels for each distribution organisation under the CRS and VRS technologies, respectively.

Appendix 1a and 1b include tables, one for each distribution organisation, showing the technical efficiency score, scale type, reference organisations and their associated lambda values, observed output and input values, the target levels of output and input, and finally the slack variables that indicate extra inefficiency at the organisation level. The technical efficiency scores printed in these tables are reported for the constant returns to scale technology in Appendix 1a and for varying returns to scale in Appendix 1b. Similar tables are also prepared for the power plants studies of the following chapters.

6.5 Conclusion

The results exhibit unit technical and scale efficiency scores for the 4 privately operated distribution organisations whereas more diverse results appear for the publicly operated distribution organisations. The distribution activities of the generation companies would be expected to have higher efficiency scores since they do not have universal supply obligations like their public counterparts. The interpretation of the results for the private generating-related companies would be more plausible if the markets served by these companies contained the same mix of consumers as those supplied by public distribution organisations. Lack of data prevented us from disaggregating the market into different types of customers served.

However the following comparisons between the private companies and their public counterparts can be made. The Kepez Electric jsc (DO1) operates in the same province as (DO9), which has an overall technical efficiency score close to but less than one. The Cukurova Electric jsc (DO2) competes in three provinces, which are also supplied respectively by DO3, DO33 and DO35. All three public organisations achieve unit efficiency score in all measures. Such high scores are particularly impressive for public distribution organisations which are obliged to serve customers with a wider range of electricity demand than their private counterparts which serve mainly industrial and commercial, the most profitable, customers. Comparison of these private companies with their closest public counterparts does not suggest that private companies per se are more efficient.

The franchised distribution companies, Kayseri Electric jsc (DO40) and Aktas Electric jsc (DO70), have no direct comparators in the same distribution areas. The performance of these companies and the other eight distribution organisations offered to private investors suggest that the Government offers for private franchise those public organisations which are already operating most efficiently. Provided that there were more franchised organisations and data about their operations, a stronger answer for that investigation could be obtained by observing their efficiency growth, using a Malmquist index.

Chapter 7 Hydroelectric Power Plants Study

7.1 Introduction

This chapter investigates the potential effects of electricity privatisation by comparing the technical efficiency of private hydroelectric power plants with that of the public hydroelectric power plants in 1991. Superior performance by the private power plants may be taken as evidence for potential improvements may be achieved by privatising the TEA's power plants.

The following section gives a brief remainder about structure of the hydroelectric power generation in Turkey in 1991. The third section presents the data and variables. The fourth section evaluates the results; and the last section concludes the chapter.

7.2 Hydroelectric Power Generation in Turkey

Recall from chapter 3 that there was one dominant horizontally and vertically integrated public utility, the Turkish Electricity Authority (TEA), and two small private companies, Cukurova Electric jsc and Kepez Electric jsc, dealing with both generation and distribution of electricity in Turkey in 1991. The TEA has thermoelectric and hydroelectric plants. Cukurova Electric jsc has one very small fuel oil-fired plant and four hydroelectric plants. The fuel oil-fired plant has been kept operating at minimum level since the last oil shock occurred in the late 1970s. Kepez Electric jsc has two hydroelectric plants only.

The private companies do not have sufficient generating capacity to meet their local electricity demand, so they are heavily dependent on purchases from the national system run by the TEA. In 1991 Cukurova Electric jsc generated electricity less than one-fourth of the total electricity (4026.8 million kilowatt-hours) which it sold to its customers, whilst Kepez Electric jsc generated one-third of the total electricity sold (557.7 million kilowatt-hours) to its customers. Both companies purchased the rest of the electricity from the national system.

The TEA sells electricity to both companies at a cheaper rate of tariff than it sells to its own customers. This is to help the private companies with their investments and renewals. We could not obtain cost data to analyse the generation cost differences between the TEA and the private companies. Unfortunately there is no information on how cheaply the private companies purchase electricity from the TEA. Therefore, it is very difficult to comment on whether the private companies behave strategically, by generating less than they can, to obtain cheaper electricity from the TEA. Such strategic behaviour would have important effects had we been calculating productive or allocative efficiency. Since we focus on technical (physical) efficiency, the presence of strategic behaviour is expected to have less obvious effects on the results.

Similar to the public distribution organisations, each public plant is administered by a public manager appointed by the TEA. The public manager is responsible for realising the planned or instructed generation activities by the central dispatcher in the TEA, but has very little say about how much electricity the power plants will generate. Rather the public manager is more informed about the various inputs needed to keep the power plant running. These needs are reported to the TEA; the manager can not purchase them directly from the market. The inspection of the power plants is the same as indicated in the previous chapter for the public distribution organisations. The TEA's inspectors visit each plant routinely once a year and reports back any wrong doing to the TEA. The inspection is usually limited to examining the financial records. Failing to perform the given task at the plant level is rarely results in manager's loosing his/her job, but perhaps re appointment to another duty. There is no extra incentive to cut cost or perform the task more efficiently. This picture is not dissimilar to the one examined in chapter 2.

The private power plants are run by the associated executive board of each company. We do not know whether the salary of the members of the board is linked to the performance of the company. In 1991, the government had 20% and 35.6% shares in the CEAS and the KEPEZ, respectively. It is not clear if, and how much the government had influence on the decision making process of these companies through these shares.

However, we assume that in general the government has influence, one way or another, on these companies, through its institutions such as the Ministry of Energy and Natural Resources, and the State Hydraulic Works. Besides that, the private plants are run with close co-ordination with the TEA since the companies purchase heavily from the national system. Therefore, we assume that the TEA is well informed about the generating capacity, load structure, and local demand of each company. This should make it very difficult for the private companies to behave strategically, i.e. deliberately generating less than they can to buy cheap electricity from the TEA.

This chapter analyses the internal efficiency in the public and private plants in 1991, observing how efficiently each plant was using its resources to generate electricity.

7.3 Data and Variables

The power plant level technical efficiency measures are calculated and compared between public and private ownership, using conventional output and input variables consistent with the empirical literature of electricity generation reviewed in sub-section 5.2 in Chapter 5. The main data source of this thesis, the TEA, provided us with information, but unfortunately only for one output and two inputs. The output is the net hydroelectric generation per power plant, measured in megawatt-hours. The two inputs are labour (measured as the total number of employees per plant) and capital (measured as the installed generating capacity in megawatts and adjusted for the load factor). The installed capacity is adjusted for the load factor as suggested by Fare, Grosskopf, Yaisawarng, Li and Wang (1990) to take proper account of generating capacity used in electricity generation, and to avoid inefficiency being attributed to idle capacity. The data for the private power plants were obtained from their 1991 annual financial reports and from their responses to the survey send by the author. Fuel input is not directly relevant in the case of hydroelectric generation. The amount of water may replace the fuel input since it is one of the main factors of production in hydroelectric generation. Unfortunately this piece of information was not made available to us by either the TEA or the private companies.

The summary of the Turkish Electricity Statistics (1991) lists 48 hydroelectric power plants owned and operated by the TEA. Of 48 power plants, we did not receive any information at all for 15 power plants, most of them very small power plants with installed capacity less than 1.6 megawatts. In addition to that, 11 power plants were excluded from the sample due to missing data, leaving the final number of public power plants at 22. Adding 6 private power plants run by the private companies increased the sample size to 28.

7.4 Results

Table 7.1 shows the descriptive statistics of the efficiency scores for the full sample as well as separately for each type of ownership. The individual power plant efficiency scores are listed in Table 7.2. Appendix 2a and 2b include tables, showing disaggragated results for each power plant.

Table 7.1 Descriptive Statistics of Efficiency Scores for the Hydroelectric Plants

	No. of Plants	Mean	Standard Deviation.	Min. Value	Max. Value
All Plants					
OTE	28	0.788455	0.180611	0.230380	1.000
PTE	28	0.824699	0.169736	0.325041	1.000
SE	28	0.949967	0.078065	0.690426	1.000
Public Plants					
OTE	22	0.775581	0.196757	0.230380	1.000
PTE	22	0.805502	0.183241	0.325041	1.000
SE	22	0.952946	0.065140	0.708772	1.000
Private Plants					
OTE	6	0.835663	0.100754	0.690426	1.000
PTE	6	0.895086	0.083573	0.810130	1.000
SE	6	0.939046	0.122085	0.690426	1.000

Table 7.2 The individual Efficiency Scores per Plant

PLANTS	OTE	PTE	SE	Scale Type
Public Plants:				
1. HP SARIYER	0.799963	0.801960	0.997509	DRS
2. HAZAR I	0.380072	0.434918	0.873893	IRS
3. KEMER	0.657447	0.692666	0.949154	IRS
4. DEMIRKOPRU	0.814377	0.837706	0.972151	IRS
5. HIRFANLI	0.784725	0.806851	0.972577	DRS
6. TORTUM	0.776363	0.785902	0.987862	IRS
7. ALMUS	0.813876	0.826195	0.985089	IRS
8. KESIKKOPRU	0.902287	0.935503	0.964493	IRS
9. DOGANKENT	0.628978	0.636063	0.988861	IRS
10. GOKCEKAYA	0.832400	0.880438	0.945438	DRS
11. KEBAN	1.000000	1.000000	1.000000	CRS
12. CILDIR	0.474605	0.506783	0.936505	IRS
13. HS.UGURLU	0.947947	0.972542	0.974710	DRS
14. OYMAPINAR	0.707170	0.799461	0.884558	DRS
15. ASLANTAS	0.892374	0.980236	0.910366	DRS
16. KARAKAYA	1.000000	1.000000	1.000000	CRS
17. ALTINKAYA	0.900292	0.920706	0.977827	DRS
18. KOKLUCE	0.911003	0.912785	0.998047	IRS
19. KAPULUKAYA	0.849466	0.853579	0.995181	IRS
20. KILICKAYA	0.897178	0.922175	0.972893	IRS
21. KARACAOREN	0.230380	0.325041	0.708772	IRS
22. TERCAN	0.861883	0.889542	0.968906	IRS
Private Plants:				
23. SEYHAN*	1.000000	1.000000	1.000000	CRS
24. KADINCIK I*	0.867041	0.870806	0.995676	IRS
25. YUREGIR*	0.690426	1.000000	0.690426	IRS
26. KADINCIK II*	0.830296	0.849409	0.977498	IRS
27. KEPEZ+	0.795413	0.810130	0.981833	IRS
28. MANAVGAT+	0.830802	0.840176	0.988842	IRS

*Cukurova Electric jsc's power plants; + Kepez Electric jsc's power plants.

Regarding 28 power plants, the average scale efficiency score is quite high (94.9%) indicating that pure technical inefficiency contributes more than scale inefficiency to the overall inefficiency. On average, compared to the private power plants, the public power plants have slightly higher scale efficiency score. However, the private power plants outperform the public power plants in terms of both average overall and pure technical efficiency. To test the significance of these findings between ownership types Mann-Whitney test is used. The null hypothesis is defined as that there is no significant difference in the efficiency measures between public and private power plants. The null hypothesis is tested against the alternative hypothesis of superior efficiency measures for private power plants. Table 7.3 shows the observed z-values and their probabilities (*p*-values) for corresponding efficiency scores. The test result provides no evidence to reject the null hypothesis.

Table 7.3. The Mann-Whitney test results for 22 public vs 6 private Plants

Efficiency scores	OTE	PTE	SE
z-values	0.2241	1.0653	0.8963
P-values (probabilities)	(0.4129)	(0.1446)	(0.1867)

OTE=Overall Technical Efficiency; PTE=Pure Technical Efficiency; SE=Scale Efficiency.

As can be seen from Table 7.2 which shows individual scores of overall, pure technical, and scale efficiency for each power plant in the sample, there are only three power plants with unit overall technical efficiency score, one of them is SEYHAN, a private power plant operated by Cukurova Electric jsc. The other two power plants are publicly owned namely KEBAN and KARAKAYA. The remaining 25 power plants are overall technically inefficient. From a policy implication point of view, it is important to search for the sources of overall technical inefficiency, so that appropriate policy strategies can be arranged. Very high efficiency scores suggest that scale inefficiency is a less serious problem than managerial inefficiency at the majority of the power plants. However, there are still some scale inefficiencies at a large number of power plants which need to be eliminated. Table 7.4 exhibits the sources of scale inefficiency for the public and private plants.

Table 7.4 The source of scale inefficiency between the ownership types

Public Plants			Private Plants		
IRS	CRS	DRS	IRS	CRS	DRS
13	2	7	5	1	-

IRS: Increasing Returns to Scale; CRS: Constant Returns to Scale;
DRS: Decreasing Returns to Scale

Five private and thirteen public power plants are scale inefficient due to operating in the increasing returns region whereas seven public plants are scale inefficient as a result of operating in the decreasing returns region. The former group can become scale efficient if they increase their operations until they reach the level of constant returns to scale. The latter group of power plants, however, should reduce their operation to the level of constant returns to scale. Power plants that are operating at constant returns to scale are regarded as overall technically efficient. The performance of the overall technically inefficient power plants can be improved as they adjust their operations to the operation of the plant(s) making their reference set.

Appendix 2a and 2b show the target levels of output and inputs which each inefficient power plant should achieve to become overall technically efficient and pure technically efficient, respectively. This is done as was shown in chapter 4, by each power plant reducing its input levels proportionately to the efficiency score level and further reducing the inputs by the amount of relevant slack variables. Meanwhile, the output level should be increased by the amount of output slack.

However, since the pure technical (managerial) inefficiency appears to be the main problem across the inefficient power plants, lets focus on the target levels should be achieved by the inefficient power plants under varying returns to scale technology. The power plant that adjusted its output and input levels to the target levels becomes pure technically efficient, regardless of its scale of operation, that is, it can still be scale inefficient due to operating at increasing or decreasing returns region.

As seen from Table 7.2, there are four power plants, two of them publicly owned: KEBAN and KARAKAYA, and the other two privately owned: SEYHAN and YUREGIR (both belonging to Cukurova Electric jsc), which are pure technically efficient. YUREGIR is pure technically efficient but not scale efficient, since it operates in the increasing returns region. Managerial inefficiency is a more serious problem for some public power plants namely for HAZAR I, KEMER, DOGANKENT, CILDIR, and KARACAOREN, than it is for the private power plants.

In Appendix 2b only six power plants, five public namely KESIKKOPRU, KOKLUCE, KAPULUKAYA, KILICKAYA, KARACAOREN, and one private power plant KADINCIK II, have no slack variables in labour input, indicating the need for extra reduction in the number of employees by the remaining plants. This may be treated as evidence of over employment in these public power plants as well as in three private power plants.

Finally, in Appendix 2b, two private power plants SEYHAN and YUREGIR have a high number of appearances, 24 and 21 times respectively, in the reference set of the other power plants, and therefore, they can be treated as a reference model for the inefficient power plants. The public power plant KEBAN appeared 16 times whereas KARAKAYA appeared only 3 times in the reference set of the inefficient power plants. KEBAN can be regarded as model but KARAKAYA should be treated as 'self-evaluator'.

7.5 Conclusion

This chapter aimed to investigate potential effects of privatisation in electricity generation by comparing the technical efficiency of private hydroelectric power plants with those of owned by the TEA. The results provide no evidence for significant difference between private and public power plants. Pure technical inefficiency is identified as the major contributor to the overall technical inefficiency for the whole sample. However, that was a more serious problem for some public power plants than it was for the private power plants. Two private power plants appear in the reference set of majority of inefficient power plants, thus present a model to follow. This may, though weakly, confirm the expectation of relatively better managerial performance under private ownership.

Chapter 8 Thermoelectric Plants in Turkey

8.1 Introduction

This chapter applies a causality analysis similar to the one applied in the distribution organisations study to observe whether the government was genuine in its declaration that the immediate candidates of four thermoelectric power plants were selected amongst the group most in need for rehabilitation.

The following section describes the structure of the thermoelectric power generation in Turkey in 1991. The third section presents the data and variables. The fourth section evaluates the results; and the last section concludes the chapter.

8.2 Thermoelectric Power Generation in Turkey

We recall from chapter 3 that since the announcement of the Electricity Liberalisation Law of 1984, the Turkish government has pursued a partial privatisation policy, transferring the management rights rather than the property rights of the publicly owned electrical equipment, and attracting private financial resources through the BOT scheme to construct and to renew power plants and distribution networks. To date, only three very small hydroelectric power plants have been constructed under the BOT scheme, and only two distribution organisations changed their management to private bodies. Several projects of large thermoelectric and hydroelectric generating plants were abandoned since the Government realised that financing the construction of these plants was not cheaper under the BOT scheme than alternative financial arrangements.

Table 8.1 The List of the Thermoelectric Plants in 1991.

Plants	Fuel Type	Installed Capacity (MW)
1. TUNCBILEK	Lignite	429.0
2. SOMA-A*+	Lignite	44.0
3. SOMA-B*+	Lignite	825.5
4. SEYITOMER*+	Lignite	600.0
5. YATAGAN*	Lignite	630.0
6. AFSIN-ELBISTAN	Lignite	1360.0
7. YENIKOY*+	Lignite	420.0
8. CAYIRHAN	Lignite	300.0
9. KANGAL*	Lignite	300.0
10. ORHANELI*	Lignite	N.A.
11. KEMERKOY*	Lignite	N.A
12. CATALAGZI-B*	H-Coal	300.0
13. AMBARLI	Natural Gas	1350.9
14. HAMITABAT*+	Natural Gas	1200.0
15. AMBARLI	Fuel Oil	630.0
16. HOPA	Fuel Oil	50.0

*The power plants to be privatised; +The power plants to be privatised immediately;
N.A.= not available

Disagreement between the Government and private investors under the BOT scheme led the Government to change its partial privatisation strategy in the electricity supply industry. Recently the Government announced its plan to privatise ten out of sixteen publicly owned thermoelectric plants in 1995. The list of these plants is given in Table 8.1. At the first stage, five plants, four lignite-fired plants namely SOMA(A), SOMA(B), SEYITOMER, and YENIKOY, and one natural gas-fired plant, HAMITABAT, were given priority to be privatised immediately.

These five plants generate about 27% of total electricity in Turkey. The shares of these plants will be handled by the Public Participation Administration and the sale will be by public offerings or block sales, or a combination of both. The projected revenue from the sale of ten plants, 200,000 billion Turkish Lira, will be used to finance new energy projects and to rehabilitate the power plants remaining in public hands. The privatised power plants will operate to meet base-load demand and will sell the electricity they produce to the TEAS (created following the split of the TEA) for a price within in the limits determined by the MENR.

During and after privatisation, the MENR will monitor the operations of the power plants and will take necessary measures to avoid any private power plant emerging as a private monopoly. The measures that the MENR can take are not publicised yet. The MENR could use the non-parametric DEA in order to monitor the performance of the thermoelectric plants prior to and after privatisation. Recall that the technical efficiency score shows whether a particular plant, relative to other plants in the sample, is operating efficiently in converting limited resources to generate given levels of electricity. The DEA identifies the sources and quantities of any inefficiency, thus identifying where improvements are needed, i.e. which inputs need to be reduced or which outputs increased. The comparison set of an inefficient plant includes the efficient plant(s) most similar to its own operational characteristics so that a review of the plants can be made and ideas for improved performance obtained.

The government announced that the first five candidates were selected amongst the power plants most in need of rehabilitation. The government stressed that the private investors will provide the financial resources to rehabilitate the power plants and will run them more efficiently than if they were operated under public management. This claim of the government is not supported by any published empirical work.

The aim of this chapter is to examine whether the first five candidates of privatisation were amongst the most efficient plants relative to the other plants in the sample, or as the government claimed, most needed rehabilitation. This is an important issue to investigate since, as we have seen in the distribution organisation study in chapter 6, the government tend to privatise firstly its most efficient operations to attract potential investors.

8.3 Data and Variables

The TEA, the main data source of this chapter, supplied us with information only for one year: 1991. The data contain power plant level information about three conventional inputs: labour, capital and fuel employed to generate thermoelectric electricity. Labour is measured as the number of employees. Capital is defined as installed generating capacity, measured in megawatts. The installed capacity is adjusted for the load factor as we did in the previous chapter in order to take proper account of generating capacity used in electricity generation, and to avoid inefficiency being attributed to idle capacity. Fuel is measured as heat content 10^7 Kilocalorie, to include the non-lignite fired power plants in the sample. Output is defined as net thermoelectric generation per power plant and measured in megawatt-hours. These variables are commonly used in the empirical literature of thermoelectric generation reviewed in chapter 5. Table 8.2 shows the variables and their definition.

Table 8.3 presents the simple correlation matrix between the variables. Labour is weakly correlated with net generation, implying that there may be some plants with a large number of employees and relatively small net generation. This indicates the likelihood of finding relatively larger inefficiency associated with labour input than with other inputs. Moderate correlation between labour and capital, and a higher correlation between capital and fuel are identified.

Table 8.2 Definition of the Variables

OUTPUT	MEASURE
Y1: Net thermoelectric generation	MWh
INPUT	
X1: Manpower	Number of employees
X2: Installed generating capacity	MW (adjusted for the load factor)
X3: Fuel	Heat content in 10^7 Kilocalorie

Table 8.3 Correlation Matrix

	Y1	X1	X2	X3
Y1	1			
X1	0.314662	1		
X2	0.970533	0.406313	1	
X3	0.898574	0.662388	0.920951	1

Since the majority for the candidates of privatisation (eight out of ten candidates, and four out of five immediate candidates) were lignite-fired power plants, at first we aimed to calculate the input-saving technical efficiency measures for a sample of eleven lignite-fired power plants. This plan had to be abandoned since two lignite fired power plants namely ORHANLI and KEMERKOY, were dropped from the sample due to missing data. The calculation could result in poor discriminatory power of the DEA between the power plants in the presence of four variables and nine plants. Recall from chapter 4 the DEA requires the number of observations to be at least three times larger than the number of variables to get a reasonably good discriminatory power between the power plants. To increase the number of observations, the non-lignite fired power plants are also included into the sample. HAMITABAT, an immediate candidate for privatisation, was dropped from the sample due to lack of data on its input variables. Dropping three plants from the list in Table 8.1 left the final number of observations at thirteen.

8.4 Results

As explained in chapter 4, each power plant in the sample receives an input-saving technical efficiency score according to its ability to generate a given level of electricity by consuming minimum possible levels of labour, capital and fuel inputs. Unit efficiency score implies that the power plant in question is relatively efficient in converting the inputs to the given level of output. A score of less than unity indicates that the power plant is inefficient and has scope for producing the same level of output by consuming fewer inputs.

Table 8.4 presents the descriptive statistics for the whole sample as well as between the immediate four candidates and the rest of the plants, and also between the seven candidates of privatisation and the rest of the plants. Table 8.5 shows the individual overall technical, pure technical, and scale efficiency scores per plant. Appendix 3a and 3b contain tables similar to the tables in Appendixes 1a and 1b, arranged to give detailed information about the performance of each power plant.

Table 8.4 Descriptive Statistics of Efficiency Scores for Thermoelectric P-Plants

All Plants	No. of Plants	Mean	Std.Dev.	Min. Value	Max. Value
OTE	13	0.839105	0.196669	0.419514	1.000
PTE	13	0.885640	0.166507	0.462201	1.000
SE	13	0.949214	0.134352	0.510230	1.000
Immediate Candidates	No. of Plants	Mean	Std.Dev.	Min. Value	Max. Value
OTE	4	0.928793	0.114420	0.758573	1.000
PTE	4	0.940920	0.118160	0.763680	1.000
SE	4	0.987478	0.015144	0.965479	1.000
The Rest					
OTE	9	0.799244	0.217484	0.419514	1.000
PTE	9	0.861071	0.184782	0.462201	1.000
SE	9	0.932208	0.161035	0.510230	1.000
Candidates					
OTE	7	0.945354	0.089627	0.758573	1.000
PTE	7	0.954786	0.089410	0.763680	1.000
SE	7	0.990124	0.012879	0.965479	1.000
The Rest					
OTE	6	0.715148	0.221239	0.419514	1.000
PTE	6	0.804970	0.206018	0.462201	1.000
SE	6	0.901487	0.195053	0.510230	1.000

The average efficiency scores of 13 power plants are quite high. High average scale efficiency (94,9%) suggests that scale inefficiency is less a problem for the power plants in the sample. The average pure technical efficiency (88,5) indicates that the power plants can generate the same level of output, regardless of their scale of operation, by reducing the input levels by 11,5%. To achieve the optimal scale of operation and managerial efficiency together, the power plants should reduce their input consumption up to the average overall technical efficiency level of 83,9%. On average, four immediate candidates of privatisation have higher efficiency scores than the rest of the plants. This supports the perception that the Government is expected to choose the most efficient plants to privatise first. This deduction is still in place when the average efficiency score of the seven candidates for privatisation is compared with the rest of the plants.

Table 8.5 The individual Efficiency Scores per Plant

PLANTS	OTE	PTE	SE	Scale Type
1. TUNCBILEK	0.798373	0.798800	0.999465	IRS
2. SOMA(A)*+	0.965479	1.000000	0.965479	IRS
3. SOMA(B)*+	0.758573	0.763680	0.993312	DRS
4. SEYITOMER*+	0.991122	1.000000	0.991122	DRS
5. YATAGAN*	0.902305	0.919823	0.980955	DRS
6. AFSIN-ELBISTAN	0.685205	0.690148	0.992837	DRS
7. YENIKOY*+	1.000000	1.000000	1.000000	CRS
8. CAYIRHAN	0.877569	0.878671	0.998745	IRS
9. KANGAL*	1.000000	1.000000	1.000000	CRS
10. CATALAGZI(B)-C*	1.000000	1.000000	1.000000	CRS
11. AMBARLI-F	0.419514	0.462201	0.907644	IRS
12. HOPA-F	0.510230	1.000000	0.510230	IRS
13. AMBARLI-N	1.000000	1.000000	1.000000	CRS

* The candidates to be privatised; + The immediate candidates to be privatised.

To test the significance of these differences between the immediate candidates (all candidates) of privatisation and the rest of plants will remain in public hands, the Mann-Whitney test is calculated. The null hypothesis is defined as that there is no significant performance difference between these groups. The null hypothesis is tested against the alternative hypothesis that the immediate candidates (all candidates) have higher performance level than the rest of the plants.

Considering the immediate candidates only, the null hypothesis is not rejected at the 5% significance level (Table 8.6). When all candidates are taking into account the null hypothesis is rejected only for the overall efficiency scores at the 5% significance level (Table 8.7).

Table 8.6 Mann-Whitney test for 4 immediate candidates vs. 9 remain in public.

Efficiency scores	OTE	PTE	SE
z-values	0.7041	0.8387	0.2347
P-values (probabilities)	(0.2420)	(0.2033)	(0.4090)

Table 8.7 Mann-Whitney test for 7 immediate candidates vs. 6 remain in public.

Efficiency scores	OTE	PTE	SE
z-values	1.9556	1.5530	0.6519
P-values (probabilities)	(0.0256)	(0.0606)	(0.2578)

OTE=Overall Technical Efficiency; PTE=Pure Technical Efficiency; SE=Scale Efficiency.

In Table 8.4, recall from chapter 4 that overall technical efficiency is calculated from Model 1, pure technical efficiency is measured from Model 2, and scale efficiency is derived as the ratio of the overall technical efficiency to pure technical efficiency. The power plants have quite high overall technical efficiency scores, the lowest scores belonging to two fuel-fired power plants namely AMBARLI-F (41,9%) and HOPA-F (51,0%). There are only four power plants with unit score of overall technical efficiency. These are YENIKOY (immediate candidate), KANGAL (candidate), CATALAGZI(B)-C (candidate), and AMBARLI-N. The remainder of the power plants are overall technically inefficient.

For the inefficient power plants identifying the shares of managerial incompetence (pure technical inefficiency) and scale inefficiency in the overall inefficiency is important to arrange strategies of improving their performance. Amongst the inefficient power plants, two immediate candidates SOMA (A) and

SEYITOMER, and another power plant HOPA-F score unit pure technical efficiency, indicating that their overall technical inefficiency originated from scale inefficiency.

TUNCBILEK, SOMA(B), YATAGAN, AFSIN-ELBISTAN, CAYIRHAN and AMBARLI-F have quite high scale efficiency scores, suggesting that managerial inefficiency makes a bigger contribution to their overall inefficiency. That is, given their scale of operation, these plants consume more than needed to produce the given output level.

As shown in Appendix 3a and 3b, these power plants can become overall and pure technically efficient by adjusting their operations to the target level (the Target Value), respectively. In Appendix 3a, SOMA(B), SEYITOMER, YATAGAN, AFSIN-ELBISTAN and CAYIRHAN can become efficient by simply reducing their input consumption proportionately to their efficiency score level. In addition to this reduction, TUNCBILEK, SOMA(A), AMBARLI-F and HOPA-F should reduce their input consumption further by the amount of the input slacks.

Amongst the overall technically efficient power plants, CATALAGZI(B)-C (immediate candidate), AMBARLI-N. and YENIKOY (immediate candidate) have a high number of appearances in the other power plants' reference set, eleven, ten and seven times, respectively. This implies that these power plants are dominant over a large number of power plants. However, KANGAL appeared only three times, thus it may be viewed as being somewhat unique with respect to its output-input combination, and regarded as a 'self evaluator'. Being a self evaluator may be due to to differences in system characteristics, differences in operating procedures, or both.

8.5 Conclusion

Considering the whole sample, the power plants have high average scale efficiency scores, indicating that the scale inefficiency is not a major problem. The remaining scale inefficiency can be eliminated by the central dispatcher in the TEA by changing the scale of operation of the associated scale inefficient power plants. The TEA should consider the power plants operating in the increasing returns region first to increase their operations since these power plants have the potential to increase output greater than proportionately to a unit increase in their inputs. On the other hand, the TEA should consider reducing the operations of the power plants operating in the decreasing returns region.

Managerial inefficiency appears to be a bigger problem in the thermoelectric plants, however, this is less of a problem for the immediate and long-term candidates of privatisation. Amongst the immediate candidates, except SOMA(B) with efficiency rate of 75,8%, the plants have overall efficiency scores very close to unity. This contradicts the Government's announcement that these power plants were selected amongst the most in need of rehabilitation.

Chapter 9 Conclusion

The three empirical studies of this thesis makes it the first performance investigation to accompany the still ongoing privatisation process in Turkey in general, and in particular for the electricity supply industry. The empirical results suggested no significant difference in average technical efficiency between public ownership and private ownership. However, examination of organisation and plant level disaggregated results suggested relatively better performance by private ownership. This may be taken as a weak evidence for superior performance by private ownership. The results also indicated that the government tended to select the candidates for privatisation amongst the best performers in the public sector. We assume that this was due to the government's desire to find a buyer, or to give the best impression about privatisation by providing evidence that those privatisations result in efficient performance. From the government perspective this may ease and expedite future privatisation.

In the light of our empirical results we conclude that the financial difficulties in the dominant electric utility, the TEA, were the main driving force behind electricity privatisation in Turkey. This can be easily observed through the developments in electricity privatisation since it started in 1984 to date. At the very beginning, the government aimed a partial privatisation strategy for renewal and expansion investments in the electricity supply industry by attracting private financial resources under the BOT scheme without transferring the physical assets of electrical equipment. Failure to bring the needed capital under the BOT scheme has led the government to abandon that strategy. This was evident from the split of the TEA into two large public companies (the TEAS and the TEDAS) in 1993.

This was said to prepare the TEA for a privatisation similar to the British example, which, in our opinion, is unlikely to materialise due to the weak institutional and unfavorable macroeconomic conditions in Turkey. Perhaps for that reason, the government's next move was towards pursuing a step-by-step approach and selling power plants one-by-one rather than selling the TEAS complete. The government has not solved the financial problems of the heirs of the TEA, and still needs to find extra-budgetary resources in order to finance renewal and expansion investments in the electricity supply industry. This task has proved to be a difficult one, and may eventually be solved to a degree by giving more freedom to private investors to shape the electricity tariff.

In this thesis we also indicated that the government had difficulty in monitoring the performance of the newly privatised companies. We propose the DEA as a useful tool to analyse the performance of distribution organisations and power plants while they are still in the public sector or after being privatised. The DEA is useful because it does not only identify the best and the worst performers, but also suggests ways of improving inefficient performance. As shown in the appendices, each distribution organisation and power plant have a reference set consisting of its companion with the most similar operating characteristics, and input and output combinations. This information can be used to regulate the activities of an inefficient organisation and plant, by forcing it to perform at least as well as those making up its reference set. By identifying sources of inefficiency these can be eliminated within the public sector, and enable acceleration of the privatisation program.

Finally, a future extension of this research may be applying a Malmquist type index to a time series data (of course we assume that the MENR and other electric companies will supply us the data), and investigating productivity growth for the distribution organisations and power plants. The lack of large numbers of franchised distribution organisations may handicap our efforts to relate the findings directly to the performance differences between ownership types. In any case, a declining trend of productivity of public organisations between years may indicate deteriorating performance under public ownership.

Appendices

Appendix 1a Detailed organisation level efficiency under CRS Frontier

1.KEPEZ	Efficiency Score: 1.000000		Scale Type: CRS
Facet (and Lambda):	1(1.000000) 14	2	Banker's indicator: 1.000000
Outputs	Observed Value	Target Value	Slack
Y1	753.0	753.0	0.00
Y2	195000.0	195000.0	0.00
Y3	130.0	130.0	0.00
Y4	20591.0	20591.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	66.0	66.0	0.00
X2	355.0	355.0	0.00
X3	1200.0	1200.0	0.00
X4	7481.6	7481.6	0.00
X5	39300.0	39300.0	0.00

2. CUKUROVA	Efficiency Score: 1.000000		Scale Type: CRS
Facet (and Lambda):	2(1.000000)	13	Banker's indicator: 1.000000
Outputs	Observed Value	Target Value	Slack
Y1	2562.0	2562.0	0.00
Y2	4026800.0	4026800.0	0.00
Y3	746.0	746.0	0.00
Y4	38509.0	38509.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	297.0	297.0	0.00
X2	1812.5	1812.5	0.00
X3	2681.7	2681.7	0.00
X4	25045.0	25045.0	0.00
X5	254900.0	254900.0	0.00

3. ADANA	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
3(1.000000)	12	33	
35	37		
Outputs	Observed Value	Target Value	Slack
Y1	484473.0	484473.0	0.00
Y2	687281.0	687281.0	0.00
Y3	534.0	534.0	0.00
Y4	17253.0	17253.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	1240.0	1240.0	0.00
X2	817.0	817.0	0.00
X3	13059.7	13059.7	0.00
X4	255645.4	255645.4	0.00
X5	116277.0	116277.0	0.00

4. ADIYAMAN	Efficiency Score:	0.852451	Scale Type: IRS
Facet (and Lambda):	2(0.018672)	40(0.014485)	Banker's indicator: 0.471258
45(0.337982)	60(0.089252)	69(0.010867)	
Outputs	Observed Value	Target Value	Slack
Y1	87633.0	87633.0	0.00
Y2	233225.0	233225.0	0.00
Y3	48.5	61.32	12.82
Y4	7614.0	7614.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	267.0	214.73	12.87
X2	165.7	165.7	0.00
X3	6288.1	3223.82	2136.48
X4	51438.1	51438.1	0.00
X5	21958.0	21958.0	0.00

5. AFYON	Efficiency Score:	0.889313	Scale Type: IRS
Facet (and Lambda):	17(0.01294)	21(0.615264)	Banker's indicator: 0.951001
40(0.122946)	44(0.013491)	51(0.065132)	
60(0.108814)	70(0.012414)		
Outputs	Observed Value	Target Value	Slack
Y1	179660.0	179660.0	0.00
Y2	311270.0	311270.0	0.00
Y3	83.5	83.5	0.00
Y4	14230.0	14230.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	481.0	410.82	16.94
X2	318.7	283.42	0.00
X3	6478.2	5761.15	0.00
X4	79574.3	70766.46	0.00
X5	38582.0	34311.47	0.00

6. AGRI	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	2	6(1.00000)	Banker's indicator: 1.000000
13	40	51	
60	70		
Outputs	Observed Value	Target Value	Slack
Y1	69801.0	69801.0	0.00
Y2	70388.0	70388.0	0.00
Y3	19.5	19.5	0.00
Y4	11376.0	11376.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	235.0	235.0	0.00
X2	69.5	69.5	0.00
X3	4553.4	4553.4	0.00
X4	23770.2	23770.2	0.00
X5	19861.0	19861.0	0.00

7. AMASYA	Efficiency Score:	0.690068	Scale Type: IRS
Facet (and Lambda):	2(0.000729)	17(0.74075)	Banker's indicator: 0.795042
45(0.028518)	66(0.001267)	70(0.023778)	
Outputs	Observed Value	Target Value	Slack
Y1	94586.0	94586.0	0.00
Y2	135640.0	135640.0	0.00
Y3	28.5	35.45	6.95
Y4	5520.0	5520.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	345.0	180.03	58.04
X2	167.3	115.45	0.00
X3	4124.8	2640.74	205.65
X4	30157.8	20810.93	0.00
X5	34634.0	23899.82	0.00

8. ANKARA	Efficiency Score:	0.759302	Scale Type: DRS
Facet (and Lambda):	2(0.027476)	35(0.155906)	Banker's indicator: 4.09272
37(0.307876)	40(0.011493)	66(3.335459)	
70(0.25451)			
Outputs	Observed Value	Target Value	Slack
Y1	973195.0	973195.0	0.00
Y2	2693228.0	2693228.0	0.00
Y3	655.5	770.49	114.99
Y4	25706.0	25706.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	2997.0	1826.90	448.73
X2	2049.1	1555.89	0.00
X3	21526.2	16344.89	0.00
X4	729619.9	554001.85	0.00
X5	336516.0	255517.27	0.00

9. ANTALYA	Efficiency Score:	0.983943	Scale Type: DRS
Facet (and Lambda):	12(0.461305)	17(0.401938)	Banker's indicator: 1.501938
44(0.067258)	45(0.41556)	60(0.12886)	
70(0.027017)			
Outputs	Observed Value	Target Value	Slack
Y1	373415.0	373415.0	0.00
Y2	551842.0	651005.85	99163.85
Y3	207.0	207.0	0.00
Y4	20591.0	20591.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	781.0	768.50	0.00
X2	543.3	534.58	0.00
X3	16230.8	10933.77	5036.41
X4	161140.6	158553.17	0.00
X5	68034.0	66941.58	0.00

10. ARTVIN	Efficiency Score:	0.84266	Scale Type: IRS
Facet (and Lambda):	1(0.006015)	2(0.007321)	Banker's indicator: 0.374485
12(0.012488)	13(0.122796)	60(0.22167)	
70(0.004195)			
Outputs	Observed Value	Target Value	Slack
Y1	57636.0	57636.0	0.00
Y2	170421.0	170421.0	0.00
Y3	28.0	47.63	19.63
Y4	7436.0	7436.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	196.0	165.16	0.00
X2	119.0	100.28	0.00
X3	4258.1	2760.49	827.64
X4	42892.7	36143.96	0.00
X5	15424.0	12997.19	0.00

11. AYDIN	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	11(1.00000)	17	Banker's indicator: 1.000000
35	40	66	
70			
Outputs	Observed Value	Target Value	Slack
Y1	305822.0	305822.0	0.00
Y2	472537.0	472537.0	0.00
Y3	117.5	117.5	0.00
Y4	8007.0	8007.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	666.0	666.0	0.00
X2	3860.5	3860.5	0.00
X3	5212.9	5212.9	0.00
X4	123454.2	123454.2	0.00
X5	69460.0	69460.0	0.00

12. BALIKESIR	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
12(1.000000)	37	43	
70			
Outputs	Observed Value	Target Value	Slack
Y1	383470.0	383470.0	0.00
Y2	718346.0	718346.0	0.00
Y3	215.0	215.0	0.00
Y4	14292.0	14292.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	626.0	626.0	0.00
X2	610.6	610.6	0.00
X3	9686.7	9686.7	0.00
X4	189395.4	189395.4	0.00
X5	58883.0	58883.0	0.00

13. BILECIK	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
13(1.000000)	33	37	
40	69	70	
Outputs	Observed Value	Target Value	Slack
Y1	53851.0	53851.0	0.00
Y2	419021.0	419021.0	0.00
Y3	99.0	99.0	0.00
Y4	4307.0	4307.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	167.0	167.0	0.00
X2	67.7	67.7	0.00
X3	1999.7	1999.7	0.00
X4	116256.0	116256.0	0.00
X5	18465.0	18465.0	0.00

14. BINGOL	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	2	13	Banker's indicator: 1.000000
14(1.000000)	60	66	
Outputs	Observed Value	Target Value	Slack
Y1	43412.0	43412.0	0.00
Y2	26920.0	26920.0	0.00
Y3	8.5	8.5	0.00
Y4	8125.0	8125.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	217.0	217.0	0.00
X2	62.8	62.8	0.00
X3	3328.9	3328.9	0.00
X4	19354.3	19354.3	0.00
X5	3675.0	3675.0	0.00

15. BITLIS	Efficiency Score:	0.643806	Scale Type: IRS
Facet (and Lambda):	1(0.005684)	6(0.578953)	Banker's indicator: 0.586642
	70(0.002005)		
Outputs	Observed Value	Target Value	Slack
Y1	42260.0	42260.0	0.00
Y2	34681.0	35852.93	1171.93
Y3	10.5	13.11	2.61
Y4	6707.0	6707.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	214.0	137.77	0.00
X2	67.9	43.71	0.00
X3	4246.1	2651.54	82.12
X4	22334.2	13947.13	431.76
X5	21382.0	12618.93	1146.93

16. BOLU	Efficiency Score:	0.821596	Scale Type: IRS
Facet (and Lambda):	6(0.210725)	13(0.209446)	Banker's indicator: 0.921063
40(0.142875)	45(0.229986)	60(0.08879)	
70(0.039241)			
Outputs	Observed Value	Target Value	Slack
Y1	162790.0	162790.0	0.00
Y2	389377.0	389377.0	0.00
Y3	89.5	100.35	10.85
Y4	11051.0	11051.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	444.0	364.79	0.00
X2	199.1	163.58	0.00
X3	7116.2	4789.36	1057.28
X4	106215.1	87265.90	0.00
X5	53587.0	44026.86	0.00

17. BURDUR	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
17(1.00000)	21	44	
60	70		
Outputs	**Observed Value**	**Target Value**	**Slack**
Y1	90800.0	90800.0	0.00
Y2	93688.0	93688.0	0.00
Y3	26.0	26.0	0.00
Y4	6887.0	6887.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	205.0	205.0	0.00
X2	121.9	121.9	0.00
X3	3189.8	3189.8	0.00
X4	22252.9	22252.9	0.00
X5	16514.0	16514.0	0.00

18. BURSA	Efficiency Score:	0.932389	Scale Type: IRS
Facet (and Lambda):	1(0.114254)	2(0.024864)	Banker's indicator: 0.793456
12(0.091352)	37(0.531912)	70(0.031074)	
Outputs	**Observed Value**	**Target Value**	**Slack**
Y1	567985.0	567985.0	0.00
Y2	2523853.0	2523853.0	0.00
Y3	595.5	777.09	181.59
Y4	11043.0	11043.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	1300.0	1212.11	0.00
X2	1461.1	1202.58	159.73
X3	8179.5	7626.48	0.00
X4	684926.5	596279.12	42338.81
X5	175564.0	163693.94	0.00

19.CANAKKALE	Efficiency Score:	0.928267	Scale Type: IRS
Facet (and Lambda):	1(0.146784)	2(0.004382)	Banker's indicator: 0.930735
12(0.308749)	13(0.406974)	37(0.005933)	
66(0.057913)			
Outputs	Observed Value	Target Value	Slack
Y1	152799.0	152799.0	0.00
Y2	474671.0	474671.0	0.00
Y3	101.0	139.68	38.68
Y4	9737.0	9737.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	322.0	298.90	0.00
X2	345.9	298.57	22.52
X3	4581.7	4253.04	0.00
X4	125427.9	116430.58	0.00
X5	37497.0	34807.23	0.00

20.CANKIRI	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	17	Banker's indicator: 1.000000
20(1.00000)	21	51	
60			
Outputs	Observed Value	Target Value	Slack
Y1	65325.0	65325.0	0.00
Y2	65015.0	65015.0	0.00
Y3	18.0	18.0	0.00
Y4	8454.0	8454.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	248.0	248.0	0.00
X2	114.9	114.9	0.00
X3	3158.1	3158.1	0.00
X4	22129.7	22129.7	0.00
X5	11330.0	11330.0	0.00

21.CORUM	Efficiency Score:	1.00000	Scale Type: CRS
Facet (and Lambda):	17	21(1.0000)	Banker's indicator: 1.000000
40	44	51	
60	66		
Outputs	Observed Value	Target Value	Slack
Y1	164077.0	164077.0	0.00
Y2	249385.0	249385.0	0.00
Y3	61.5	61.5	0.00
Y4	12820.0	12820.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	333.0	333.0	0.00
X2	327.4	327.4	0.00
X3	5460.6	5460.6	0.00
X4	54467.2	54467.2	0.00
X5	24621.0	24621.0	0.00

22.DENIZLI	Efficiency Score:	0.880903	Scale Type: DRS
Facet (and Lambda):	2(0.006645)	12(0.328017)	Banker's indicator: 1.328043
21(0.556351)	66(0.425038)	70(0.011992)	
Outputs	Observed Value	Target Value	Slack
Y1	277592.0	277592.0	0.00
Y2	507654.0	507654.0	0.00
Y3	134.5	136.6	2.10
Y4	11868.0	14369.1	2501.1
Inputs	Observed Value	Target Value	Slack
X1	573.0	504.76	0.00
X2	576.4	482.90	24.85
X3	8709.4	7672.14	0.00
X4	131220.7	115592.71	0.00
X5	51627.0	45478.38	0.00

23.DIYARBAKIR	Efficiency Score:	0.764513	Scale Type: DRS
Facet (and Lambda):	13(0.021486)	40(0.158553)	Banker's indicator: 1.752183
	51(1.523765)	70(0.048379)	
Outputs	Observed Value	Target Value	Slack
Y1	171132.0	171132.0	0.00
Y2	293056.0	293056.0	0.00
Y3	68.5	78.9	10.40
Y4	15355.0	15355.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	723.0	430.61	122.13
X2	184.3	140.90	0.00
X3	9814.3	3936.13	3567.03
X4	81837.1	62565.53	0.00
X5	194828.0	63089.96	85858.58

24.EDIRNE	Efficiency Score:	0.819223	Scale Type: IRS
Facet (and Lambda):	1(0.053443)	2(0.030171)	Banker's indicator: 0.406267
12(0.267549)	13(0.035471)	70(0.019633)	
Outputs	Observed Value	Target Value	Slack
Y1	122682.0	122682.0	0.00
Y2	383415.0	383415.0	0.00
Y3	98.5	101.15	2.65
Y4	6276.0	6276.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	243.0	199.07	0.00
X2	309.7	253.71	0.00
X3	4600.0	2891.07	877.36
X4	101304.8	57349.81	25641.41
X5	42702.0	34982.46	0.00

25.ELAZIG	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	2	13	Banker's indicator: 1.000000
25(1.00000)	60	69	
Outputs	Observed Value	Target Value	Slack
Y1	132458.0	132458.0	0.00
Y2	580822.0	580822.0	0.00
Y3	104.0	104.0	0.00
Y4	9153.0	9153.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	752.0	752.0	0.00
X2	229.0	229.0	0.00
X3	6398.9	6398.9	0.00
X4	122043.3	122043.3	0.00
X5	35135.0	35135.0	0.00

26. ERZINCAN	Efficiency Score:	0.996073	Scale Type: DRS
Facet (and Lambda):	1(0.071719)	14(0.613406)	Banker's indicator: 1.141128
17(0.249685)	20(0.065017)	21(0.054397)	
60(0.086904)			
Outputs	Observed Value	Target Value	Slack
Y1	79131.0	79131.0	0.00
Y2	99066.0	99066.0	0.00
Y3	26.5	35.06	8.56
Y4	11903.0	11903.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	371.0	274.8	94.74
X2	146.1	145.53	0.00
X3	4365.0	4347.86	0.00
X4	29923.3	29805.79	0.00
X5	13684.0	13630.26	0.00

27.ERZURUM	Efficiency Score:	0.878574	Scale Type: DRS
Facet (and Lambda):	6(1.472983)	14(0.734366)	Banker's indicator: 2.501475
17(0.20248)	40(0.026858)	57(0.048294)	
70(0.016494)			
Outputs	Observed Value	Target Value	Slack
Y1	192616.0	192616.0	0.00
Y2	223485.0	223485.0	0.00
Y3	61.5	61.5	0.00
Y4	25066.0	25066.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	799.0	626.31	75.67
X2	229.5	201.63	0.00
X3	13563.0	10683.72	1232.38
X4	76358.9	67086.94	0.00
X5	56221.0	49394.31	0.00

28.ESKISEHIR	Efficiency Score:	0.692075	Scale Type: IRS
Facet (and Lambda):	1(0.031599)	12(0.185766)	Banker's indicator: 0.816025
21(0.306346)	60(0.220564)	70(0.07175)	
Outputs	Observed Value	Target Value	Slack
Y1	229657.0	229657.0	0.00
Y2	441202.0	447928.01	6726.01
Y3	126.0	126.0	0.00
Y4	13652.0	13652.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	577.0	399.33	0.00
X2	495.2	342.72	0.00
X3	10068.0	6152.63	815.18
X4	135611.2	76095.79	17757.20
X5	83523.0	57804.10	0.00

29.G.ANTEP	Efficiency Score:	0.900364	Scale Type: DRS
Facet (and Lambda):	2(0.031794)	37(0.051568)	Banker's indicator: 1.170862
40(0.287239)	66(0.705762)	69(0.084524)	
70(0.009975)			
Outputs	Observed Value	Target Value	Slack
Y1	249781.0	249781.0	0.00
Y2	777583.0	777583.0	0.00
Y3	205.0	205.0	0.00
Y4	7642.0	11218.68	3576.68
Inputs	Observed Value	Target Value	Slack
X1	706.0	565.86	69.8
X2	425.6	383.19	0.00
X3	6410.0	5771.33	0.00
X4	188758.5	169951.36	0.00
X5	65843.0	59282.67	0.00

30.GIRESUN	Efficiency Score:	0.964497	Scale Type: IRS
Facet (and Lambda):	12(0.020256)	17(0.387978)	Banker's indicator: 0.861957
44(0.045423)	45(0.407773)	70(0.000527)	
Outputs	Observed Value	Target Value	Slack
Y1	141798.0	141798.0	0.00
Y2	202409.0	214979.75	12570.75
Y3	73.0	73.0	0.00
Y4	6934.0	9542.53	2608.53
Inputs	Observed Value	Target Value	Slack
X1	362.0	349.14	0.00
X2	193.5	186.63	0.00
X3	8760.8	4697.87	3751.90
X4	59261.2	57157.25	0.00
X5	24247.0	23386.16	0.00

31.GUMUSHANE	Efficiency Score:	0.839945	Scale Type: IRS
Facet (and Lambda):	1(0.054746)	6(0.091473)	Banker's indicator: 0.698415
14(0.400869)	32(0.096284)	60(0.001763)	
64(0.05328)			
Outputs	Observed Value	Target Value	Slack
Y1	27544.0	27544.0	0.00
Y2	29198.0	31869.06	2671.06
Y3	13.5	13.5	0.00
Y4	6575.0	6575.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	172.0	140.24	4.23
X2	68.3	57.37	0.00
X3	3186.8	2676.74	0.00
X4	15297.6	12849.14	0.00
X5	8080.0	6786.76	0.00

32.HAKKARI	Efficiency Score:	1.00000	Scale Type: CRS
Facet (and Lambda):	6	14	Banker's indicator: 1.000000
	32(1.00000)	64	
Outputs	Observed Value	Target Value	Slack
Y1	18933.0	18933.0	0.00
Y2	21869.0	21869.0	0.00
Y3	6.5	6.5	0.00
Y4	7121.0	7121.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	169.0	169.0	0.00
X2	35.2	35.2	0.00
X3	2508.0	2508.0	0.00
X4	14555.3	14555.3	0.00
X5	10995.0	10995.0	0.00

33. HATAY	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	6	Banker's indicator: 1.000000
33(1.00000)	44	51	
60			
Outputs	Observed Value	Target Value	Slack
Y1	273321.0	273321.0	0.00
Y2	413307.0	413307.0	0.00
Y3	347.5	347.5	0.00
Y4	5403.0	5403.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	710.0	710.0	0.00
X2	329.1	329.1	0.00
X3	5603.2	5603.2	0.00
X4	162417.2	162417.2	0.00
X5	83066.0	83066.0	0.00

34. ISPARTA	Efficiency Score:	0.99016	Scale Type: DRS
Facet (and Lambda):	1(0.141823)	13(0.136715)	Banker's indicator: 1.290135
	37(0.00316)	66(1.008437)	
Outputs	Observed Value	Target Value	Slack
Y1	127852.0	127852.0	0.00
Y2	286725.0	286725.0	0.00
Y3	66.0	84.57	18.57
Y4	8933.0	8933.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	384.0	285.91	94.31
X2	311.0	254.86	53.08
X3	3812.2	3774.69	0.00
X4	73920.4	72913.21	279.81
X5	21938.0	21722.13	0.00

35. ICEL	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
12	35(1.00000)	37	
40	45	70	
Outputs	Observed Value	Target Value	Slack
Y1	356831.0	356831.0	0.00
Y2	414249.0	414249.0	0.00
Y3	260.0	260.0	0.00
Y4	15853.0	15853.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	862.0	862.0	0.00
X2	590.0	590.0	0.00
X3	3307.7	3307.7	0.00
X4	168445.6	168445.6	0.00
X5	90790.0	90790.0	0.00

36. ISTANBUL	Efficiency Score:	0.740206	Scale Type: DRS
Facet (and Lambda):	1(4.321431)	13(1.707278)	Banker's indicator: 8.684327
33(0.979845)	37(0.205655)	69(0.0986)	
70(1.371518)			
Outputs	Observed Value	Target Value	Slack
Y1	1851078.0	1851078.0	0.00
Y2	6041272.0	6041272.0	0.00
Y3	2121.5	2121.5	0.00
Y4	3822.0	107535.23	103713.23
Inputs	Observed Value	Target Value	Slack
X1	3622.0	2681.03	0.00
X2	4597.5	3403.10	0.00
X3	31603.0	23392.73	0.00
X4	1738152.2	735379.23	551211.46
X5	1290111.0	954947.90	0.00

37. IZMIR	Efficiency Score:	1.00000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
33	35	37(1.0000)	
40	44		
Outputs	Observed Value	Target Value	Slack
Y1	947946.0	947946.0	0.00
Y2	4259133.0	4259133.0	0.00
Y3	1329.5	1329.5	0.00
Y4	11973.0	11973.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	2104.0	2104.0	0.00
X2	1952.5	1952.5	0.00
X3	12042.9	12042.9	0.00
X4	1081545.4	1081545.4	0.00
X5	251144.0	251144.0	0.00

38. KARS	Efficiency Score:	0.882552	Scale Type: DRS
Facet (and Lambda):	1(0.103511)	6(1.404135)	Banker's indicator: 1.585033
	17(0.061218)	70(0.016169)	
Outputs	Observed Value	Target Value	Slack
Y1	118518.0	118518.0	0.00
Y2	128223.0	161357.25	33134.25
Y3	31.5	51.2	19.70
Y4	18557.0	18557.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	474.0	360.21	58.12
X2	174.0	153.56	0.00
X3	7805.3	6781.77	106.81
X4	41543.9	36664.65	0.00
X5	45549.0	40199.36	0.00

39. KASTAMONU	Efficiency Score:	0.872207	Scale Type: DRS
Facet (and Lambda):	2(0.007705)	14(0.567617)	Banker's indicator: 1.419256
17(0.511999)	21(0.315508)	44(0.016427)	
Outputs	Observed Value	Target Value	Slack
Y1	131034.0	131034.0	0.00
Y2	184095.0	184095.0	0.00
Y3	50.5	50.5	0.00
Y4	13108.0	13108.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	497.0	367.82	65.67
X2	264.9	228.61	2.44
X3	9410.9	5562.81	2645.44
X4	48979.8	42720.52	0.00
X5	24781.0	21614.16	0.00

40. KAYSERI	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	13	33	Banker's indicator: 1.000000
40(1.0000)	57	58	
69	70		
Outputs	Observed Value	Target Value	Slack
Y1	286628.0	286628.0	0.00
Y2	668206.0	668206.0	0.00
Y3	160.0	160.0	0.00
Y4	16917.0	16917.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	749.0	749.0	0.00
X2	203.8	203.8	0.00
X3	6481.9	6481.9	0.00
X4	188636.6	188636.6	0.00
X5	65313.0	65313.0	0.00

41. KIRKLARELI	Efficiency Score:	0.782191	Scale Type: IRS
Facet (and Lambda):	1(0.144315)	2(0.017945)	Banker's indicator: 0.627462
35(0.007724)	37(0.04848)	66(0.408998)	
Outputs	Observed Value	Target Value	Slack
Y1	96477.0	96477.0	0.00
Y2	386466.0	386466.0	0.00
Y3	105.0	118.24	13.24
Y4	6550.0	6550.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	303.0	223.72	13.28
X2	338.0	259.66	4.72
X3	2769.5	2166.28	0.00
X4	97895.5	76572.98	0.00
X5	36214.0	28326.26	0.00

42. KIRSEHIR	Efficiency Score:	0.780626	Scale Type: IRS
Facet (and Lambda):	6(0.096828)	17(0.119359)	Banker's indicator: 0.46766
40(0.03598)	44(0.032707)	51(0.112278)	
60(0.065156)	70(0.005352)		
Outputs	Observed Value	Target Value	Slack
Y1	67337.0	67337.0	0.00
Y2	101911.0	101911.0	0.00
Y3	37.0	37.0	0.00
Y4	6570.0	6570.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	315.0	201.10	44.80
X2	107.1	83.61	0.00
X3	3272.5	2554.60	0.00
X4	32758.9	25572.45	0.00
X5	19648.0	15337.74	0.00

43. KOCAELI	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
12	37	43(1.0000)	
69	70		
Outputs	Observed Value	Target Value	Slack
Y1	305731.0	305731.0	0.00
Y2	3024289.0	3024289.0	0.00
Y3	767.0	767.0	0.00
Y4	3626.0	3626.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	801.0	801.0	0.00
X2	1527.8	1527.8	0.00
X3	6303.6	6303.6	0.00
X4	808941.2	808941.2	0.00
X5	169717.0	169717.0	0.00

44. KONYA	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	6	Banker's indicator: 1.000000
14	17	44(1.00000)	
51			
Outputs	Observed Value	Target Value	Slack
Y1	494060.0	494060.0	0.00
Y2	677879.0	677879.0	0.00
Y3	439.0	439.0	0.00
Y4	38257.0	38257.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	1968.0	1968.0	0.00
X2	808.2	808.2	0.00
X3	18053.9	18053.9	0.00
X4	180403.4	180403.4	0.00
X5	81622.0	81622.0	0.00

45. KUTAHYA	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	2	40	Banker's indicator: 1.000000
44	45(1.0000)	60	
69	70		
Outputs	Observed Value	Target Value	Slack
Y1	186073.0	186073.0	0.00
Y2	323943.0	323943.0	0.00
Y3	94.0	94.0	0.00
Y4	11875.0	11875.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	410.0	410.0	0.00
X2	220.4	220.4	0.00
X3	5988.1	5988.1	0.00
X4	89401.1	89401.1	0.00
X5	29043.0	29043.0	0.00

46. MALATYA	Efficiency Score:	0.744373	Scale Type: DRS
Facet (and Lambda):	14(0.171111)	17(0.609904)	Banker's indicator: 1.123557
44(0.018453)	45(0.107927)	60(0.162642)	
70(0.05352)			
Outputs	Observed Value	Target Value	Slack
Y1	172427.0	172427.0	0.00
Y2	281920.0	281920.0	0.00
Y3	82.5	82.5	0.00
Y4	12313.0	12313.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	570.0	375.18	49.11
X2	283.7	211.18	0.00
X3	13209.3	5446.17	4386.48
X4	63953.0	47604.89	0.00
X5	58781.0	43754.99	0.00

47. MANISA	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	2	12	Banker's indicator: 1.000000
45	47(1.0000)	66	
69	70		
Outputs	Observed Value	Target Value	Slack
Y1	357344.0	357344.0	0.00
Y2	664044.0	664044.0	0.00
Y3	172.0	172.0	0.00
Y4	13810.0	13810.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	640.0	640.0	0.00
X2	557.9	557.9	0.00
X3	10257.1	10257.1	0.00
X4	171520.4	171520.4	0.00
X5	52195.0	52195.0	0.00

48. K.MARAS	Efficiency Score:	0.932404	Scale Type: DRS
Facet (and Lambda):	1(0.259525)	35(0.064342)	Banker's indicator: 1.140647
40(0.19423)	51(0.555138)	70(0.067412)	
Outputs	Observed Value	Target Value	Slack
Y1	169986.0	169986.0	0.00
Y2	384640.0	384640.0	0.00
Y3	114.0	127.3	13.30
Y4	14327.0	14327.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	546.0	363.79	145.30
X2	262.7	244.94	0.00
X3	3259.0	3038.70	0.00
X4	99392.8	63951.44	28722.80
X5	75145.0	70065.50	0.00

49. MARDIN	Efficiency Score:	0.700676	Scale Type: DRS
Facet (and Lambda):	1(0.08525)	13(0.00753)	Banker's indicator: 1.018872
33(0.130111)	51(0.77637)	70(0.019611)	
Outputs	Observed Value	Target Value	Slack
Y1	90240.0	94845.57	4605.57
Y2	152894.0	152894.0	0.00
Y3	80.5	80.5	0.00
Y4	8891.0	8891.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	361.0	252.94	0.00
X2	177.7	124.51	0.00
X3	6753.0	2284.95	2446.72
X4	53737.6	37652.64	0.00
X5	150673.0	105572.95	66863.52

50. MUGLA	Efficiency Score:	0.870265	Scale Type: IRS
Facet (and Lambda):	1(0.175257)	12(0.332179)	Banker's indicator: 0.917591
	21(0.384865)	70(0.02529)	
Outputs	Observed Value	Target Value	Slack
Y1	213921.0	213921.0	0.00
Y2	426026.0	426026.0	0.00
Y3	100.5	131.6	31.10
Y4	13338.0	13338.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	419.0	364.64	0.00
X2	573.7	409.46	89.81
X3	19916.4	5637.08	11695.47
X4	123863.3	86987.81	20806.08
X5	54278.0	47236.24	0.00

51. MUS	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	21	Banker's indicator: 1.000000
35	40	51(1.0000)	
60			

Outputs	Observed Value	Target Value	Slack
Y1	52523.0	52523.0	0.00
Y2	45012.0	45012.0	0.00
Y3	16.5	16.5	0.00
Y4	8196.0	8196.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	181.0	181.0	0.00
X2	47.2	47.2	0.00
X3	1745.6	1745.6	0.00
X4	17531.4	17531.4	0.00
X5	20145.0	20145.0	0.00

52. NEVSEHIR	Efficiency Score:	0.702174	Scale Type: IRS
Facet (and Lambda):	2(0.004863)	21(0.393428)	Banker's indicator: 0.523026
	66(0.112544)	70(0.012191)	

Outputs	Observed Value	Target Value	Slack
Y1	88878.0	88878.0	0.00
Y2	166311.0	166311.0	0.00
Y3	31.5	39.84	8.34
Y4	5467.0	5855.14	388.14
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	312.0	168.22	50.86
X2	268.2	167.60	20.72
X3	3675.3	2580.70	0.00
X4	40278.3	28282.38	0.00
X5	25366.0	17811.35	0.00

53. NIGDE	Efficiency Score:	0.88514	Scale Type: IRS
Facet (and Lambda):	1(0.052933)	2(0.004078)	Banker's indicator: 0.424238
37(0.006549)	40(0.002926)	44(0.08411)	
60(0.054338)	66(0.219304)		
Outputs	**Observed Value**	**Target Value**	**Slack**
Y1	84563.0	84563.0	0.00
Y2	171685.0	171685.0	0.00
Y3	72.5	72.5	0.00
Y4	7312.0	7312.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	354.0	272.16	41.18
X2	186.2	164.81	0.00
X3	3369.9	2982.83	0.00
X4	44495.5	39384.75	0.00
X5	18173.0	16085.65	0.00

54. ORDU	Efficiency Score:	0.88101	Scale Type: DRS
Facet (and Lambda):	17(1.442327)	57(0.14759)	Banker's indicator: 1.606306
	70(0.016389)		
Outputs	**Observed Value**	**Target Value**	**Slack**
Y1	196971.0	196971.0	0.00
Y2	234553.0	251017.72	16464.72
Y3	58.5	70.89	12.39
Y4	6001.0	11378.04	5377.04
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	533.0	453.68	15.90
X2	251.2	221.31	0.00
X3	13732.6	6632.25	5466.31
X4	62432.9	55004.01	0.00
X5	52578.0	46321.74	0.00

55. RIZE	Efficiency Score:	0.879818	Scale Type: IRS
Facet (and Lambda):	40(0.094882)	45(0.203936)	Banker's indicator: 0.369379
	57(0.038918)	70(0.031643)	
Outputs	Observed Value	Target Value	Slack
Y1	107677.0	107677.0	0.00
Y2	177445.0	221872.04	44427.04
Y3	52.5	57.99	5.49
Y4	3920.0	4459.46	539.46
Inputs	Observed Value	Target Value	Slack
X1	244.0	214.68	0.00
X2	109.3	96.16	0.00
X3	4726.0	2487.99	1670.03
X4	50142.8	44116.54	0.00
X5	34411.0	30275.42	0.00

56. SAKARYA	Efficiency Score:	0.724815	Scale Type: DRS
Facet (and Lambda):	2(0.007992)	44(0.001473)	Banker's indicator: 1.277482
45(0.083584)	66(1.115559)	69(0.020235)	
70(0.048639)			
Outputs	Observed Value	Target Value	Slack
Y1	197394.0	197394.0	0.00
Y2	398708.0	398708.0	0.00
Y3	101.0	101.0	0.00
Y4	4817.0	7581.42	2764.42
Inputs	Observed Value	Target Value	Slack
X1	630.0	358.22	98.41
X2	393.3	285.07	0.00
X3	6350.6	4603.01	0.00
X4	103091.4	74722.19	0.00
X5	57916.0	41978.39	0.00

57. SAMSUN	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	6	33	Banker's indicator: 1.000000
40	44	45	
57(1.0000)	70		

Outputs	Observed Value	Target Value	Slack
Y1	345104.0	345104.0	0.00
Y2	533830.0	533830.0	0.00
Y3	166.0	166.0	0.00
Y4	9579.0	9579.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	996.0	996.0	0.00
X2	227.4	227.4	0.00
X3	13292.7	13292.7	0.00
X4	147306.3	147306.3	0.00
X5	102797.0	102797.0	0.00

58. SIIRT	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	13	32	Banker's indicator: 1.000000
	58(1.00000)		

Outputs	Observed Value	Target Value	Slack
Y1	35080.0	35080.0	0.00
Y2	249029.0	249029.0	0.00
Y3	65.5	65.5	0.00
Y4	5406.0	5406.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	225.0	225.0	0.00
X2	46.1	46.1	0.00
X3	3708.0	3708.0	0.00
X4	91740.2	91740.2	0.00
X5	160289.0	160289.0	0.00

59. SINOP	Efficiency Score:	0.827966	Scale Type: IRS
Facet (and Lambda):	17(0.800452)	40(0.01664)	Banker's indicator: 0.82454
45(0.003659)	57(0.002233)	70(0.001556)	
Outputs	Observed Value	Target Value	Slack
Y1	80333.0	80333.0	0.00
Y2	81336.0	92011.12	10675.12
Y3	21.0	25.03	4.03
Y4	5862.0	5862.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	219.0	181.32	0.00
X2	124.9	103.41	0.00
X3	4791.9	2719.35	1248.18
X4	26230.8	21718.21	0.00
X5	18524.0	15337.24	0.00

60. SIVAS	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
37	40	44	
45	60(1.0000)	69	
Outputs	Observed Value	Target Value	Slack
Y1	191061.0	191061.0	0.00
Y2	315092.0	315092.0	0.00
Y3	109.5	109.5	0.00
Y4	28488.0	28488.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	593.0	593.0	0.00
X2	297.2	297.2	0.00
X3	10598.1	10598.1	0.00
X4	85604.1	85604.1	0.00
X5	27136.0	27136.0	0.00

61. TEKIRDAG	Efficiency Score:	0.793908	Scale Type: IRS
Facet (and Lambda):	2(0.04389)	12(0.139342)	Banker's indicator: 0.669274
13(0.278873)	43(0.013305)	69(0.136612)	
70(0.057252)			
Outputs	Observed Value	Target Value	Slack
Y1	169179.0	169179.0	0.00
Y2	698651.0	698651.0	0.00
Y3	176.0	176.0	0.00
Y4	6218.0	6218.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	355.0	281.84	0.00
X2	363.7	288.74	0.00
X3	5004.3	3735.98	236.97
X4	188711.6	109849.98	39969.67
X5	78282.0	62148.71	0.00

62. TOKAT	Efficiency Score:	0.999238	Scale Type: DRS
Facet (and Lambda):	14(0.183067)	17(1.379504)	Banker's indicator: 1.631652
44(0.066384)	45(0.000186)	57(0.002511)	
Outputs	Observed Value	Target Value	Slack
Y1	166905.0	166905.0	0.00
Y2	180572.0	180572.0	0.00
Y3	67.0	67.0	0.00
Y4	9958.0	13553.97	3595.97
Inputs	Observed Value	Target Value	Slack
X1	483.0	455.75	26.88
X2	234.1	233.92	0.00
X3	8767.5	6242.74	2518.08
X4	46639.0	46603.46	0.00
X5	29158.0	29135.78	0.00

63. TRABZON	Efficiency Score:	0.920355	Scale Type: DRS
Facet (and Lambda):	11(0.010588)	17(1.768125)	Banker's indicator: 2.018832
	40(0.222973)	66(0.017146)	
Outputs	Observed Value	Target Value	Slack
Y1	229690.0	229690.0	0.00
Y2	292248.0	322849.26	30601.26
Y3	71.0	83.71	12.71
Y4	4685.0	16125.46	11440.46
Inputs	Observed Value	Target Value	Slack
X1	827.0	540.73	220.40
X2	291.5	268.28	0.00
X3	7819.2	7196.44	0.00
X4	90842.4	83607.26	0.00
X5	48585.0	44715.45	0.00

64. TUNCELI	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	14	32	Banker's indicator: 1.000000
	64(1.0000)		
Outputs	Observed Value	Target Value	Slack
Y1	29196.0	29196.0	0.00
Y2	24444.0	24444.0	0.00
Y3	7.0	7.0	0.00
Y4	7774.0	7774.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	203.0	203.0	0.00
X2	46.7	46.7	0.00
X3	11259.6	11259.6	0.00
X4	17911.5	17911.5	0.00
X5	4482.0	4482.0	0.00

65. S.URFA	Efficiency Score:	0.525066	Scale Type: DRS
Facet (and Lambda):	1(0.867495)	12(0.026539)	Banker's indicator: 1.075042
	70(0.181008)		
Outputs	Observed Value	Target Value	Slack
Y1	177311.0	177311.0	0.00
Y2	543911.0	597984.76	54073.76
Y3	95.0	216.76	121.76
Y4	18584.0	18584.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	372.0	195.32	0.00
X2	1570.1	455.91	368.50
X3	17850.8	2067.15	7305.70
X4	119029.8	24406.06	38092.44
X5	222116.0	116625.56	0.00

66. USAK	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	2	12	Banker's indicator: 1.000000
21	44	66(1.0000)	
70			
Outputs	Observed Value	Target Value	Slack
Y1	116405.0	116405.0	0.00
Y2	186747.0	186747.0	0.00
Y3	48.0	48.0	0.00
Y4	5341.0	5341.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	245.0	245.0	0.00
X2	187.5	187.5	0.00
X3	3265.5	3265.5	0.00
X4	52100.5	52100.5	0.00
X5	12723.0	12723.0	0.00

67. VAN	Efficiency Score:	0.794232	Scale Type: DRS
Facet (and Lambda):	1(0.032469)	2(0.001142)	Banker's indicator: 1.748073
	6(1.444834)	32(0.269628)	
Outputs	**Observed Value**	**Target Value**	**Slack**
Y1	91882.0	105983.09	14101.09
Y2	118525.0	118525.0	0.00
Y3	32.5	34.99	2.49
Y4	19069.0	19069.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	488.0	387.59	0.00
X2	155.5	123.50	0.00
X3	12105.3	7297.17	2317.25
X4	48524.9	38540.03	0.00
X5	68569.0	33227.51	21232.18

68. YOZGAT	Efficiency Score:	0.905857	Scale Type: DRS
Facet (and Lambda):	6(0.103738)	14(0.144569)	Banker's indicator: 1.081641
17(0.461153)	45(0.101853)	60(0.25836)	
70(0.011968)			
Outputs	**Observed Value**	**Target Value**	**Slack**
Y1	134712.0	134712.0	0.00
Y2	195893.0	195893.0	0.00
Y3	53.0	59.6	6.60
Y4	14123.0	14123.0	0.00
Inputs	**Observed Value**	**Target Value**	**Slack**
X1	390.0	353.28	0.00
X2	199.2	180.45	0.00
X3	10952.9	5823.49	4098.27
X4	52547.6	47600.61	0.00
X5	28183.0	25529.77	0.00

69. ZONGULDAK	Efficiency Score:	1.0000000	Scale Type: CRS
Facet (and Lambda):	1	2	Banker's indicator: 1.000000
33	37	40	
44	69(1.00000)	70	
Outputs	Observed Value	Target Value	Slack
Y1	321279.0	321279.0	0.00
Y2	989115.0	989115.0	0.00
Y3	325.0	325.0	0.00
Y4	8629.0	8629.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	629.0	629.0	0.00
X2	316.5	316.5	0.00
X3	10128.9	10128.9	0.00
X4	256930.8	256930.8	0.00
X5	71285.0	71285.0	0.00

70. AKTAS	Efficiency Score:	1.000000	Scale Type: CRS
Facet (and Lambda):	2	17	Banker's indicator: 1.000000
21	60	66	
70(1.0000)			
Outputs	Observed Value	Target Value	Slack
Y1	919744.0	919744.0	0.00
Y2	2263764.0	2263764.0	0.00
Y3	543.0	543.0	0.00
Y4	1890.0	1890.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	671.0	671.0	0.00
X2	727.8	727.8	0.00
X3	4248.8	4248.8	0.00
X4	71208.9	71208.9	0.00
X5	447330.0	447330.0	0.00

Appendix 1b Detailed organisation level efficiency under VRS Frontier

1.KEPEZ	Efficiency Score:	1.000000		
Facet (and Lambda):	1(1.000000)	2	14	
Outputs	Observed Value	Target Value		Slack
Y1	753.0	753.0		0.00
Y2	195000.0	195000.0		0.00
Y3	130.0	130.0		0.00
Y4	20591.0	20591.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	66.0	66.0		0.00
X2	355.0	355.0		0.00
X3	1200.0	1200.0		0.00
X4	7481.6	7481.6		0.00
X5	39300.0	39300.0		0.00

2. CUKUROVA	Efficiency Score:	1.000000		
Facet (and Lambda):	2(1.000000)	13	37	43
Outputs	Observed Value	Target Value		Slack
Y1	2562.0	2562.0		0.00
Y2	4026800.0	4026800.0		0.00
Y3	746.0	746.0		0.00
Y4	38509.0	38509.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	297.0	297.0		0.00
X2	1812.5	1812.5		0.00
X3	2681.7	2681.7		0.00
X4	25045.0	25045.0		0.00
X5	254900.0	254900.0		0.00

3. ADANA	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	
3(1.000000)	12	37	
60	69	70	
Outputs	Observed Value	Target Value	Slack
Y1	484473.0	484473.0	0.00
Y2	687281.0	687281.0	0.00
Y3	534.0	534.0	0.00
Y4	17253.0	17253.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	1240.0	1240.0	0.00
X2	817.0	817.0	0.00
X3	13059.7	13059.7	0.00
X4	255645.4	255645.4	0.00
X5	116277.0	116277.0	0.00

4. ADIYAMAN	Efficiency Score:	0.895632	
Facet (and Lambda):	2(0.016245)	13(0.121322)	
14(0.423458)	17(0.097842)	45(0.086336)	
66(0.244758)	70(0.010039)		
Outputs	Observed Value	Target Value	Slack
Y1	87633.0	87633.0	0.00
Y2	233225.0	233225.0	0.00
Y3	48.5	55.58	7.08
Y4	7614.0	7614.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	267.0	226.26	12.87
X2	165.7	148.41	0.00
X3	6288.1	3366.81	2265.01
X4	51438.1	46069.61	0.00
X5	21958.0	19666.29	0.00

5. AFYON	Efficiency Score:	0.889514	
Facet (and Lambda):	2(0.000514)	21(0.574727)	
40(0.111062)	44(0.012015)	51(0.099882)	
60(0.114552)	66(0.074427)	70(0.012821)	
Outputs	Observed Value	Target Value	Slack
Y1	179660.0	179660.0	0.00
Y2	311270.0	311270.0	0.00
Y3	83.5	83.5	0.00
Y4	14230.0	14230.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	481.0	411.22	16.64
X2	318.7	283.49	0.00
X3	6478.2	5762.45	0.00
X4	79574.3	70782.45	0.00
X5	38582.0	34319.23	0.00

6. AGRI	Efficiency Score:	1.000000	
Facet (and Lambda):	2	6(1.00000)	
13	14	40	
60	70		
Outputs	Observed Value	Target Value	Slack
Y1	69801.0	69801.0	0.00
Y2	70388.0	70388.0	0.00
Y3	19.5	19.5	0.00
Y4	11376.0	11376.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	235.0	235.0	0.00
X2	69.5	69.5	0.00
X3	4553.4	4553.4	0.00
X4	23770.2	23770.2	0.00
X5	19861.0	19861.0	0.00

7. AMASYA	Efficiency Score:	0.727428	
Facet (and Lambda):	2(0.003406)	14(0.040053)	
17(0.743226)	32(0.086205)	51(0.107455)	
70(0.019655)			
Outputs	Observed Value	Target Value	Slack
Y1	94586.0	94586.0	0.00
Y2	135640.0	135640.0	0.00
Y3	28.5	35.21	6.71
Y4	5520.0	7106.89	1586.89
Inputs	Observed Value	Target Value	Slack
X1	345.0	209.27	41.69
X2	167.3	121.70	0.00
X3	4124.8	3000.50	0.00
X4	30157.8	21937.63	0.00
X5	34634.0	25193.74	0.00

8. ANKARA	Efficiency Score:	1.000000		
Facet (and Lambda):	2	8(1.0000)		
36	37	44	70	
Outputs	Observed Value	Target Value		Slack
Y1	973195.0	973195.0		0.00
Y2	2693228.0	2693228.0		0.00
Y3	655.5	655.5		0.00
Y4	25706.0	25706.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	2997.0	2997.0		0.00
X2	2049.1	2049.1		0.00
X3	21526.2	21526.2		0.00
X4	729619.9	729619.9		0.00
X5	336516.0	336516.0		0.00

9. ANTALYA	Efficiency Score:	1.000000		
Facet (and Lambda):	9(1.0000)	12		
37	44	60	70	
Outputs	Observed Value	Target Value		Slack
Y1	373415.0	373415.0		0.00
Y2	551842.0	551842.0		0.00
Y3	207.0	207.0		0.00
Y4	20591.0	20591.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	781.0	781.0		0.00
X2	543.3	543.3		0.00
X3	16230.8	16230.8		0.00
X4	161140.6	161140.6		0.00
X5	68034.0	68034.0		0.00

10. ARTVIN	Efficiency Score:	0.967561	
Facet (and Lambda):	1(0.057257)	2(0.005601)	
13(0.211266)	14(0.233528)	17(0.259809)	
31(0.164252)	66(0.068287)		
Outputs	Observed Value	Target Value	Slack
Y1	57636.0	57636.0	0.00
Y2	170421.0	170421.0	0.00
Y3	28.0	46.77	18.77
Y4	7436.0	7436.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	196.0	189.64	0.00
X2	119.0	115.14	0.00
X3	4258.1	2858.76	1261.21
X4	42892.7	41501.30	0.00
X5	15424.0	14923.66	0.00

11. AYDIN	Efficiency Score:	1.000000	
Facet (and Lambda):	11(1.000)	12	
35	37	40	
66	70		
Outputs	Observed Value	Target Value	Slack
Y1	305822.0	305822.0	0.00
Y2	472537.0	472537.0	0.00
Y3	117.5	117.5	0.00
Y4	8007.0	8007.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	666.0	666.0	0.00
X2	3860.5	3860.5	0.00
X3	5212.9	5212.9	0.00
X4	123454.2	123454.2	0.00
X5	69460.0	69460.0	0.00

12. BALIKESIR	Efficiency Score:	1.000000		
Facet (and Lambda):	1	2		
12(1.000000)	37	44		
45	60	69	70	
Outputs	Observed Value	Target Value		Slack
Y1	383470.0	383470.0		0.00
Y2	718346.0	718346.0		0.00
Y3	215.0	215.0		0.00
Y4	14292.0	14292.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	626.0	626.0		0.00
X2	610.6	610.6		0.00
X3	9686.7	9686.7		0.00
X4	189395.4	189395.4		0.00
X5	58883.0	58883.0		0.00

13. BILECIK	Efficiency Score:	1.000000		
Facet (and Lambda):	1	2	6	
	13(1.000000)	51	70	
Outputs	Observed Value	Target Value		Slack
Y1	53851.0	53851.0		0.00
Y2	419021.0	419021.0		0.00
Y3	99.0	99.0		0.00
Y4	4307.0	4307.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	167.0	167.0		0.00
X2	67.7	67.7		0.00
X3	1999.7	1999.7		0.00
X4	116256.0	116256.0		0.00
X5	18465.0	18465.0		0.00

14. BINGOL	Efficiency Score:	1.000000		
Facet (and Lambda):	2	13	14(1.000000)	
Outputs	Observed Value	Target Value		Slack
Y1	43412.0	43412.0		0.00
Y2	26920.0	26920.0		0.00
Y3	8.5	8.5		0.00
Y4	8125.0	8125.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	217.0	217.0		0.00
X2	62.8	62.8		0.00
X3	3328.9	3328.9		0.00
X4	19354.3	19354.3		0.00
X5	3675.0	3675.0		0.00

15. BITLIS	Efficiency Score:	0.816585	
Facet (and Lambda):	1(0.02402)	13(0.017742)	31(0.123888)
	32(0.177089)	51(0.657261)	
Outputs	Observed Value	Target Value	Slack
Y1	42260.0	42260.0	0.00
Y2	34681.0	49192.8	14511.8
Y3	10.5	18.54	8.04
Y4	6707.0	8033.53	1326.53
Inputs	Observed Value	Target Value	Slack
X1	214.0	174.75	0.00
X2	67.9	55.45	0.00
X3	4246.1	2050.57	1416.73
X4	22334.2	18237.77	0.00
X5	21382.0	17460.22	0.00

16. BOLU	Efficiency Score:	0.824664	
Facet (and Lambda):	6(0.237049)	13(0.228418)	14(0.053182)
	40(0.123888)	45(0.257519)	60(0.059993)
	70(0.039951)		
Outputs	Observed Value	Target Value	Slack
Y1	162790.0	162790.0	0.00
Y2	389377.0	389377.0	0.00
Y3	89.5	99.97	10.47
Y4	11051.0	11051.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	444.0	366.15	0.00
X2	199.1	164.19	0.00
X3	7116.2	4863.82	1004.65
X4	106215.1	87591.77	0.00
X5	53587.0	44191.27	0.00

17. BURDUR	Efficiency Score:	1.000000	
Facet (and Lambda):	12	13	17(1.00000)
	45	51	66
	70		
Outputs	Observed Value	Target Value	Slack
Y1	90800.0	90800.0	0.00
Y2	93688.0	93688.0	0.00
Y3	26.0	26.0	0.00
Y4	6887.0	6887.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	205.0	205.0	0.00
X2	121.9	121.9	0.00
X3	3189.8	3189.8	0.00
X4	22252.9	22252.9	0.00
X5	16514.0	16514.0	0.00

18. BURSA	Efficiency Score:	0.935904	
Facet (and Lambda):	1(0.12713)	2(0.006925)	12(0.049494)
	13(0.250454)	37(0.525914)	70(0.040083)
Outputs	Observed Value	Target Value	Slack
Y1	567985.0	567985.0	0.00
Y2	2523853.0	2523853.0	0.00
Y3	595.5	778.09	182.59
Y4	11043.0	11043.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	1300.0	1216.68	0.00
X2	1461.1	1160.88	206.57
X3	8179.5	7655.23	0.00
X4	684926.5	611269.31	29756.14
X5	175564.0	164311.05	0.00

19.CANAKKALE	Efficiency Score:	0.933265	
Facet (and Lambda):	1(0.142362)	2(0.003093)	12(0.288322)
	13(0.451526)	37(0.002708)	66(0.109247)
	70(0.002742)		
Outputs	Observed Value	Target Value	Slack
Y1	152799.0	152799.0	0.00
Y2	474671.0	474671.0	0.00
Y3	101.0	137.83	36.83
Y4	9737.0	9737.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	322.0	300.51	0.00
X2	345.9	290.54	32.28
X3	4581.7	4275.94	0.00
X4	125427.9	117057.50	0.00
X5	37497.0	34994.64	0.00

20.CANKIRI	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	14
	17	20(1.000)	21
	51	66	
Outputs	Observed Value	Target Value	Slack
Y1	65325.0	65325.0	0.00
Y2	65015.0	65015.0	0.00
Y3	18.0	18.0	0.00
Y4	8454.0	8454.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	248.0	248.0	0.00
X2	114.9	114.9	0.00
X3	3158.1	3158.1	0.00
X4	22129.7	22129.7	0.00
X5	11330.0	11330.0	0.00

21.CORUM	Efficiency Score:	1.00000	
Facet (and Lambda):	2	17	21(1.000)
	44	60	62
	66	70	
Outputs	Observed Value	Target Value	Slack
Y1	164077.0	164077.0	0.00
Y2	249385.0	249385.0	0.00
Y3	61.5	61.5	0.00
Y4	12820.0	12820.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	333.0	333.0	0.00
X2	327.4	327.4	0.00
X3	5460.6	5460.6	0.00
X4	54467.2	54467.2	0.00
X5	24621.0	24621.0	0.00

22.DENIZLI	Efficiency Score:	0.896211	
Facet (and Lambda):	2(0.002528)	12(0.177645)	21(0.473199)
	44(0.002544)	47(0.330554)	70(0.01353)
Outputs	Observed Value	Target Value	Slack
Y1	277592.0	277592.0	0.00
Y2	507654.0	507654.0	0.00
Y3	134.5	134.5	0.00
Y4	11868.0	13390.48	1522.48
Inputs	Observed Value	Target Value	Slack
X1	573.0	495.18	18.35
X2	576.4	464.30	52.28
X3	8709.4	7805.46	0.00
X4	131220.7	117601.43	0.00
X5	51627.0	46268.69	0.00

23.DIYARBAKIR	Efficiency Score:	0.850928	
Facet (and Lambda):	6(0.526402)	27(0.245205)	40(0.17453)
	57(0.02159)	70(0.032273)	
Outputs	Observed Value	Target Value	Slack
Y1	171132.0	171132.0	0.00
Y2	293056.0	293056.0	0.00
Y3	68.5	74.37	5.87
Y4	15355.0	15355.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	723.0	493.51	121.71
X2	184.3	156.82	0.00
X3	9814.3	7278.04	1073.22
X4	81837.1	69637.48	0.00
X5	194828.0	52295.32	113489.28

24.EDIRNE	Efficiency Score:	0.913339	
Facet (and Lambda):	1(0.093655)	12(0.008535)	13(0.388364)
	66(0.460746)	70(0.0487)	
Outputs	Observed Value	Target Value	Slack
Y1	122682.0	122682.0	0.00
Y2	383415.0	383415.0	0.00
Y3	98.5	101.01	2.51
Y4	6276.0	6276.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	243.0	221.94	0.00
X2	309.7	186.59	96.27
X3	4600.0	2683.16	1518.2
X4	101304.8	74939.79	17585.83
X5	42702.0	39001.40	0.00

25.ELAZIG	Efficiency Score:	1.000000		
Facet (and Lambda):	2	25(1.000)	47	
	60	66	69	
Outputs	Observed Value	Target Value		Slack
Y1	132458.0	132458.0		0.00
Y2	580822.0	580822.0		0.00
Y3	104.0	104.0		0.00
Y4	9153.0	9153.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	752.0	752.0		0.00
X2	229.0	229.0		0.00
X3	6398.9	6398.9		0.00
X4	122043.3	122043.3		0.00
X5	35135.0	35135.0		0.00

26. ERZINCAN	Efficiency Score:	1.000000		
Facet (and Lambda):	1	2	14	
	17	26(1.000)	60	
Outputs	Observed Value	Target Value		Slack
Y1	79131.0	79131.0		0.00
Y2	99066.0	99066.0		0.00
Y3	26.5	26.5		0.00
Y4	11903.0	11903.0		0.00
Inputs	Observed Value	Target Value		Slack
X1	371.0	371.0		0.00
X2	146.1	146.1		0.00
X3	4365.0	4365.0		0.00
X4	29923.3	29923.3		0.00
X5	13684.0	13684.0		0.00

27.ERZURUM	Efficiency Score:	1.000000	
Facet (and Lambda):	6	27(1.000)	40
	57	60	70
Outputs	Observed Value	Target Value	Slack
Y1	192616.0	192616.0	0.00
Y2	223485.0	223485.0	0.00
Y3	61.5	61.5	0.00
Y4	25066.0	25066.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	799.0	799.0	0.00
X2	229.5	229.5	0.00
X3	13563.0	13563.0	0.00
X4	76358.9	76358.9	0.00
X5	56221.0	56221.0	0.00

28.ESKISEHIR	Efficiency Score:	0.696221	
Facet (and Lambda):	1(0.08532)	12(0.250705)	17(0.368426)
	21(0.063401)	60(0.170058)	70(0.06209)
Outputs	Observed Value	Target Value	Slack
Y1	229657.0	229657.0	0.00
Y2	441202.0	441202.0	0.00
Y3	126.0	130.8	4.8
Y4	13652.0	13652.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	577.0	401.72	0.00
X2	495.2	344.77	0.00
X3	10068.0	6118.40	891.15
X4	135611.2	78751.56	15663.81
X5	83523.0	58150.47	0.00

29.G.ANTEP	Efficiency Score:	0.902371	
Facet (and Lambda):	2(0.033878)	12(0.099648)	37(0.046938)
	40(0.316368)	66(0.430693)	69(0.06765)
	70(0.004825)		
Outputs	Observed Value	Target Value	Slack
Y1	249781.0	249781.0	0.00
Y2	777583.0	777583.0	0.00
Y3	205.0	205.0	0.00
Y4	7642.0	11535.94	3893.94
Inputs	Observed Value	Target Value	Slack
X1	706.0	559.47	77.6
X2	425.6	384.05	0.00
X3	6410.0	5784.20	0.00
X4	188758.5	170330.20	0.00
X5	65843.0	59414.81	0.00

30.GIRESUN	Efficiency Score:	0.971031	
Facet (and Lambda):	14(0.056898)	17(0.423031)	33(0.027055)
	44(0.032431)	45(0.342833)	66(0.117752)
Outputs	Observed Value	Target Value	Slack
Y1	141798.0	141798.0	0.00
Y2	202409.0	207379.55	4970.55
Y3	73.0	73.0	0.00
Y4	6934.0	9462.66	2528.66
Inputs	Observed Value	Target Value	Slack
X1	362.0	351.51	0.00
X2	193.5	187.89	0.00
X3	8760.8	4713.34	3793.67
X4	59261.2	57544.50	0.00
X5	24247.0	23544.59	0.00

31.GUMUSHANE	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	13
	17	31(1.000)	33
	51	64	70
Outputs	Observed Value	Target Value	Slack
Y1	27544.0	27544.0	0.00
Y2	29198.0	29198.0	0.00
Y3	13.5	13.5	0.00
Y4	6575.0	6575.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	172.0	172.0	0.00
X2	68.3	68.3	0.00
X3	3186.8	3186.8	0.00
X4	15297.6	15297.6	0.00
X5	8080.0	8080.0	0.00

32.HAKKARI	Efficiency Score:	1.00000	
Facet (and Lambda):	14	32(1.000)	
	51	64	
Outputs	Observed Value	Target Value	Slack
Y1	18933.0	18933.0	0.00
Y2	21869.0	21869.0	0.00
Y3	6.5	6.5	0.00
Y4	7121.0	7121.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	169.0	169.0	0.00
X2	35.2	35.2	0.00
X3	2508.0	2508.0	0.00
X4	14555.3	14555.3	0.00
X5	10995.0	10995.0	0.00

33. HATAY	Efficiency Score:	1.000000	
Facet (and Lambda):	2	13	33(1.00000)
	37	69	70
Outputs	Observed Value	Target Value	Slack
Y1	273321.0	273321.0	0.00
Y2	413307.0	413307.0	0.00
Y3	347.5	347.5	0.00
Y4	5403.0	5403.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	710.0	710.0	0.00
X2	329.1	329.1	0.00
X3	5603.2	5603.2	0.00
X4	162417.2	162417.2	0.00
X5	83066.0	83066.0	0.00

34. ISPARTA	Efficiency Score:	0.998597	
Facet (and Lambda):	1(0.107394)	13(0.00143)	37(0.021785)
	60(0.078249)	66(0.791142)	
Outputs	Observed Value	Target Value	Slack
Y1	127852.0	127852.0	0.00
Y2	286725.0	286725.0	0.00
Y3	66.0	89.6	23.6
Y4	8933.0	8933.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	384.0	293.40	90.06
X2	311.0	252.35	58.21
X3	3812.2	3806.85	0.00
X4	73920.4	72448.42	1368.27
X5	21938.0	21907.22	0.00

35. ICEL	Efficiency Score:	1.000000	
Facet (and Lambda):	2	21	35(1.000)
	40	44	51
	60	66	70
Outputs	Observed Value	Target Value	Slack
Y1	356831.0	356831.0	0.00
Y2	414249.0	414249.0	0.00
Y3	260.0	260.0	0.00
Y4	15853.0	15853.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	862.0	862.0	0.00
X2	590.0	590.0	0.00
X3	3307.7	3307.7	0.00
X4	168445.6	168445.6	0.00
X5	90790.0	90790.0	0.00

36. ISTANBUL	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	36(1.000)
	37	43	70
Outputs	Observed Value	Target Value	Slack
Y1	1851078.0	1851078.0	0.00
Y2	6041272.0	6041272.0	0.00
Y3	2121.5	2121.5	0.00
Y4	3822.0	3822.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	3622.0	3622.0	0.00
X2	4597.5	4597.5	0.00
X3	31603.0	31603.0	0.00
X4	1738152.2	1738152.2	0.00
X5	1290111.0	1290111.0	0.00

37. IZMIR	Efficiency Score:	1.00000	
Facet (and Lambda):	1	2	12
	33	35	37(1.000)
	44	45	70
Outputs	Observed Value	Target Value	Slack
Y1	947946.0	947946.0	0.00
Y2	4259133.0	4259133.0	0.00
Y3	1329.5	1329.5	0.00
Y4	11973.0	11973.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	2104.0	2104.0	0.00
X2	1952.5	1952.5	0.00
X3	12042.9	12042.9	0.00
X4	1081545.4	1081545.4	0.00
X5	251144.0	251144.0	0.00

38. KARS	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	6
	38(1.000)	60	67
	70		
Outputs	Observed Value	Target Value	Slack
Y1	118518.0	118518.0	0.00
Y2	128223.0	128223.0	0.00
Y3	31.5	31.5	0.00
Y4	18557.0	18557.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	474.0	474.0	0.00
X2	174.0	174.0	0.00
X3	7805.3	7805.3	0.00
X4	41543.9	41543.9	0.00
X5	45549.0	45549.0	0.00

39. KASTAMONU	Efficiency Score:	0.888302	
Facet (and Lambda):	2(0.000406)	17(0.568846)	21(0.192333)
	60(0.235296)	70(0.003119)	
Outputs	Observed Value	Target Value	Slack
Y1	131034.0	131034.0	0.00
Y2	184095.0	184095.0	0.00
Y3	50.5	54.37	3.87
Y4	13108.0	13108.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	497.0	322.41	119.08
X2	264.9	205.25	30.06
X3	9410.9	5372.79	2986.93
X4	48979.8	43508.85	0.00
X5	24781.0	22013.01	0.00

40. KAYSERI	Efficiency Score:	1.000000	
Facet (and Lambda):	2	21	35
	40(1.0000)	44	60
	70		
Outputs	Observed Value	Target Value	Slack
Y1	286628.0	286628.0	0.00
Y2	668206.0	668206.0	0.00
Y3	160.0	160.0	0.00
Y4	16917.0	16917.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	749.0	749.0	0.00
X2	203.8	203.8	0.00
X3	6481.9	6481.9	0.00
X4	188636.6	188636.6	0.00
X5	65313.0	65313.0	0.00

41. KIRKLARELI	Efficiency Score:	0.860768	
Facet (and Lambda):	1(0.010274)	2(0.026435)	13(0.441086)
	35(0.10018)	51(0.191362)	66(0.230663)
Outputs	Observed Value	Target Value	Slack
Y1	96477.0	96477.0	0.00
Y2	386466.0	386466.0	0.00
Y3	105.0	105.0	0.00
Y4	6550.0	7517.83	967.83
Inputs	Observed Value	Target Value	Slack
X1	303.0	259.70	1.11
X2	338.0	192.82	98.12
X3	2769.5	2383.90	0.00
X4	97895.5	84265.31	0.00
X5	36214.0	31171.85	0.00

42. KIRSEHIR	Efficiency Score:	0.876528	
Facet (and Lambda):	2(0.006008)	13(0.031834)	14(0.389368)
	17(0.226017)	33(0.042683)	51(0.303463)
	70(0.000627)		
Outputs	Observed Value	Target Value	Slack
Y1	67337.0	67337.0	0.00
Y2	101911.0	101911.0	0.00
Y3	37.0	37.0	0.00
Y4	6570.0	7807.66	1237.66
Inputs	Observed Value	Target Value	Slack
X1	315.0	223.59	52.52
X2	107.1	93.88	0.00
X3	3272.5	2868.44	0.00
X4	32758.9	28714.10	0.00
X5	19648.0	17222.02	0.00

43. KOCAELI	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	13
	37	43(1.0000)	69
	70		
Outputs	Observed Value	Target Value	Slack
Y1	305731.0	305731.0	0.00
Y2	3024289.0	3024289.0	0.00
Y3	767.0	767.0	0.00
Y4	3626.0	3626.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	801.0	801.0	0.00
X2	1527.8	1527.8	0.00
X3	6303.6	6303.6	0.00
X4	808941.2	808941.2	0.00
X5	169717.0	169717.0	0.00

44. KONYA	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	37
	40	44(1.00000)	45
	60	69	70
Outputs	Observed Value	Target Value	Slack
Y1	494060.0	494060.0	0.00
Y2	677879.0	677879.0	0.00
Y3	439.0	439.0	0.00
Y4	38257.0	38257.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	1968.0	1968.0	0.00
X2	808.2	808.2	0.00
X3	18053.9	18053.9	0.00
X4	180403.4	180403.4	0.00
X5	81622.0	81622.0	0.00

45. KUTAHYA	Efficiency Score:	1.000000	
Facet (and Lambda):	2	14	44
	45(1.0000)	60	69
	70		
Outputs	Observed Value	Target Value	Slack
Y1	186073.0	186073.0	0.00
Y2	323943.0	323943.0	0.00
Y3	94.0	94.0	0.00
Y4	11875.0	11875.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	410.0	410.0	0.00
X2	220.4	220.4	0.00
X3	5988.1	5988.1	0.00
X4	89401.1	89401.1	0.00
X5	29043.0	29043.0	0.00

46. MALATYA	Efficiency Score:	0.745772	
Facet (and Lambda):	17(0.575784)	44(0.006997)	45(0.052462)
	57(0.01788)	60(0.228367)	62(0.068904)
	70(0.049606)		
Outputs	Observed Value	Target Value	Slack
Y1	172427.0	172427.0	0.00
Y2	281920.0	281920.0	0.00
Y3	82.5	82.5	0.00
Y4	12313.0	12313.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	570.0	373.12	51.97
X2	283.7	211.58	0.00
X3	13209.3	5749.94	4101.19
X4	63953.0	47694.36	0.00
X5	58781.0	43837.22	0.00

47. MANISA	Efficiency Score:	1.000000	
Facet (and Lambda):	2	12	21
	44	45	47(1.000)
	60	66	70
Outputs	Observed Value	Target Value	Slack
Y1	357344.0	357344.0	0.00
Y2	664044.0	664044.0	0.00
Y3	172.0	172.0	0.00
Y4	13810.0	13810.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	640.0	640.0	0.00
X2	557.9	557.9	0.00
X3	10257.1	10257.1	0.00
X4	171520.4	171520.4	0.00
X5	52195.0	52195.0	0.00

48. K.MARAS	Efficiency Score:	0.967678	
Facet (and Lambda):	1(0.262177)	35(0.101472)	40(0.27176)
	51(0.32246)	70(0.042131)	
Outputs	Observed Value	Target Value	Slack
Y1	169986.0	169986.0	0.00
Y2	384640.0	384640.0	0.00
Y3	114.0	132.14	18.14
Y4	14327.0	14327.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	546.0	394.36	133.99
X2	262.7	254.21	0.00
X3	3259.0	3153.66	0.00
X4	99392.8	78971.10	17209.13
X5	75145.0	62608.04	10108.12

49. MARDIN	Efficiency Score:	0.701764	
Facet (and Lambda):	1(0.083854)	6(0.053118)	13(0.005805)
	33(0.131622)	51(0.706081)	70(0.01952)
Outputs	Observed Value	Target Value	Slack
Y1	90240.0	95097.5	4857.5
Y2	152894.0	152894.0	0.00
Y3	80.5	80.5	0.00
Y4	8891.0	8891.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	361.0	253.34	0.00
X2	177.7	124.70	0.00
X3	6753.0	2407.08	2331.93
X4	53737.6	37711.11	0.00
X5	150673.0	38346.81	67390.08

50. MUGLA	Efficiency Score:	0.8792	
Facet (and Lambda):	1(0.1814)	12(0.294155)	21(0.360399)
	66(0.13572)	70(0.028326)	
Outputs	Observed Value	Target Value	Slack
Y1	213921.0	213921.0	0.00
Y2	426026.0	426026.0	0.00
Y3	100.5	130.88	30.38
Y4	13338.0	13338.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	419.0	368.38	0.00
X2	573.7	408.07	96.33
X3	19916.4	17510.50	11911.88
X4	123863.3	85786.90	23113.72
X5	54278.0	47721.22	0.00

51. MUS	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	13
	33	35	40
	44	51(1.000)	66
Outputs	Observed Value	Target Value	Slack
Y1	52523.0	52523.0	0.00
Y2	45012.0	45012.0	0.00
Y3	16.5	16.5	0.00
Y4	8196.0	8196.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	181.0	181.0	0.00
X2	47.2	47.2	0.00
X3	1745.6	1745.6	0.00
X4	17531.4	17531.4	0.00
X5	20145.0	20145.0	0.00

52. NEVSEHIR	Efficiency Score:	0.772665	
Facet (and Lambda):	2(0.013389)	17(0.395003)	51(0.255641)
	66(0.335417)	70(0.00055)	
Outputs	Observed Value	Target Value	Slack
Y1	88878.0	88878.0	0.00
Y2	166311.0	166311.0	0.00
Y3	31.5	40.87	9.37
Y4	5467.0	7123.7	1656.7
Inputs	Observed Value	Target Value	Slack
X1	312.0	213.77	27.3
X2	268.2	147.78	59.45
X3	3675.3	2839.78	0.00
X4	40278.3	31121.63	0.00
X5	25366.0	19599.42	0.00

53. NIGDE	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	14
	17	33	44
	53(1.000)	66	
Outputs	Observed Value	Target Value	Slack
Y1	84563.0	84563.0	0.00
Y2	171685.0	171685.0	0.00
Y3	72.5	72.5	0.00
Y4	7312.0	7312.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	354.0	354.0	0.00
X2	186.2	186.2	0.00
X3	3369.9	3369.9	0.00
X4	44495.5	44495.5	0.00
X5	18173.0	18173.0	0.00

54. ORDU	Efficiency Score:	0.908091	
Facet (and Lambda):	17(0.179571)	45(0.084766)	57(0.09948)
	62(0.603798)	70(0.032385)	
Outputs	Observed Value	Target Value	Slack
Y1	196971.0	196971.0	0.00
Y2	234553.0	279728.2	45175.2
Y3	58.5	87.18	28.68
Y4	6001.0	9270.05	3269.05
Inputs	Observed Value	Target Value	Slack
X1	533.0	484.01	0.00
X2	251.2	228.11	0.00
X3	13732.6	7834.14	4636.31
X4	62432.9	56694.75	0.00
X5	52578.0	47745.61	0.00

55. RIZE	Efficiency Score:	0.983182	
Facet (and Lambda):	17(0.334068)	40(0.028788)	51(0.562513)
	69(0.048615)	70(0.026016)	
Outputs	Observed Value	Target Value	Slack
Y1	107677.0	107677.0	0.00
Y2	177445.0	182834.82	5389.82
Y3	52.5	52.5	0.00
Y4	3920.0	7866.75	3946.75
Inputs	Observed Value	Target Value	Slack
X1	244.0	239.90	0.00
X2	109.3	107.46	0.00
X3	4726.0	2837.10	1809.43
X4	50142.8	37069.25	12230.25
X5	34411.0	33832.28	0.00

56. SAKARYA	Efficiency Score:	0.730549	
Facet (and Lambda):	2(0.006647)	44(0.004183)	45(0.039784)
	47(0.153009)	66(0.736312)	69(0.007269)
	70(0.052796)		
Outputs	Observed Value	Target Value	Slack
Y1	197394.0	197394.0	0.00
Y2	398708.0	398708.0	0.00
Y3	101.0	101.0	0.00
Y4	4817.0	7168.12	2351.12
Inputs	Observed Value	Target Value	Slack
X1	630.0	344.66	115.59
X2	393.3	287.32	0.00
X3	6350.6	4639.42	0.00
X4	103091.4	75313.32	0.00
X5	57916.0	42310.48	0.00

57. SAMSUN	Efficiency Score:	1.000000	
Facet (and Lambda):	12	40	44
	45	57(1.000)	69
	70		
Outputs	Observed Value	Target Value	Slack
Y1	345104.0	345104.0	0.00
Y2	533830.0	533830.0	0.00
Y3	166.0	166.0	0.00
Y4	9579.0	9579.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	996.0	996.0	0.00
X2	227.4	227.4	0.00
X3	13292.7	13292.7	0.00
X4	147306.3	147306.3	0.00
X5	102797.0	102797.0	0.00

58. SIIRT	Efficiency Score:	1.000000	
Facet (and Lambda):	6	13	33
	40	51	58(1.000)
Outputs	Observed Value	Target Value	Slack
Y1	35080.0	35080.0	0.00
Y2	249029.0	249029.0	0.00
Y3	65.5	65.5	0.00
Y4	5406.0	5406.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	225.0	225.0	0.00
X2	46.1	46.1	0.00
X3	3708.0	3708.0	0.00
X4	91740.2	91740.2	0.00
X5	160289.0	160289.0	0.00

59. SINOP	Efficiency Score:	0.900957	
Facet (and Lambda):	1(0.014273)	13(0.027048)	17(0.789167)
	31(0.067814)	51(0.101698)	
Outputs	Observed Value	Target Value	Slack
Y1	80333.0	80333.0	0.00
Y2	81336.0	94610.1	13274.1
Y3	21.0	27.64	6.64
Y4	5862.0	7124.78	1262.78
Inputs	Observed Value	Target Value	Slack
X1	219.0	197.31	0.00
X2	124.9	112.53	0.00
X3	4791.9	2982.14	1335.16
X4	26230.8	23632.82	0.00
X5	18524.0	16689.33	0.00

60. SIVAS	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	
	44	60(1.000)	
Outputs	Observed Value	Target Value	Slack
Y1	191061.0	191061.0	0.00
Y2	315092.0	315092.0	0.00
Y3	109.5	109.5	0.00
Y4	28488.0	28488.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	593.0	593.0	0.00
X2	297.2	297.2	0.00
X3	10598.1	10598.1	0.00
X4	85604.1	85604.1	0.00
X5	27136.0	27136.0	0.00

61. TEKIRDAG	Efficiency Score:	0.805268	
Facet (and Lambda):	1(0.038444)	2(0.004373)	12(0.134143)
	13(0.712251)	43(0.036732)	70(0.074057)
Outputs	Observed Value	Target Value	Slack
Y1	169179.0	169179.0	0.00
Y2	698651.0	698651.0	0.00
Y3	176.0	176.0	0.00
Y4	6218.0	6218.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	355.0	285.88	0.00
X2	363.7	261.38	31.5
X3	5004.3	3327.75	702.05
X4	188711.6	143594.16	8369.25
X5	78282.0	63037.99	0.00

62. TOKAT	Efficiency Score:	1.000000	
Facet (and Lambda):	17	21	44
	60	62(1.000)	66
	70		
Outputs	Observed Value	Target Value	Slack
Y1	166905.0	166905.0	0.00
Y2	180572.0	180572.0	0.00
Y3	67.0	67.0	0.00
Y4	9958.0	9958.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	483.0	483.0	0.00
X2	234.1	234.1	0.00
X3	8767.5	8767.5	0.00
X4	46639.0	46639.0	0.00
X5	29158.0	29158.0	0.00

63. TRABZON	Efficiency Score:	0.965504	
Facet (and Lambda):	44(0.072934)	45(0.666787)	57(0.020529)
	62(0.209882)	70(0.029868)	
Outputs	Observed Value	Target Value	Slack
Y1	229690.0	229690.0	0.00
Y2	292248.0	381911.24	89663.24
Y3	71.0	128.38	57.38
Y4	4685.0	13051.44	8366.44
Inputs	Observed Value	Target Value	Slack
X1	827.0	558.78	239.69
X2	291.5	281.44	0.00
X3	7819.2	7549.47	0.00
X4	90842.4	87708.70	0.00
X5	48585.0	46909.01	0.00

64. TUNCELI	Efficiency Score:	1.000000	
Facet (and Lambda):	14	32	64(1.0000)
Outputs	Observed Value	Target Value	Slack
Y1	29196.0	29196.0	0.00
Y2	24444.0	24444.0	0.00
Y3	7.0	7.0	0.00
Y4	7774.0	7774.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	203.0	203.0	0.00
X2	46.7	46.7	0.00
X3	11259.6	11259.6	0.00
X4	17911.5	17911.5	0.00
X5	4482.0	4482.0	0.00

65. S.URFA	Efficiency Score:	0.571854	
Facet (and Lambda):	1(0.714093)	2(0.061699)	
	60(0.040619)	70(0.183589)	
Outputs	Observed Value	Target Value	Slack
Y1	177311.0	177311.0	0.00
Y2	543911.0	816098.4	272187.4
Y3	95.0	242.99	147.99
Y4	18584.0	18584.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	372.0	212.73	0.00
X2	1570.1	511.03	386.84
X3	17850.8	2232.89	7975.16
X4	119029.8	23438.10	44629.57
X5	222116.0	127017.92	0.00

66. USAK	Efficiency Score:	1.000000	
Facet (and Lambda):	1	2	33
	35	37	40
	45	66(1.000)	70
Outputs	Observed Value	Target Value	Slack
Y1	116405.0	116405.0	0.00
Y2	186747.0	186747.0	0.00
Y3	48.0	48.0	0.00
Y4	5341.0	5341.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	245.0	245.0	0.00
X2	187.5	187.5	0.00
X3	3265.5	3265.5	0.00
X4	52100.5	52100.5	0.00
X5	12723.0	12723.0	0.00

67. VAN	Efficiency Score:	1.000000	
Facet (and Lambda):	6	27	38
	60	67(1.000)	
Outputs	Observed Value	Target Value	Slack
Y1	91882.0	91882.0	0.00
Y2	118525.0	118525.0	0.00
Y3	32.5	32.5	0.00
Y4	19069.0	19069.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	488.0	488.0	0.00
X2	155.5	155.5	0.00
X3	12105.3	12105.3	0.00
X4	48524.9	48524.9	0.00
X5	68569.0	68569.0	0.00

68. YOZGAT	Efficiency Score:	0.90809	
Facet (and Lambda):	6(0.067534)	17(0.577247)	40(0.01996)
	45(0.001744)	57(0.014677)	60(0.311214)
	70(0.007624)		
Outputs	Observed Value	Target Value	Slack
Y1	134712.0	134712.0	0.00
Y2	195893.0	195893.0	0.00
Y3	53.0	60.33	7.33
Y4	14123.0	14123.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	390.0	354.16	0.00
X2	199.2	180.89	0.00
X3	10952.9	5814.40	4131.82
X4	52547.6	47717.95	0.00
X5	28183.0	25592.70	0.00

69. ZONGULDAK	Efficiency Score:	1.0000000	
Facet (and Lambda):	2	33	37
	40	44	45
	66	69(1.000)	70
Outputs	Observed Value	Target Value	Slack
Y1	321279.0	321279.0	0.00
Y2	989115.0	989115.0	0.00
Y3	325.0	325.0	0.00
Y4	8629.0	8629.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	629.0	629.0	0.00
X2	316.5	316.5	0.00
X3	10128.9	10128.9	0.00
X4	256930.8	256930.8	0.00
X5	71285.0	71285.0	0.00

70. AKTAS	Efficiency Score:	1.000000	
Facet (and Lambda):	2	17	21
	60	62	66
	70(1.000)		
Outputs	Observed Value	Target Value	Slack
Y1	919744.0	919744.0	0.00
Y2	2263764.0	2263764.0	0.00
Y3	543.0	543.0	0.00
Y4	1890.0	1890.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	671.0	671.0	0.00
X2	727.8	727.8	0.00
X3	4248.8	4248.8	0.00
X4	71208.9	71208.9	0.00
X5	447330.0	447330.0	0.00

Appendix 2a Detailed hydroelectric plant efficiency under CRS Frontier

1. HP. SARIYER	Efficiency score: 0.799963		Scale Type:DRS
Facet (and Lambda)	23(1.012047)		Banker's indicator:1.012047
Output	Observed Values	Target Value	Slack
Y1	252437.84	252437.84	0.00
Inputs	Observed Values	Target Value	Slack
X1	170.0	45.54	90.45
X2	29.92	23.93	0.00

2.HAZAR I	Efficiency score: 0.380072		Scale Type:IRS
Facet (and Lambda)	23(0.057533)		Banker's indicator:0.057533
Output	Observed Values	Target Value	Slack
Y1	14350.66	14350.66	0.00
Inputs	Observed Values	Target Value	Slack
X1	79.0	2.59	27.43
X2	3.58	1.36	0.00

3. KEMER	Efficiency score: 0.657447		Scale Type:IRS
Facet (and Lambda)	23(0.141219)		Banker's indicator:0.141219
Output	Observed Values	Target Value	Slack
Y1	35224.69	35224.69	0.00
Inputs	Observed Values	Target Value	Slack
X1	76.0	6.35	43.61
X2	5.08	3.33	0.00

4. DEMIRKOPRU	Efficiency score: 0.814377		Scale Type:IRS
Facet (and Lambda)	23(0.235188)		Banker's indicator:0.235188
Output	Observed Values	Target Value	Slack
Y1	58663.65	58663.65	0.00
Inputs	Observed Values	Target Value	Slack
X1	75.0	10.58	50.49
X2	6.83	5.56	0.00

5. HIRFANLI	Efficiency score: 0.784725		Scale Type:DRS
Facet (and Lambda)	23(1.155353)		Banker's indicator:1.155353
Output	Observed Values	Target Value	Slack
Y1	288183.26	288183.26	0.00
Inputs	Observed Values	Target Value	Slack
X1	139.0	51.99	57.08
X2	34.82	27.32	0.00

6. TORTUM	Efficiency score: 0.776363		Scale Type:IRS
Facet (and Lambda)	23(0.417562)		Banker's indicator:0.417562
Output	Observed Values	Target Value	Slack
Y1	104153.70	104153.70	0.00
Inputs	Observed Values	Target Value	Slack
X1	57.0	18.79	25.46
X2	12.72	9.87	0.00

7. ALMUS	Efficiency score: 0.813876		Scale Type:IRS
Facet (and Lambda)	23(0.367879)		Banker's indicator:0.367879
Output	Observed Values	Target Value	Slack
Y1	91761.11	91761.11	0.00
Inputs	Observed Values	Target Value	Slack
X1	62.0	16.56	33.9
X2	10.69	8.70	0.00

8. KESIKKOPRU	Efficiency score:	0.902287	Scale Type:IRS
Facet (and Lambda)	11(0.007304)	23(0.558186)	Banker's indicator:0.56549
Output	Observed Values	Target Value	Slack
Y1	185874.88	185874.88	0.00
Inputs	Observed Values	Target Value	Slack
X1	30.0	27.06	0.00
X2	20.52	18.51	0.00

9. DOGANKENT	Efficiency score:	0.628978	Scale Type:IRS
Facet (and Lambda)	23(0.438822)		Banker's indicator:0.438822
Output	Observed Values	Target Value	Slack
Y1	109456.64	109456.64	0.00
Inputs	Observed Values	Target Value	Slack
X1	93.0	19.75	38.74
X2	16.5	10.37	0.00

10. GOKCEKAYA	Efficiency score:	0.8324	Scale Type:DRS
Facet (and Lambda)	23(1.379707)		Banker's indicator:1.379707
Output	Observed Values	Target Value	Slack
Y1	344144.37	344144.37	0.00
Inputs	Observed Values	Target Value	Slack
X1	115.0	62.09	33.63
X2	39.2	32.63	0.00

11. KEBAN	Efficiency score:	1.000	Scale Type:CRS
Facet (and Lambda)	11(1.000)	16	Banker's indicator:1.000
Output	Observed Values	Target Value	Slack
Y1	6386010.0	6386010.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	267.0	267.0	0.00
X2	727.5	727.5	0.00

12. CILDIR	Efficiency score:	0.474605	Scale Type:IRS
Facet (and Lambda)	23(0.114989)		Banker's indicator:0.114989
Output	Observed Values	Target Value	Slack
Y1	28682.04	28682.04	0.00
Inputs	Observed Values	Target Value	Slack
X1	44.0	5.18	15.7
X2	5.73	2.71	0.00

13. HS.UGURLU	Efficiency score:	0.947947	Scale Type:DRS
Facet (and Lambda)	11(0.195599)	23(1.767549)	Banker's indicator:1.963148
Output	Observed Values	Target Value	Slack
Y1	1689982.47	1689982.47	0.00
Inputs	Observed Values	Target Value	Slack
X1	139.0	131.76	0.00
X2	194.21	184.10	0.00

14. OYMAPINAR	Efficiency score:	0.70717	Scale Type:DRS
Facet (and Lambda)	23(2.648073)		Banker's indicator:2.648073
Output	Observed Values	Target Value	Slack
Y1	660516.84	660516.84	0.00
Inputs	Observed Values	Target Value	Slack
X1	180.0	119.16	8.12
X2	88.56	62.62	0.00

15. ASLANTAS	Efficiency score:	0.892374	Scale Type:DRS
Facet (and Lambda)	23(1.885115)		Banker's indicator:1.885115
Output	Observed Values	Target Value	Slack
Y1	470210.0	470210.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	116.0	84.83	18.68
X2	49.96	44.58	0.00

16. KARAKAYA	Efficiency score:	1.000	Scale Type:CRS
Facet (and Lambda)	11	16(1.000)	Banker's indicator:1.000
Output	Observed Values	Target Value	Slack
Y1	7608350.0	7608350.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	260.0	260.0	0.00
X2	883.8	883.8	0.00

17. ALTINKAYA	Efficiency score:	0.900292	Scale Type:DRS
Facet (and Lambda)	11(0.138387)	23(1.481431)	Banker's indicator:1.619518
Output	Observed Values	Target Value	Slack
Y1	1251340.88	1251340.88	0.00
Inputs	Observed Values	Target Value	Slack
X1	115.0	103.53	0.00
X2	150.5	135.04	0.00

18. KOKLUCE	Efficiency score:	0.911003	Scale Type:IRS
Facet (and Lambda)	11(0.038817)	23(0.90338)	Banker's indicator:0.942197
Output	Observed Values	Target Value	Slack
Y1	473217.08	473217.08	0.00
Inputs	Observed Values	Target Value	Slack
X1	56.0	51.01	0.00
X2	54.45	49.6	0.00

19. KAPULUKAYA	Efficiency score:	0.849466	Scale Type:IRS
Facet (and Lambda)	23(0.698251)		Banker's indicator:0.698251
Output	Observed Values	Target Value	Slack
Y1	174166.76	174166.76	0.00
Inputs	Observed Values	Target Value	Slack
X1	40.0	31.42	2.55
X2	19.44	16.51	0.00

20. KILICKAYA	Efficiency score:	0.897178	Scale Type:IRS
Facet (and Lambda)	11(0.032893)	23(0.422888)	Banker's indicator:0.455781
Output	Observed Values	Target Value	Slack
Y1	315540.0	315540.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	31.0	27.81	0.00
X2	37.82	33.93	0.00

21. KARACAOREN	Efficiency score: 0.23038		Scale Type:IRS
Facet (and Lambda)	23(0.107835)		Banker's indicator:0.107835
Output	Observed Values	Target Value	Slack
Y1	26897.69	26897.69	0.00
Inputs	Observed Values	Target Value	Slack
X1	33.0	4.86	2.74
X2	11.07	2.55	0.00

22. TERCAN	Efficiency score: 0.861883		Scale Type:IRS
Facet (and Lambda)	23(0.21538)		Banker's indicator:0.21538
Output	Observed Values	Target Value	Slack
Y1	53722.8	53722.8	0.00
Inputs	Observed Values	Target Value	Slack
X1	28.0	9.69	14.44
X2	5.91	5.09	0.00

23. SEYHAN-(CEAS)	Efficiency score: 1.000		Scale Type:CRS
Facet (and Lambda)	11	23(1.000)	Banker's indicator:1.000
Output	Observed Values	Target Value	Slack
Y1	249433.0	249433.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	45.0	45.0	0.00
X2	23.65	23.65	0.00

24. KADINCIK I-(CEAS)	Efficiency score: 0.867041		Scale Type:IRS
Facet (and Lambda)	23(0.669803)		Banker's indicator:0.669803
Output	Observed Values	Target Value	Slack
Y1	167071.0	167071.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	62.0	30.14	23.61
X2	18.27	15.84	0.00

25. YUREGIR-(CEAS)	Efficiency score: 0.690426		Scale Type:IRS
Facet (and Lambda)	23(0.019268)		Banker's indicator:0.019268
Output	Observed Values	Target Value	Slack
Y1	4806.0	4806.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	10.0	0.87	6.03
X2	0.66	0.45	0.00

26. KADINCIK II-(CEAS)	Efficiency score: 0.830296		Scale Type:IRS
Facet (and Lambda)	23(0.501337)		Banker's indicator:0.501337
Output	Observed Values	Target Value	Slack
Y1	125050.0	125050.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	31.0	22.56	3.17
X2	14.28	11.85	0.00

27. KEPEZ	Efficiency score: 0.795413		Scale Type:IRS
Facet (and Lambda)	23(0.322537)		Banker's indicator:0.322537
Output	Observed Values	Target Value	Slack
Y1	80451.45	80451.45	0.00
Inputs	Observed Values	Target Value	Slack
X1	323.0	14.51	242.4
X2	9.59	7.62	0.00

28. MANAVGAT	Efficiency score: 0.830802		Scale Type:IRS
Facet (and Lambda)	23(0.43841)		Banker's indicator:0.43841
Output	Observed Values	Target Value	Slack
Y1	109354.0	109354.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	30.0	19.73	5.19
X2	12.48	10.36	0.00

Appendix 2b Detailed hydroelectric plant efficiency under VRS Frontier

1. HP. SARIYER	Efficiency score:	0.80196	
Facet (and Lambda)	11(0.00049)	23(0.99951)	
Output	Observed Values	Target Value	Slack
Y1	252437.84	252437.84	0.00
Inputs	Observed Values	Target Value	Slack
X1	170.0	45.11	91.22
X2	29.92	27.99	0.00

2.HAZAR I	Efficiency score:	0.434918	
Facet (and Lambda)	23(0.039017)	25(0.960983)	
Output	Observed Values	Target Value	Slack
Y1	14350.66	14350.66	0.00
Inputs	Observed Values	Target Value	Slack
X1	79.0	11.36	22.99
X2	3.58	1.55	0.00

3. KEMER	Efficiency score:	0.692666	
Facet (and Lambda)	23(0.124347)	25(0.875653)	
Output	Observed Values	Target Value	Slack
Y1	35224.69	35224.69	0.00
Inputs	Observed Values	Target Value	Slack
X1	76.0	14.35	38.29
X2	5.08	3.52	0.00

4. DEMIRKOPRU	Efficiency score:	0.837706	
Facet (and Lambda)	23(0.220162)	25(0.779838)	
Output	Observed Values	Target Value	Slack
Y1	58663.65	58663.65	0.00
Inputs	Observed Values	Target Value	Slack
X1	75.0	17.71	45.12
X2	6.83	5.72	0.00

5. HIRFANLI	Efficiency score:	0.806851	
Facet (and Lambda)	11(0.006315)	23(0.993685)	
Output	Observed Values	Target Value	Slack
Y1	288183.26	288183.26	0.00
Inputs	Observed Values	Target Value	Slack
X1	139.0	46.40	65.75
X2	34.82	28.09	0.00

6. TORTUM	Efficiency score:	0.785902	Scale Type:IRS
Facet (and Lambda)	23(0.406119)	25(0.593881)	Banker's indicator:0.417562
Output	Observed Values	Target Value	Slack
Y1	104153.70	104153.70	0.00
Inputs	Observed Values	Target Value	Slack
X1	57.0	24.21	20.58
X2	12.72	9.99	0.00

7. ALMUS	Efficiency score:	0.826195	
Facet (and Lambda)	23(0.35546)	25(0.64454)	
Output	Observed Values	Target Value	Slack
Y1	91761.11	91761.11	0.00
Inputs	Observed Values	Target Value	Slack
X1	62.0	22.44	28.78
X2	10.69	8.83	0.00

8. KESIKKOPRU	Efficiency score:	0.935503	
Facet (and Lambda)	11(0.011954) 25(0.559673)	23(0.428373)	
Output	Observed Values	Target Value	Slack
Y1	185874.88	185874.88	0.00
Inputs	Observed Values	Target Value	Slack
X1	30.0	28.06	0.00
X2	20.52	19.19	0.00

9. DOGANKENT	Efficiency score:	0.636063	
Facet (and Lambda)	23(0.427797)	25(0.572203)	
Output	Observed Values	Target Value	Slack
Y1	109456.64	109456.64	0.00
Inputs	Observed Values	Target Value	Slack
X1	93.0	24.97	34.18
X2	16.5	10.49	0.00

10. GOKCEKAYA	Efficiency score:	0.880438	Scale Type:DRS
Facet (and Lambda)	11(0.015434)	23(0.984566)	Banker's indicator:1.379707
Output	Observed Values	Target Value	Slack
Y1	344144.37	344144.37	0.00
Inputs	Observed Values	Target Value	Slack
X1	115.0	48.43	52.82
X2	39.2	34.51	0.00

11. KEBAN	Efficiency score:	1.000000	
Facet (and Lambda)	11(1.000) 25	16	
Output	Observed Values	Target Value	Slack
Y1	6386010.0	6386010.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	267.0	267.0	0.00
X2	727.5	727.5	0.00

12. CILDIR	Efficiency score:	0.506783	
Facet (and Lambda)	23(0.097602)	25(0.902398)	
Output	Observed Values	Target Value	Slack
Y1	28682.04	28682.04	0.00
Inputs	Observed Values	Target Value	Slack
X1	44.0	13.41	8.88
X2	5.73	2.90	0.00

13. HS.UGURLU	Efficiency score:	0.972542	
Facet (and Lambda)	11(0.234748)	23(0.765252)	
Output	Observed Values	Target Value	Slack
Y1	1689982.47	1689982.47	0.00
Inputs	Observed Values	Target Value	Slack
X1	139.0	97.12	38.06
X2	194.21	188.87	0.00

14. OYMAPINAR	Efficiency score:	0.799461	
Facet (and Lambda)	11(0.066989)	23(0.933011)	
Output	Observed Values	Target Value	Slack
Y1	660516.84	660516.84	0.00
Inputs	Observed Values	Target Value	Slack
X1	180.0	59.87	84.03
X2	88.56	70.80	0.00

15. ASLANTAS	Efficiency score:	0.980236	
Facet (and Lambda)	11(0.035977)	23(0.964023)	
Output	Observed Values	Target Value	Slack
Y1	470210.0	470210.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	116.0	52.98	60.72
X2	49.96	48.97	0.00

16. KARAKAYA	Efficiency score:	1.000000	
Facet (and Lambda)	11 25	16(1.000)	
Output	Observed Values	Target Value	Slack
Y1	7608350.0	7608350.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	260.0	260.0	0.00
X2	883.8	883.8	0.00

17. ALTINKAYA	Efficiency score:	0.920706	
Facet (and Lambda)	11(0.163268)	23(0.836732)	
Output	Observed Values	Target Value	Slack
Y1	1251340.88	1251340.88	0.00
Inputs	Observed Values	Target Value	Slack
X1	115.0	81.25	24.63
X2	150.5	138.56	0.00

18. KOKLUCE	Efficiency score:	0.912785	
Facet (and Lambda)	11(0.039485	23(0.884808)	
	25(0.075707)		
Output	Observed Values	Target Value	Slack
Y1	473217.08	473217.08	0.00
Inputs	Observed Vaiues	Target Value	Slack
X1	56.0	51.11	0.00
X2	54.45	49.7	0.00

19. KAPULUKAYA	Efficiency score:	0.853579	
Facet (and Lambda)	11(0.000134)	23(0.688818)	
	25(0.311048)		
Output	Observed Values	Target Value	Slack
Y1	174166.76	174166.76	0.00
Inputs	Observed Values	Target Value	Slack
X1	40.0	34.14	0.00
X2	19.44	16.59	0.00

20. KILICKAYA	Efficiency score:	0.922175	
Facet (and Lambda)	11(0.039438)	23(0.241484)	
	25(0.719078)		
Output	Observed Values	Target Value	Slack
Y1	315540.0	315540.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	31.0	28.58	0.00
X2	37.82	34.87	0.00

21. KARACAOREN	Efficiency score:	0.325041	Scale Type:IRS
Facet (and Lambda)	16(0.002905)	25(0.997095)	Banker's indicator:0.107835
Output	Observed Values	Target Value	Slack
Y1	26897.69	26897.69	0.00
Inputs	Observed Values	Target Value	Slack
X1	33.0	10.72	0.00
X2	11.07	3.22	0.37

22. TERCAN	Efficiency score:	0.889542	
Facet (and Lambda)	23(0.199965)	25(0.800035)	
Output	Observed Values	Target Value	Slack
Y1	53722.8	53722.8	0.00
Inputs	Observed Values	Target Value	Slack
X1	28.0	17.00	7.9
X2	5.91	5.25	0.00

23. SEYHAN-(CEAS)	Efficiency score:	1.000000	
Facet (and Lambda)	11 25	23(1.000)	
Output	Observed Values	Target Value	Slack
Y1	249433.0	249433.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	45.0	45.0	0.00
X2	23.65	23.65	0.00

24. KADINCIK I-(CEAS)	Efficiency score:	0.870806	
Facet (and Lambda)	23(0.663316)	25(0.336684)	
Output	Observed Values	Target Value	Slack
Y1	167071.0	167071.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	62.0	33.21	20.77
X2	18.27	15.9	0.00

25. YUREGIR-(CEAS)	Efficiency score:	1.000000	
Facet (and Lambda)	11	25(1.000)	
Output	Observed Values	Target Value	Slack
Y1	4806.0	4806.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	10.0	10.0	0.00
X2	0.66	0.66	0.00

26. KADINCIK II-(CEAS)	Efficiency score:	0.849409	
Facet (and Lambda)	11(0.00133)	23(0.456856)	
	25(0.541814)		
Output	Observed Values	Target Value	Slack
Y1	125050.0	125050.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	31.0	26.33	0.00
X2	14.28	12.12	0.00

27. KEPEZ	Efficiency score:	0.81013	
Facet (and Lambda)	23(0.309228)	25(0.690772)	
Output	Observed Values	Target Value	Slack
Y1	80451.45	80451.45	0.00
Inputs	Observed Values	Target Value	Slack
X1	323.0	21.67	240.0
X2	9.59	7.76	0.00

28. MANAVGAT	Efficiency score:	0.840176	
Facet (and Lambda)	23(0.427377)	25(0.572623)	
Output	Observed Values	Target Value	Slack
Y1	109354.0	109354.0	0.00
Inputs	Observed Values	Target Value	Slack
X1	30.0	24.96	0.24
X2	12.48	10.48	0.00

Appendix 3a Detailed thermoelectric plant efficiency under CRS Frontier

1. TUNCBILEK	Efficiency score:	0.798373	Scale Type: IRS
Facet (and Lambda)	10(0.862797)	13(0.093192)	Banker's indicator:0.955989
Output	Observed Value	Target Value	Slack
Y1	1204965.5	1204965.5	0.00
Inputs	Observed Value	Target Value	Slack
X1	913.0	728.91	108.98
X2	201.2	160.63	0.00
X3	348900.0	278552.33	0.00

2. SOMA(A)	Efficiency score:	0.965479	Scale Type:IRS
Facet (and Lambda)	9(0.178482)	10(0.098937)	Banker's indicator:0.277419
Output	Observed Value	Target Value	Slack
Y1	292515.06	292515.06	0.00
Inputs	Observed Value	Target Value	Slack
X1	253.0	161.25	83.01
X2	37.62	36.32	0.00
X3	94641.7	91374.57	0.00

3. SOMA(B)	Efficiency score:	0.758573	Scale Type:DRS
Facet (and Lambda)	7(0.367462) 13(0.238637)	10(1.094075)	Banker's indicator:1.700174
Output	Observed Value	Target Value	Slack
Y1	2912427.08	2912427.08	0.00
Inputs	Observed Value	Target Value	Slack
X1	1381.0	1047.58	0.00
X2	516.45	391.76	0.00
X3	882365.4	669338.56	0.00

4. SEYITOMER	Efficiency score:	0.991122	Scale Type:DRS
Facet (and Lambda)	7(1.097754) 13(0.069669)	10(0.52245)	Banker's indicator:1.689873
Output	Observed Value	Target Value	Slack
Y1	3136109.77	3136109.77	0.00
Inputs	Observed Value	Target Value	Slack
X1	1162.0	1151.68	0.00
X2	408.0	404.37	0.00
X3	829582.5	822217.46	0.00

5. YATAGAN	Efficiency score:	0.900305	Scale Type:DRS
Facet (and Lambda)	7(0.526371) 10(0.082404)	9(1.049799)	Banker's indicator:1.658574
Output	Observed Value	Target Value	Slack
Y1	2414318.71	2414318.71	0.00
Inputs	Observed Value	Target Value	Slack
X1	1069.0	962.42	0.00
X2	336.42	302.88	0.00
X3	810275.4	729494.99	0.00

6. AFSIN-ELBISTAN	Efficiency score:	0.685205	Scale Type:DRS
Facet (and Lambda)	7(.689678) 13(0.214437)	10(0.762617)	Banker's indicator:1.666732
Output	Observed Value	Target Value	Slack
Y1	3194365.48	3194365.48	0.00
Inputs	Observed Value	Target Value	Slack
X1	1514.0	1037.4	0.00
X2	621.52	425.86	0.00
X3	1110077.8	760627.52	0.00

7. YENIKOY	Efficiency score:	1.000	Scale Type:CRS
Facet (and Lambda)	7(1.000)	10	Banker's indicator:1.000
	13		
Output	Observed Value	Target Value	Slack
Y1	2132007.05	2132007.05	0.00
Inputs	Observed Value	Target Value	Slack
X1	707.0	707.0	0.00
X2	270.9	270.9	0.00
X3	585230.8	585230.8	0.00

8. CAYIRHAN	Efficiency score:	0.877569	Scale Type:IRS
Facet (and Lambda)	7(0.296779)	10(0.606509)	Banker's indicator:0.926424
	13(0.023136)		
Output	Observed Value	Target Value	Slack
Y1	1268355.85	1268355.85	0.00
Inputs	Observed Value	Target Value	Slack
X1	735.0	645.0	0.00
X2	184.8	162.17	0.00
X3	380531.7	333942.82	0.00

9. KANGAL	Efficiency score:	1.000	Scale Type:CRS
Facet (and Lambda)	7	9(1.000)	Banker's indicator:1.000
	10		
Output	Observed Value	Target Value	Slack
Y1	1163476.35	1163476.35	0.00
Inputs	Observed Value	Target Value	Slack
X1	506.0	506.0	0.00
X2	144.3	144.3	0.00
X3	383225.8	383225.8	0.00

10. CATALAGZI(B)-C	Efficiency score:	1.000	Scale Type:CRS
Facet (and Lambda)	10(1.000)	13	Banker's indicator:1.000
Output	Observed Value	Target Value	Slack
Y1	857681.0	857681.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	717.0	717.0	0.00
X2	106.8	106.8	0.00
X3	232227.8	232227.8	0.00

11. AMBARLI-F	Efficiency score:	0.419514	Scale Type:IRS
Facet (and Lambda)	13(0.037437)		Banker's indicator:0.037437
Output	Observed Value	Target Value	Slack
Y1	186784.86	186784.86	0.00
Inputs	Observed Value	Target Value	Slack
X1	483.0	0.52	202.1
X2	75.6	27.51	4.2
X3	74870.8	31409.34	0.00

12. HOPA-F	Efficiency score:	0.51023	Scale Type:IRS
Facet (and Lambda)	10(0.004961)	13(0.002195)	Banker's indicator:0.007156
Output	Observed Value	Target Value	Slack
Y1	15206.71	15206.71	0.00
Inputs	Observed Value	Target Value	Slack
X1	114.0	3.59	54.57
X2	4.2	2.14	0.00
X3	5867.3	2993.67	0.00

13. AMBARLI-N	Efficiency score: 1.000		Scale Type:CRS
Facet (and Lambda)	13(1.000)		Banker's indicator:1.000
Output	Observed Value	Target Value	Slack
Y1	4989277.51	4989277.51	0.00
Inputs	Observed Value	Target Value	Slack
X1	14.0	14.0	0.00
X2	734.89	734.89	0.00
X3	838986.1	838986.1	0.00

Appendix 3b Detailed thermoelectric plant efficiency under VRS Frontier

1. TUNCBILEK	Efficiency score:	0.798800	
Facet (and Lambda)	10(0.862829)	12(0.044119)	13(0.093052)
Output	Observed Value	Target Value	Slack
Y1	1204965.5	1204965.5	0.00
Inputs	Observed Value	Target Value	Slack
X1	913.0	624.98	104.32
X2	201.2	160.71	0.00
X3	348900.0	278701.33	0.00

2. SOMA(A)	Efficiency score:	1.000000		
Facet (and Lambda)	2(1.0000)	7	10	12
Output	Observed Value	Target Value		Slack
Y1	292515.06	292515.06		0.00
Inputs	Observed Value	Target Value		Slack
X1	253.0	253.0		0.00
X2	37.62	36.32		0.00
X3	94641.7	91374.57		0.00

3. SOMA(B)	Efficiency score:	0.763680	
Facet (and Lambda)	4(0.124407)	7(0.646178)	13(0.229415)
Output	Observed Value	Target Value	Slack
Y1	2912427.08	2912427.08	0.00
Inputs	Observed Value	Target Value	Slack
X1	1381.0	604.64	450.0
X2	516.45	394.90	0.00
X3	882365.4	673844.80	0.00

4. SEYITOMER	Efficiency score:	1.000000	
Facet (and Lambda)	4(1.000)	7	13
Output	Observed Value	Target Value	Slack
Y1	3136109.77	3136109.77	0.00
Inputs	Observed Value	Target Value	Slack
X1	1162.0	1162.0	0.00
X2	408.0	408.0	0.00
X3	829582.5	829582.5	0.00

5. YATAGAN	Efficiency score:	0.919823	
Facet (and Lambda)	4(0.281158)	7(0.718842)	
Output	Observed Value	Target Value	Slack
Y1	2414318.71	2414318.71	0.00
Inputs	Observed Value	Target Value	Slack
X1	1069.0	834.93	148.36
X2	336.42	309.44	0.00
X3	810275.4	653932.44	91377.5

6. AFSIN-ELBISTAN	Efficiency score:	0.690148	
Facet (and Lambda)	4(0.557678)	7(0.266498)	13(0.175824)
Output	Observed Value	Target Value	Slack
Y1	3194365.48	3194365.48	0.00
Inputs	Observed Value	Target Value	Slack
X1	1514.0	838.89	205.99
X2	621.52	428.94	0.00
X3	1110077.8	766117.97	0.00

7. YENIKOY	Efficiency score:	1.000000		
Facet (and Lambda)	7(1.000)	10	13	
Output	Observed Value	Target Value		Slack
Y1	2132007.05	2132007.05		0.00
Inputs	Observed Value	Target Value		Slack
X1	707.0	707.0		0.00
X2	270.9	270.9		0.00
X3	585230.8	585230.8		0.00

8. CAYIRHAN	Efficiency score:	0.878671		
Facet (and Lambda)	7(0.305659)	10(0.585145)	12(0.086446)	
	13(0.02275)			
Output	Observed Value	Target Value		Slack
Y1	1268355.85	1268355.85		0.00
Inputs	Observed Value	Target Value		Slack
X1	735.0	645.82		0.00
X2	184.8	161.67		0.00
X3	380531.7	334362.16		0.00

9. KANGAL	Efficiency score:	1.000000		
Facet (and Lambda)	7	9(1.000)	10	
Output	Observed Value	Target Value		Slack
Y1	1163476.35	1163476.35		0.00
Inputs	Observed Value	Target Value		Slack
X1	506.0	506.0		0.00
X2	144.3	144.3		0.00
X3	383225.8	383225.8		0.00

10. CATALAGZI(B)-C	Efficiency score:	1.000000	
Facet (and Lambda)	7	9	10(1.000)
Output	Observed Value	Target Value	Slack
Y1	857681.0	857681.0	0.00
Inputs	Observed Value	Target Value	Slack
X1	717.0	717.0	0.00
X2	106.8	106.8	0.00
X3	232227.8	232227.8	0.00

11. AMBARLI-F	Efficiency score:	0.462201	
Facet (and Lambda)	12(0.965505)	13(0.034495)	
Output	Observed Value	Target Value	Slack
Y1	186784.86	186784.86	0.00
Inputs	Observed Value	Target Value	Slack
X1	483.0	110.55	112.69
X2	75.6	29.41	5.53
X3	74870.8	34605.35	0.00

12. HOPA-F	Efficiency score:	1.000000		
Facet (and Lambda)	7	10	12(1.000)	13
Output	Observed Value	Target Value	Slack	
Y1	15206.71	15206.71	0.00	
Inputs	Observed Value	Target Value	Slack	
X1	114.0	114.0	0.00	
X2	4.2	4.2	0.00	
X3	5867.3	5867.3	0.00	

13. AMBARLI-N	Efficiency score: 1.000000		
Facet (and Lambda)	13(1.000)		
Output	Observed Value	Target Value	Slack
Y1	4989277.51	4989277.51	0.00
Inputs	Observed Value	Target Value	Slack
X1	14.0	14.0	0.00
X2	734.89	734.89	0.00
X3	838986.1	838986.1	0.00

References

Ahn, T., A. Charnes, and W. W. Cooper (1988) Efficiency characteristics in different DEA modeis. *Socio-Econ.Plann.Sci.* 22:6, pp.253-257.

Alchian, A. (1965) Some economics of property rights. *Il Politico* 30:4, pp.816-829.

Armstrong, M., S. Cowan and G. Yarrow (1994) *Regulatory reform: Economic analysis and British experience.* London: MIT Press.

Atkinson, S. E. and R. Halvorsen (1984) The relative efficiency of pubiic and private firms in a regulated environment: The case of US electric utilities. Department of Economics. University of Wyoming.

Atkinson, S. E. and R. Halvorsen (1986) The relative efficiency of pubiic and private firms in a regulated environment: The case of US eiectric utilities. *Journal of Public Economics*, 29, pp.281-294.

Augenblick, M. and B. S. Custer (1990) The build-operate and transfer (BOT) approach to infrastructure projects in developing countries. Policy Research and External Affairs Working Papers. Washington, D.C.: Worid Bank.

Averch, H. and L. L. Johnson (1962) Behaviour of the firm under regulatory constraint. *American Economic Review* 52, pp.1053-1069.

Aybar, E. N. (1993) Privatisation impiementations. *Electrical Engineers Chamber* 38(392), pp. 111-115. (In Turkish).

Bagdadiogiu, N., C. M. Waddams Price and T. G. Weyman-Jones (1996) Efficiency and ownership in electricity distribution: A non-parametric modei of the Turkish experience. To appear in *Energy Economics* 18:1 (January).

Banker, R. D. (1984) Estimating most productive scale size using data envelopment analysis. *European Journal of Operational Research* 17, pp.35-44.

Banker, R. D. and R. C. Morey (1986) Efficiency analysis for exogenously fixed inputs and outputs. *Operations Research* 34:4, pp.523-521.

Banker, R. D., A. Charnes and W. W. Cooper (1984) Some models for estimating technical and scale efficiencies in data envelopment analysis. *Management Science* 30, pp.1078-1092.

Barnett, A. (1993) Aid donor policies and power sector performance in developing countries. *Energy Policy*, pp. 100-113.

Bateson, J. and P. L. Swan (1989) Economies of scale and utilisation: An analysis of the multi-plant generation costs of the electricity commission of New South Wales, 1970/71-1984/85. *The Economic Record* 65:191, pp.329-344.

Bauer, P. W. (1990) Recent developments in the econometric estimation of frontiers. *The Journal of Econometrics* 46, pp.39-56.

Baumol, W. J. and D. F. Bradford (1970) Optimal departure from marginal cost pricing. *American Economic Review* 60:3, pp.265-283.

Baumol, W. J., J. Panzar and R. Willig (1982) *Contestable markets and the theory of industry structure.* New York: Jovanovich.

Beesley, M. E. and S. C. Littlechild (1989) The regulation of privatised monopolies in the United Kingdom. *The Rand Journal of Economics* 20, pp.454-472.

Boardman, A. and A. R. Vining (1989) Ownership and performance in competitive environments: A comperison of the performance of private, mixed, and state-owned enterprises. *Journal of Law and Economics* 32, pp.1-33.

Borcherding, T. E., W. W. Pommerehne and F Schnider (1982) Comparing the efficiency of private and public production: The evidence from five countries. *Journal of Economic Theory: Public Production* Supplement 2, pp. 127-156.

Bradley, I. and C. Price (1988) Economic regulation of private monopolies through price constraint. *Journal of Industrial Economics* XXXVII:1, pp.99-106.

Bradley, I. and C. Price (1989) Partial and mixed regulation of newly privatised UK monopolies. University of Leicester Department of Economics Paper No.122.

Burns, P. and T. G. Weyman-Jones (1994a) Cost drivers and cost efficiency in electricity distribution: A stochastic frontier approach. CRI.

Burns, P. and T. G. Weyman-Jones (1994b) Regulatory incentives, privatisation and productivity growth in UK electricity distribution. CRI.

Button, K. J. and T. G. Weyman-Jones (1992) X-efficiency in the UK: Upper and lower bounds. Economic Research Paper 92/9, Loughborough University.

Cakmak, E. H. and O. Zaim (1991) Comparative efficiency of public and private enterprises: An application of data envelopment analysis on Turkish cement industry.(In Turkish). *ODTU Gelisme Dergisi* 18:4, pp.441-451.

Cakmak, E. H. and O. Zaim (1992) Privatisation and comparative efficiency of public and private enterprise in Turkey: The cement industry, *Annals of Public and Cooperative Economics* 63:3, pp.271-284.

Canevi, Y. (1994) Turkey. In J. Williamson (ed.) *The political economy of policy reforms*. Institute for International Economics.

Chadwick, E. (1859) Research of different principles of legislation in Europe: of competition for the field compared with competition within the field of service. *Journal of the Royal Statistical Society* Series A22, pp.381-420.

Chang Y. -L. and T. Sueyoshi (1991) An interactive application of data envelopment analysis in microcomputers. *Computer Science in Economics and Management* 4, pp.51-64.

Charnes, A. and W. W. Cooper (1985) Preface to topics in data envelopment analysis. *Annals of Operations Research* 2, pp.55-94.

Charnes, A., W. W. Cooper and E. Rhodes (1978) Measuring the efficiency of decision making units. *European Journal of Operational Research* 2, pp. 429-444.

Charnes, A., W. W. Cooper and E. Rhodes (1979) Short communications: measuring the efficiency of decision making units. *European Journal of Operational Research,* p.339.

Cook, P. and C. Kirkpatrick (1995) Privatisation policy and performance. In Cook, P. and C. Kirkpatrick (eds.) *Privatisation policy and performance: International perspectives.* London: Prentice Hail.

Cote, D. O. (1989) Firm efficiency and ownership structure-the case of US electric utilities using panel data. *Annals of Public and Cooparative Economics* 60:4 10-12, pp.431-450.

Cowing, T. G. and V. K. Smith (1978) The estimation of a production technology: A survey of econometric analysis of steam-electric generation. *Land Economics* 54, pp.156-186.

Demsetz, H. (1968) Why regulate utilities. *Journal of Law and Economics* 11, pp.55-65.

Doble, M. and T. G. Weyman-Jones (1991) Measuring productlve efficiency in the area electricity boards of England and Wales using data enveiopment analysis: A dynamic approach. Public Sector Economics Research Centre Discussion Paper, University of Leicester.

Eden, R. et al. (1982) *Energy Economics.* Cambridge: Cambridge University Press.

Fare, R., S. Grosskopf and C. Pasurka (1986) Effects on relative efficiency in eiectric power generation due to environmental controls. *Resources and Energy* 8, pp.167-184.

Fare, R., S. Grosskopf and C. Pasurka (1989) The effect of environmental regulations on the efficiency of electric utiiities: 1969 versus 1975. *Applied Economics* 21, pp.225-235.

Fare, R., S. Grosskopf and J. Logan (1983) The relative efficiency of Illinois electric utilities. *Resources and Energy* 5, pp.349-367.

Fare, R., S. Grosskopf and J. Logan (1985) The relative performance of publicly-owned and privately-owned eiectric utilities. *Journal of Public Economics* 26, pp. 89-106.

Fare, R., S. Grosskopf and J. Logan (1987) The comparative efficiency of Western coal-fired steam-electric generating plants: 1977-1979. *Engineering Costs and Production Economics* 11, pp.21-30.

Fare, R., S. Grosskopf, M. Norris, and Z. Zhang (1994) Productivity growth, technical progress, and efficiency change in industrialised countries. *The American Economic Review* 84:1, pp.66-83.

Fare, R., S. Grosskopf, S. Yaisawarng, S. K. Li and Z. Wang (1990) Productivity growth in Illinois eiectric utiiities. *Resources and Energy* 12, pp.383-398.

Farreil, J. (1957) The measurement of productive efficiency. *Journal of the Royal Statistical Society* (Series A) 120, pp. 253-281.

Flawin, C. and Lenssen, N. (1994) Reshaping the electric power industry. *Energy Policy* 22(12), pp. 1029-1044.

Gegax, D. and K. Nowotny (1993) Competition and the electric utility industry: An evaluation. *The Yale Journal of Regulation* 16:63, pp.63-87

Gelal, A., L. Jones, P. Tandon and I. Vogelsang (1992) *Welfare consequences of selling public enterprises.* Washington, D.C.: World Bank.

Golany, B., Y. Roll and D. Rybak (1994) Measuring efficiency of power plants in Israel by using data envelopment analysis. *IEET Transactions on Engineering Management* 41:3, pp.291-301.

Green, R. and C. Price (1993) Privatisation and restructuring: optimal timing. Discussion Papers in Economics No. 93/15, Department of Economics, University of Leicester.

Grosskopf, S. (1986) The role of the reference technology in measuring productive efficiency. *The Economic Journal* 96, pp.499-513.

Gultekin, N. B. (1993) Privatisation in Turkey. In V. V. Ramanadham (ed.) *Privatisation: A global perspective.* London: Routledge.

Hammond, C. J. (1992) Privatisation and the efficiency of decentralised electricity generation: Some evidence from inter-war Britain. *The Economic Journal* 102, pp.538-553.

Hausman, W. J. and J. L. Neufeld (1991) Property rights versus public spirit: ownership and efficiency of US electric utiiities prior to rate-of-return regulation. *The Review of Economics and Statistics* 73(2), pp. 414-423.

Hjalmarsson, L. and A. Veiderpass (1992a) Productivity in Swedish electricity retail distribution. *Scandinavian Journal of Economics* 94, pp.193-205.

Hjalmarsson, L. and A. Veiderpass (1992b) Efficiency and ownership in Swedish electricity retail distribution. *The Journal of Productivity Analysis* 3, pp.7-23.

Hjalmarsson, L. and F. R. Forsund (1993) Productivity in electricity generation in developing countries: An international comparison of far eastern power production. Presented at the EARIE conference, Tel-Aviv, Sept. 4-7.

Holmes, A. (1991) *Electricity in Europe: The triumph of free enterprise?.* London: Financial Times Business Information.

Jones, L., P. Tandon and I. Vogelsang (1990) *Selling public enterprises: A cost-benefit methodology.* London: MIT Press.

Joskow, P. L. and R. Schmalensee (1983) *Markets for power: An analysis of electrical utility deregulation.* London: The MIT Press.

Karatas, C. (1990) *Privatisation in Britain and Turkey.* Istanbul: Istanbul Chamber of Industry.

Karatas, C. (1995) Has privatisation improved profitability and performance of the public enterprises in Turkey. In P. Cook and C. Kirkpatrick (eds.)

Privatisation policy and performance: International perspectives. London: Prentice Hali.

Keiman, S. (1987) Pubiic choice and public spirit. *The Public Interest* 36, pp.80-94.

Kikeri, S., Neilis, J. and Shirley, M. (1992) *Privatisation: the lessons of experience.* Washington, DC.:World Bank.

Kirkpatrick, C. and O. Onis (1991) Turkey, In P. Mosley, J. Harringan and J. Toye (eds) *Aid and Power: the World Bank and Policy-Based Lending.* Vol. 2, London: Routledge.

Kolars, J. (1986) The hydro-imperative of Turkey's search for energy. *The Middle East Journal* 40:1, pp.53-67.

Kolars, J. F. and W. A. Mitchell (1991) *The Euphrates river and the south anatolia development project.* Carbondale: Southern Illinois University Press.

Kopp, R. J. and V. R. Schmidt (1980) Frontier production function estimates for steam electric generation: A comparative analysis. *Southern Economic Journal* 46:4, pp.1046-1059.

Koutsoyiannis, A. (1979) Modern Microeconomics. The MacMiiiian Press.

Lee, B. -J. (1995) Separability test for the eiectricity supply industry. *Journal of Applied Econometrics* 10, pp.49-60.

Leeds, R. (1988) Turkey: Rhetoric and reality. In R. Vernon (ed.) *The promise of privatisation: A challenge for US policy.* New York.

Leibenstein, H. (1966) Allocative efficiency versus X-efficiency. *American Economic Review* 56 (June), pp. 392-415.

Lovell, C. A. K. and P. Schmidt (1988) A comparison of alternative approaches to the measurement of productive efficiency. In A. Dogramaci and R. Fare (eds.) *Applications of modern production theory: Efficiency and productivity.* Boston: Kluwer-Nijhoff.

Megginson, W., L., R. C. Nash and M. V. Randenborgh (1994) The financial and operating performance of newly privatised firms: An international empirical analysis. *The Journal of Finance* XLIX:2, pp.404-452.

Miliotis, P. A. (1992) Data envelopment analysis applied to electricity distribution districts. *Journal of Operational Research Society* 43:5, pp.549-555.

Morgan Guaranty Bank (1986) *Privatisation master plan: SEEs recommended for sale, action plans.* Ankara: Morgan Guaranty Bank.

Munasinghe, M. (1990) *Electric Power Economics: Selected works.* Butterworth and Co (Publishers) Ltd.

Neuberg, L. G. (1977) Two issues in the municipal ownership of electric power distribution systems. *The Bell Journal of Economics*, pp.303-323.

Newbery, D. M. (1994) Restructurlng and privatising electric utilities in Eastern Europe. *Economics of Transition* 2:3, pp.291-316.

Oliveria de A. and G. MacKerron (1992) Is the World Bank approach to structural reform supported by experience of electricity privatisation in the UK? *Energy Policy*, pp.153-162.

Onis, Z. (1991a) The evolution of privatisation in Turkey: The Institutional context of pubiic-enterprise reform. *International Journal of Middle East Studies* 23, pp.163-176.

Onis, Z. (1991b) Privatisation and the logic of coalition building: a comparative analysis of state divestiture in Turkey and the United Kingdom. *Comparative Political Studies* 24(2), pp. 231-253.

Ordover, J. A., R. W. Pittman and P. Clyde (1994) Competition policy for natural monopolies in a developing market economy. *Economics of Transition* 2:3, pp.317-343.

Patton, M. J. (1992) Constraints to privatisation in Turkey. In I. Harik and D. J. Sullivan (eds.) *Privatisation and liberalisation in the Middle East.* Indiana: Indiana University Press.

Plehwe, D. and S. Beckert (1992) *Energy Privatisation and Deregulation*. ICEF.

Pollitt, M. G. (1993) The Relative Performance of Pubiiciy Owned and Privateiy Owned Electric Utilities: international evidence. DPhil thesis. University of Oxford.

Prager, J. (1992) Is privatisation a panacea for LDCs? Market failure versus public sector failure. *The Journal of Developing Areas* 26, pp.301-322.

Price, C. M. (1977) *Welfare economics in theory and practice*. The Macmillan Press.

Price, C. M. (1994) Privatisation in less developed countries. In Jackson, P. M. and C. M. Price (eds.) *Privatisation and regulation: A review of the issues*. London: Longman.

Rees, R. (1984) *Public sector economics*. London: Phiilip Alian.

Rousseau, J. J. and J. H. Sempie (1993) Categorical outputs in data envelopment analysis. *Management Science* 39:3, pp.384-387.

Schmalansee, R. (1979) *The control of natural monopolies*. Toronto: Lexington Books.

Seiford, L. M. (1990) A bibliography of data envelopment anaiysis (1978-1990) Version 5.0. Technicai Report (Department of Industrial Englneering. University of Massachusetts, Amherst MA).

Seiford, L. M. and R. M. Thrali (1990) Recent developments in DEA: The mathematical programming approach to frontier anaiysis. *Journal of Econometrics* 46, pp.7-38.

Sexton, T. R. (1986) The methodoiogy of data envelopment analysis. In R. H. Silkman (ed.) *Measuring efficiency: An assessment of data envelopment analysis*. San Fransisco: Jossey-Bass.

Sharkey, W. W. (1982) *The theory of natural monopoly*. Cambridge: Cambridge University Press.

Sharpe, T. (1983) The control of natural monopoly by franchising. *Public Money*, pp.17-66.

Shleifer, A. (1985) A theory of yardstick competition. *Rand Journal of Economics* 16:3, pp.317-327.

Siegei, S. and N. J. Castelian (1988) *Non-Parametric Statistics*. London: McGraw-Hiil Book Co.

Silkman, R. H. (1986) *Measuring efficiency: An assessment of data envelopment analysis*. San Fransisco: Jossey-Bass.

Sirtaine, S. (1994) Financing infrastructure in Asian developing countries: Attracting Asian capitai market investors in BOT scheme. Development Economics Research Programme No. 52, London School of Economics.

Tasdemir, E. (1988) Hydroelectric power potentials and its use in Turkey. *Energy* 13(7), pp. 549-556.

Tenenbaum, B., R. Lock and J. Barker (1992) Electricity privatisation: Structural, competitive and regulatory options. *Energy Policy*, pp. 1134-1160.

Toktas, K. (1993) Privatisation of eiectricity sector. *The Turkish Electrical Engineers Chamber* 38(392), pp.101-107 (in Turkish).

Turkish Eiectricity Statistics. (1991) Research and Planning Board. Ankara: The Turkish Electricity Authority. (In Turkish).

Varian, H. R. (1987) Intermediate microeconomics: A modern approach. New York: Norton.

Vickers, J. and G. Yarrow (1985) *Privatisation and the natural monopolies*. London: Pubiic Policy Centre.

Vickers, J. and G. Yarrow (1988) *Privatisation: An economic analysis*. London: MIT Press.

Vickers, J. and G. Yarrow (1991a) The British eiectricity experiment. *Economic Policy*, pp.187-227.

Vickers, J. and G. Yarrow (1991b) Economic perspectives on privatisation. *Journal of Economic Perspectives* 5:2, pp.111-132.

Vining, A. R. and A. Boardman (1992) Ownership versus competition: Efficiency in public enterprise. *Public Choice* 73, pp.153-162.

Waterson, M. (1988) *Regulation of the firm and natural monopoly*. Oxford: Blackwell.

Weyman-Jones, T. G. (1991) Productive efficiency in regulated industry: The area electricity boards of England and wales. *Energy Economics* 13, pp.116-122.

Weyman-Jones, T. G. (1992) Problems of yardstick regulation in electricity distribution. To appear in M. Bishop, J. Kay, C. Mayer and D. Thompson (eds.) *Privatisation and Regulation II*. Oxford: Oxford University Press.

Weyman-Jones, T. G. (1994) Deregulation. In P. M. Jackson and C. M. Price (eds.) *Privatisation and regulation: A review of the issues*. London: Longman.

Williamson, O. (1976) Franchise bidding for natural monopolies-in general and with respect to CATV. *Bell Journal of Economics* 7, pp.73-104.

Yaisawarng, S. and J. D. Klein (1994) The effects of sulphur dioxide controls on productivity change in the US electric power industry. *The Review of Economics and Statistics,* pp.447-460.

Yarrow, G. (1994) Privatisation, restructuring, and regulatory reforms in eiectricity supply. In M. Bishop, J., Kay, and C. Mayer (eds) *Privatisation and economic performance*. Oxford: Oxford University Press.