

# Stochastic Frontier Estimation: an Application to Local Governments in Malaysia<sup>#</sup>

FATIMAH WATI Ibrahim and MOHD FAISOL Md Salleh\*  
*Universiti Utara Malaysia*

**Abstract:** The purpose of this paper is to estimate the level of efficiency of local governments in Malaysia in providing public goods and services. The study employs the frontier technique to measure efficiency. The study involved 99 local governments in Peninsular Malaysia, categorised into three components: City councils, municipalities and district councils. The results of the study indicate that local councils are inefficient in providing local public goods and services. The cost efficiency scores range from 0.145 to 1.643 with Jempol District Council being the least inefficient. The results also indicate that municipal councils are more inefficient than district councils.

Keywords: Cost efficiency, Local government, frontier technique

JEL classification: C13, H11, H70

## 1. Introduction

In the age of rapid urbanisation and globalisation, the local governments in Malaysia must be more responsive to the public needs and demands of local population. As instruments of national development, the ability of local authorities to manage change, deliver their functions efficiently and assume a more developmental role effectively is an imperative for local governments to excel in the new millennium.

The move towards having a better and more conducive environment and thus uplift the quality of life is an important agenda of local development. This becomes more apparent in the era of a knowledge society. In view of the growing expectations from the general public and their concerns about quality public goods and services provided by local governments, the need to evaluate the performance of local governments is essential.

At the local level, local government play a crucial role in providing public goods and services that are specific to the localities. In Malaysia, the local governments are categorised into three groups: City council for city centres, municipality for large towns and district council for small urban centres. As at 2000, there were a total of ninety-nine local governments in Peninsular Malaysia comprising four city councils, nineteen municipal councils and seventy-six district councils. They are formed and regulated by the respective state legislation and subordinate to the respective state governments. The Local Government Act of 1976 provides local authorities in Malaysia with a very comprehensive set of functions and responsibilities. The major function of the local governments is to provide public goods

---

\* Faculty of Economics, Universiti Utara Malaysia, 06010 UUM Sintok, Kedah Darul Aman, Malaysia.

<sup>#</sup> The authors are grateful for comments by an anonymous referee. This research was financially supported by a university research grant from Universiti Utara Malaysia which is gratefully acknowledged.

and services that are specific to the localities. Local public services that are undertaken by them on behalf of the respective state governments include both mandatory and discretionary functions. The mandatory functions include all critical functions such as refuse collection, maintenance of minor drainage, sewerage treatment, road maintenance, street lighting and activities pertaining to public health. Discretionary functions include all development function such as providing amenities, recreational parks, housing and commercial activities, markets, sports facilities and community centres. The sources of revenue for local governments mainly come from federal grants and also from state specific grants that include road maintenance grant, economic development grant and property tax.

At issue is the concern over the extent of efficiency of local governments in Malaysia in providing public goods and services. Proponents of the decentralisation system argue that local responsibility allows for a better match between public services and the preferences of a diverse citizenry, and an effective means to control the overall growth of government. On the other hand, one view of local government maintains that local governments are unable to influence performance because they are inefficient and do not minimise cost when making production decisions (Deller 1992). They worry less about bearing the costs of their decisions than do their private sector counterparts. Within that framework and the continuing debates that is ongoing, the ability to quantify efficiency will provide important insights into the determinants of inefficiencies and lead to a richer understanding of the sources of improvements in local government performance.

Since the efficiency scores are performance indicators in measuring the optimal provision of local public goods and services, our focus in this study is to measure and explain the performance of local governments in Malaysia by employing the tools of modern production economics and efficiency measurement. To date, very few studies have focused on the efficiency measures of local governments in Malaysia. An attempt to measure efficiency will shed light on the sources of inefficiency and the productivity differentials among the local governments. Therefore, a study on the efficiency of local governments is worthy of investigation and timely.

In general, the objective of this paper is to study the performance of local governments in Malaysia. The study focuses on efficiency analysis of local governments in the provision of local public goods and services by employing the frontier technique to measure the level of efficiency of the institutions. Specifically, the objectives are to calculate indices of cost efficiency (technical efficiency) using a parametric econometrics approach; and to estimate the technical efficiency,  $U_i$ , for each observation of local government in Peninsular Malaysia.

The rest of the paper is organised as follows. Section 2 reviews existing literature on efficiency analysis and also efficiency of local governments. Section 3 presents the method of estimating cost efficiency using the econometric approach. Section 4 describes the data used in the study and the findings of the study. Finally, Section 5 concludes.

## 2. Review of Literature

It is well understood that the improved performance of local governments is seen as a success indicator in measuring the optimal provision of local public goods and services. This performance is viewed to be a function of the state of technology and economic efficiency. The state of technology describes a frontier relationship between inputs and outputs, while economic inefficiency incorporates waste and misallocation relative to this frontier.

Economic efficiency occurs when a given amount of resources produces the most valuable combination of outputs possible. Allocative efficiency requires production of the things people want, productive (technical) efficiency is obtained when a given output is produced at the lowest possible cost and the distributive efficiency addresses who will use the specific output. It requires a person who values relatively the most used specific goods.

A theoretical discussion of inefficiency is given by Forsund *et al.* (1980). They also present a survey of econometric frontier models and relate that to efficiency measurements. Kopp and Diewert (1982) suggest a method to decompose frontier cost function deviations into technical and allocative components. They illustrate their technique with a Cobb-Douglas and non-homothetic translog cost functions. However, this technique is only applicable to a deterministic frontier. A further modification is needed for a stochastic frontier. A solution to the problem of estimating technical efficiency,  $\mu_i$ , has been suggested by Jondrow *et al.* (1982). They proposed a method of separating the error term of the stochastic frontier model into its two components for each observation. This enables one to estimate the level of technical efficiency for each observation in the sample.

In the case of Kalirajan (1990), the specification model is based on a translog production function functional form in estimating the inefficiency term. Inefficiency is identified with the disturbance term in the regression model. Cornwell *et al.* (1990) employs the random effects approach in the regression analysis using Generalised Least Squares (GLS). One advantage of the random effects model is that it allows time-invariant firm-specific attributes to enter the model. Greene (1993) elaborates and provides an extensive survey of the received techniques in estimating economic efficiency using an econometric approach.

Measurements of efficiency have been applied to many sectors. Deller (1992), Eeckaut *et al.* (1993) and Borger and Kerstens (1996) studied the efficiency of local governments. Deller (1992) examined the managerial capacity of local government officials to produce low-volume rural road service in an economically efficient manner using a sample of Mid-western townships. The findings suggest that costs may be 15 per cent higher than necessary due to production inefficiencies. In the study on cost efficiency of Belgian local governments, Borger and Kerstens (1996) utilised five output indicators to capture important aspects of the services provided by Belgian municipalities. The following indicators were used: the number of beneficiaries of minimal subsistence grants; the number of students enlisted in local primary schools; the surface of public recreational facilities; the total population; and the fraction of the population older than 65 years old. The authors caution that these 'output' variables are only crude proxies for the services delivered by municipalities since there is lack of better local government data in Belgium.

In the United Kingdom, all councils are required by law to measure their performance against targets set by the government. They utilise the citizen's charter performance indicators as an instrument to measure how councils perform with respect to their tasks. Some of the councils' major functions are dealing with the public, waste disposal, looking after the local environment, providing social services, refuse collection, leisure and recreation, and maintaining highways and streetlights (*Bristol News*, 1999).

Bauer *et al.* (1993), Yuengert (1993) and Cummins and Weiss (1993) focussed their efficiency studies on the financial services industry. Bauer *et al.* (1993) estimate individual bank inefficiencies for a panel data of 683 large U.S. branching state banks for the year 1977

to 1988. They employed a stochastic econometric approach and thick frontier approach, and the results show an average inefficiency of 15 per cent for the entire time period. Yuengert (1993) used a mixed normal-gamma error model in measuring X-inefficiency in life insurance companies. His study found a substantial amount of X-inefficiency in the industry, but the differences across firm size were insignificant. Costs, on average, were 35-50 per cent above the cost frontier. In the study by Cummins and Weiss (1993), the cost frontiers for three size-stratified samples of property-liability insurers over the period 1980-1988 were estimated using maximum likelihood technique. The results showed that large insurers operate on an average efficiency level of 90 per cent relative to the cost frontier. Efficiency levels for medium and small insurers were about 80 and 88 per cent in relation to their respective frontiers.

### 3. Theoretical Framework

An efficient local government is assumed, on its outer-bound production function, to obtain the maximum possible output using current technology. Under certain regularity conditions, this is equivalent to operating on its cost frontier, which gives the minimum level of cost for each level of output, taking input prices as given. Any deviations from the frontiers can be regarded as inefficiency, that is, local governments operating below the production frontier or above the cost frontier are said to be inefficient. Inefficiency may be due to cost efficiency (technical efficiency), that is, the result of excessive usage of inputs, and allocative efficiency if the local government uses inputs in the wrong proportions.

#### 3.1. Methodology

In analysing the efficiency of local governments in Malaysia, the study focused on the cost effectiveness of producing public goods and services. The parametric econometric approach was utilised to estimate cost efficiency of the local governments. The study focused on the cost function representations of the technology. The cost structure of producing local public goods and services is modelled as follows:

For an arbitrary observation  $i$ , the cost function,  $C = f(y, w, X; \beta)$  defines a lower bound to the expenditures  $C_i$  necessary to produce a given vector of outputs,  $y$ , for given input prices  $w$ .  $X$  refers to the other determinants of the local government's costs. The parameter vector  $\beta$  is to be estimated.

For the deterministic cost frontier model, it is assumed that any deviation of observed cost  $C_i$ , from the frontier  $C(.)$  can be attributed to technical efficiency. The model can be written as follows:

$C_i = C(y_i, w_i, X_i; \beta) = C_i^* U_i$  in which  $U_i$  is a random disturbance,  $U_i \geq 0$ . The measure of cost efficiency ( $CE$ ) for observation  $i$  is:

$$CE_i = C_i / C_i^* = U_i = e^{-ui}$$

where  $C_i$  refers to the observed cost and  $C_i^*$  is the minimal possible cost.

The stochastic cost frontier model offers a more flexible approach to the specification of the frontier model. Its parametric frontiers are based on a composed error model that allows us to differentiate between cost efficiency and the other stochastic influences. The stochastic cost frontier model is defined as follows:

$$C_i = C(y_p, w_p, X_i; \beta) + V_i + U_i + A_i = C_i^* (V_i + U_i + A_i)$$

Any errors in optimisation would have to translate into higher costs of production over the theoretical norm. Deviations from the cost frontier could then be interpreted as the total of technical and allocative efficiency. The measure of cost efficiency for observation  $i$  is

$$CE_i = C_i / C_i^* = V_i + U_i + A_i$$

where

- $V_i$  = stochastic variation in the frontier
- $U_i$  = technical efficiency,  $U \geq 0$ , and
- $A_i$  is strictly attributable to allocative efficiency,  $A \geq 0$ .

### 3.2. Specification of the Cost Function

Since the form of the cost function of the local councils is not known, we adopted two functional forms of cost function for the purpose of this study as specified below:

(a) Cobb-Douglas Cost Function:

$$\ln C = \alpha_0 + \sum \beta_i \ln Y_i + v + u \tag{1}$$

(b) Translog Cost Function:

$$\ln C = \alpha_0 + \sum \beta_i \ln Y_i + \sum \sum \gamma_i \ln Y_i \ln Y_j + v + u \tag{2}$$

### 3.3. Estimating Cost Efficiency

Several regression procedures are available to estimate the deterministic and stochastic cost frontiers. The techniques of corrected ordinary least squares and maximum likelihood are employed depending on the assumed distribution of the cost efficiency component.

To estimate the cost efficiency term for every observation in the sample, we proceeded as follows: First, the parameters of the cost functions of equations (1) and (2) were estimated using ordinary least squares (OLS). The stochastic frontier also known as ‘composed error’ model postulates that the error term,  $\varepsilon_p$  is made up of two independent components,  $v_i$  and  $u_i$ . The next step then, is to extract an estimate of efficiency from the estimated residual,  $\varepsilon$  (hat). We followed the procedure proposed by Jondrow *et al.* (1982). Three models on the distribution of  $(A_i + U_i)$  conditional on  $\varepsilon_i$  were assumed: normal-half-normal model, normal-exponential model, and normal-truncated (at 0) normal. The mean,  $E(u)$  of this distribution can provide a measure of cost efficiency.

## 4. Data and Empirical Results

The local governments in Peninsular Malaysia that we studied comprised 4 city councils, 19 municipal councils and 76 district councils. The study utilised both primary and secondary data. Since the population of the local governments in Peninsular Malaysia is not large, this study employed the population of local governments as units of analysis.

The total operating expenditure data of each local government was employed to measure the aggregate total cost incurred by local governments in supplying their local public

goods and services. The source of data on expenditure was available from the financial statement reports of the local governments. Labour was the input used in our analysis since we were unable to obtain data on capital. The price of labour was calculated as the total labour cost divided by the number of personnel.

Data on output indicators to measure the level of public goods and services provided was used as a proxy indirectly to reflect the expenditure areas most visible to the general public. Since we did not have a direct measure to quantify the local public goods and services provided by local governments, the following indicators were utilised to proxy the output indicators: The output measure that we used in our analysis were the number of public toilets, number of parking lots, number of stall spaces, amount of waste disposed, number of trees planted, total population to reflect the basic administrative services provided to the local population and the length of road (kilometre) to reflect on the road maintenance provided by local governments. These output variables are a modification of the citizen's charter performance indicators of the local councils of United Kingdom that attempted to capture the relevant aspects of local public goods and services provided by Malaysian local governments. As noted by Borger and Kerstens (1996), these variables should be considered as crude proxies for the local public goods and services provided by local councils as quality local governments data in Malaysia are lacking.

A survey instrument was utilised to obtain information on these local public goods and services provided by local governments. It included information on public facilities such as public toilets, parks and recreation, sports facilities and community centres; refuse collection; and taking care of the local environment. The survey was conducted in the year 2000. The questionnaires were distributed to all local governments throughout Peninsular Malaysia. However, some of the local governments did not respond to the questionnaires. Only 67 out of 99 local governments responded to the questionnaires (or 67.7 per cent response rate). Of this number, a total of 21 local governments did not provide information on the amount of emoluments that was required to estimate the wages for the said institutions. Thus, our data set for efficiency analysis comprised a cross-section of only 46 local governments. Data collected was analysed using the LIMDEP package.

The descriptive statistics of the input and output measures of the 46 local governments are presented in Table 1. As shown in the table, on average, the total cost incurred by local government in providing public goods and services was about RM 10.8 million.

The outputs of the estimation procedure consist of estimates of the frontiers. These results are shown in Table 2 and Table 3. Table 2 gives the ordinary least squares (OLS) estimates of the stochastic cost frontier, estimated using Equation (1), under the assumption of half normal disturbances, and Table 3 gives the maximum likelihood estimates (MLEs).

For all eight indicators, the estimated coefficients have the expected signs except for the wage variable. Three of the indicators (number of parking lots, disposal weight and number of trees planted) were also statistically significant at 0.05 per cent significant level.

From the tables, it can be observed that the estimates of the parameters of the cost function obtained with OLS and MLE are roughly similar and consistent.

What is more of interest in this paper is the estimation of models of  $\varepsilon$ , the error term. Table 4 summarises the estimates of cost efficiency,  $E(u | (v+u))$ , the expected value of  $u$  conditional on the distribution of  $v+u$ , by maximum likelihood using Equation (1) for half normal, exponential and truncated normal models. The results for our data show that the

**Table 1:** Descriptive statistics of sample local governments

Variable	Mean	Minimum	Maximum	Std. Deviation
Total cost (in RM)	10,848,179.9	751,794.6	106,536,576.0	17,565,548.0
No. of public toilets (V7)	9.1	1	40	7.7
No. of parking lots (V12)	1,839	0	18,505	3,117.5
No. of stall space (V18)	524.6	0	2,800	661.4
Disposal weight (in kg)(V25)	33,684.4	400	216,000	47,652.6
No. of trees planted (V26)	5,677.1	300	50,000	9,177.1
Population (TP)	127,900.2	16,981	475,000	113,835.9
Road length (in km) (RD)	112.64	0	554.21	121.88
Wages (WG)	11,104.10	6,094.34	234,271.41	3,317.12

**Table 2.** Ordinary least squares estimates of the stochastic cost frontier

Limited Dependent Variable Model

Ordinary least squares regression

Weighting variable = none

Dep. var. =  $\ln C$  Mean= 15.5225 , S.D.= 1.1240

Model size: Observations = 46, Parameters = 9, Deg.Freedom= 37

Residuals: Sum of squares= 14.7044 , Std.Dev.= .63041

Fit: R-squared= .7413, Adjusted R-squared = .6854

Model test:  $F[8,37] = 13.26$ , Prob value = .00000

Diagnostic: Log-L = -39.0398, Restricted(b=0) Log-L = -70.1417

LogAmemiyaPrCr.= -.744, Akaike Info. Cr.= 2.089

Variable	Coefficient	Standard error	b/s.e.	$P[ Z >z]$	Mean of X
Constant	11.9852	3.0215	3.967	.0001	
$\ln V7$	.2904	.1594	1.822	.0685	1.9178
$\ln V12$	.1897	.0443	4.285	.0000	5.7684
$\ln V18$	-.0028	.0465	-0.060	.9520	4.9765
$\ln V25$	.1768	.0701	2.522	.0117	9.3833
$\ln V26$	.2770	.1050	2.637	.0084	7.9853
$\ln TP$	.1171	.0734	1.596	.1106	-10.5637
$\ln RD$	-.1196	.0740	-1.617	.1058	-17.9263
$\ln WG$	-.3105	.3484	-0.891	.3729	9.2730

distributions of the half-normal, exponential and truncated normal are consistent. The local government-specific means of estimated cost efficiency for the truncated normal model exhibits greater sensitivity compared with the other two models, whereas the exponential model is the least sensitive.

The measure of technical efficiency varies from 0 to a positive number. The benchmark of the measure or best-practise frontier is 0 per cent inefficient. As shown in Table 4, the average level of cost efficiency of local governments in Peninsular Malaysia is 0.59. This means that, on average, the observed cost of the local government is 59 per cent more inefficient than the best practise cost. This cost efficiency rises due to the excessive usage of inputs.

**Table 3:** Maximum likelihood estimates of the stochastic cost frontier

Limited Dependent Variable Model - Maximum Likelihood Estimates		FRONTIER			
Dependent variable		<i>lnC</i>			
Weighting variable		ONE			
Number of observations		46			
Iterations completed		18			
Log likelihood function		-38.4771			
Variances: Sigma-squared(v)=		.1278			
Sigma-squared(u)=		.5390			

  

Variable	Coefficient	Standard error	b/s.e.	P[ Z >z]	Mean of X
<u>Primary Index Equation for Model</u>					
Constant	12.0763	3.0793	3.922	.0001	
<i>ln V7</i>	.2779	.1818	1.528	.1265	1.9178
<i>ln V12</i>	.1849	.0672	2.751	.0059	5.7684
<i>ln V18</i>	-0.0089	.0565	-0.158	.8745	4.9765
<i>ln V25</i>	.1794	.0850	2.111	.0348	9.3833
<i>ln V26</i>	.2878	.0864	3.332	.0009	7.9853
<i>ln TP</i>	.0947	.0856	1.106	.2687	-10.5637
<i>ln RD</i>	-0.0972	.0768	-1.266	.2056	-17.9263
<i>ln WG</i>	-0.3687	.3767	-0.979	.3276	9.2730
<u>Variance parameters for compound error</u>					
Lambda	2.0537	1.0721	1.916	.0554	
Sigma	.8166	.1911	4.274	.0000	

The cost efficiency scores of the local councils shown in Table 4 are ranked from the most efficient to the least efficient local councils. The finding shows that Jempol District Council is the least inefficient in providing public goods and services, while Petaling Jaya Municipal Council is relatively the most inefficient. The results also indicate that the inefficiency scores of the municipality councils are higher than the district councils.

### 5. Conclusion

This paper presents an analysis of cost efficiency of local governments in Peninsular Malaysia in the provision of local public goods and services using a parametric econometrics approach. Our study suggests that most of the local governments are cost inefficient, with the scores ranging from 0.145 to 1.643, and the average inefficiency scores of the local councils in Peninsular Malaysia is 0.59. This means that on average the observed cost of the local government is 59 per cent more inefficient than the best practise cost. This cost efficiency rises due to excessive usage of inputs. Furthermore, the results also indicate that municipality councils are more inefficient than district councils.

**Table 4:** Local government-specific means of estimated inefficiencies,  $E[u | (v+u)]$  by maximum likelihood estimates of stochastic cost frontiers

Municipal/District Council Model	Half-Normal Model	Exponential Normal	Truncated
Jempol District Council	0.1446	0.1245	0.1669
Rembau District Council	0.178	0.1437	0.2076
Bandar Baharu District Council	0.2029	0.1559	0.2305
Gua Musang District Council	0.2117	0.1562	0.2352
Muar Selatan District Council	0.2245	0.1629	0.2514
Lipis District Council	0.2261	0.1633	0.2493
Pontian District Council	0.2326	0.1685	0.2686
Sungai Petani Municipal Council	0.2628	0.1785	0.2908
Pasir Mas District Council	0.2962	0.1964	0.3265
Machang District Council	0.305	0.2021	0.3443
Kuala Kangsar District Council	0.3262	0.2096	0.3648
Jelebu District Council	0.3297	0.2131	0.3627
Jeli District Council	0.333	0.217	0.3668
Dungun District Council	0.3354	0.2179	0.373
Kota Setar Municipal Council	0.347	0.2117	0.3749
Tapah District Council	0.3583	0.2274	0.3917
Kinta Selatan District Council	0.3593	0.2243	0.4037
Segamat Utara District Council	0.4085	0.2443	0.4562
Setiu District Council	0.4334	0.2599	0.4677
Kuala Krai Selatan District Council	0.4564	0.2703	0.4938
Rompin District Council	0.4626	0.2686	0.5011
Besut District Council	0.4763	0.2796	0.5089
Kulai District Council	0.4958	0.2808	0.5434
Batu Pahat Timur District Council	0.5162	0.3051	0.5648
Hilir Perak District Council	0.5431	0.3011	0.5699
Langkawi District Council	0.5462	0.2918	0.5683
Kota Tinggi District Council	0.5784	0.3222	0.6281
Tanah Merah District Council	0.5848	0.3192	0.6106
Tanjung Malim District Council	0.6664	0.3616	0.6954
Kinta Barat District Council	0.6894	0.3803	0.7206
Manjung District Council	0.7134	0.3862	0.7302
Kemaman District Council	0.7388	0.4089	0.7582
Muar Utara District Council	0.7622	0.4154	0.8022
Batu Pahat Barat District Council	0.7718	0.4218	0.8014
Temerloh Municipal Council	0.8497	0.46	0.8531
Seremban Municipal Council	0.8594	0.4725	0.8682
Maran District Council	0.8653	0.4832	0.8854
Kluang Utara District Council	0.8724	0.4687	0.8892
Malacca Historical City Council	0.9227	0.5051	0.8932
Taiping Municipal Council	0.9232	0.5303	0.9298
Kuala Trengganu Municipal Council	1.02	0.5692	1.0051
Jerantut District Council	1.2518	0.8283	1.2152
Kuantan Municipal Council	1.3642	0.881	1.307
Kluang Selatan District Council	1.4753	1.0932	1.4668
Petaling Jaya Municipal Council	1.643	1.2329	1.5796
<b>Average</b>	<b>0.5903</b>	<b>0.3603</b>	<b>0.6116</b>

The above findings suggest that appropriate corrective measures to improve the efficiency of local authorities should be given high priority, especially by the Municipal Councils. Generally, inefficiency improvement of local authorities is subject to successful identification of the causes of inefficiency. As this study does not identify the variables causing inefficiency, we could only suggest that the local authorities concentrate on measures that will bring down the cost to a minimum for any given level of goods and services provided. Future research might want to focus on identifying the economic, social and political factors, which may help to explain inefficiency and the variables that have contributed significantly to such inefficiency for policy recommendation.

## References

- Ahmad Mahdzan Ayob. 1997. *Kaedah Penyelidikan Sosioekonomi*. Kuala Lumpur: Dewan Bahasa dan Pustaka, Kuala Lumpur, p. 64.
- Ali, A. I. and L. M. Seiford. 1993. The mathematical programming approach to efficiency analysis. In *The Measurement of Productive Efficiency: Techniques and Applications*, ed. H. Fried, C. A. K. Lovell and S. Schmidt. Oxford: Oxford University Press.
- Bauer P.W., A.N. Berger and D.B. Humphrey. 1993. Efficiency and productivity growth in U.S. banking. In *The Measurement of Productive Efficiency: Techniques and Applications*, ed. H. Fried, C. A. K. Lovell and S. Schmidt. Oxford: Oxford University Press.
- Borger, B.D. and K. Kerstens. 1996. Cost efficiency of Belgian local governments: a comparative analysis of FDH, DEA, and econometric approaches. *Regional Science and Urban Economics* **26**: 145-170.
- Bristol News*. No. 33 November 1999. Newsletter of Bristol City Council.
- Cornwell, C., P. Schmidt and R. Sickles. 1990. Production frontiers with cross-sectional and time series variation in efficiency levels. *Journal of Econometrics* **46**: 185-200.
- Cummins J.D. and M.A. Weiss. 1993. Measuring cost efficiency in the property-liability insurance industry. *Journal of Banking and Finance* **17**: 463-481.
- Deller, S.C. 1992. Production efficiency in local government: a parametric approach. *Public Finance* **47(1)**: 32-44.
- Don A. Dillman. 1972. Increasing mail questionnaire response in large samples of the general public. *Public Opinion Quarterly* : 254-57.
- Donald R. Cooper and C. William Emory. 1995. *Business Research Methods*. USA: Irwin Inc, p. 282.
- Eeckaut, P.V., H.Tulkens and M.A. Jamar. 1993. Cost efficiency in Belgian municipalities. In *The Measurement of Productive Efficiency: Techniques and Applications*, ed. H. Fried, C. A. K. Lovell and S. Schmidt. Oxford: Oxford University Press.
- Farrell, M.J. 1957. The measurement of productive efficiency. *Journal Royal Statistical Society (A: general)* **120**: 253-81.
- Ferrier, G. and K. Lovell. 1990. Measuring cost efficiency in banking: econometric and linear programming evidence. *Journal of Econometrics* **46**: 229-245.
- Forsund F.R., C.A.K. Lovell and P. Schmidt. 1980. A survey of frontier production functions and of their relationship to efficiency measurement. *Journal of Econometrics* **13**: 5-25.
- Fried, H.O., C.A.K. Lovell and S. Schmidt. 1993. *The Measurement of Productive Efficiency: Techniques and Applications*. Oxford: Oxford University Press.
- Greene, W. 1993. The econometric approach to efficiency analysis. In *The Measurement of Productive Efficiency: Techniques and Applications*, ed. H. Fried, C. A. K. Lovell and S. Schmidt. Oxford: Oxford University Press.
- Jondrow, J., C.A.K. Lovell, I.S. Materov and P. Schmidt. 1982. On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics* **19**: 233-238.

- Kalirajan, K. 1990. On measuring economic efficiency. *Journal of Applied Econometric* **5**(1): 75-86.
- Kopp, R. and W. Diewert. 1982. The decomposition of frontier cost function deviations into measures of technical and allocative efficiency. *Journal of Econometrics* **19**: 319-332.
- Yuengert, A. M. 1993. The measurement of efficiency in life insurance: estimates of a mixed normal-gamma error model. *Journal of Banking and Finance* **17**: 483-496.