The Measurement of English and Welsh Police Force Efficiency: A Comparison of Distance Function Models.

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Abstract

Since the Labour government came to power in 1997, it has introduced a regime whereby public services are accountable in respect of best value performance indicators (BVPIs). A recent Public Services Productivity Panel (PSP) (2000) report has developed a set of criteria whereby the economic analysis of police force efficiency by the Home Office is to be made standard. In this paper we utilise an innovative distance function strategy in contrast to the standard efficiency techniques (Data Envelopment Analysis and Stochastic cost Frontier Analysis) advocated in PSP (2000). We present results from four different distance function models; Data Envelopment Analysis; Free Disposal Hull; Super-Efficiency; and Stochastic Frontier Analysis; in order to assess police force efficiency during the sample period 1996 – 1999.

Keywords: DEA; Parametric distance functions; Technical Efficiency; English and Welsh Police Forces

1. Introduction

Since being elected in 1997, the Labour government has carried on the agenda of promoting efficiency in the police force, first instigated by the previous Conservative

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government (see the Home Office Inspectorate of Constabulary (HMIC) (1998) report "What Price Policing"). The latter report reiterated the previous Conservative government's efficiency drive in the police service with the HMIC arguing that, "police managers need to work harder to ensure that VFM [value for money] is achieved, for competitive pressure has to be created internally. The costing of activity with subsequent measurement and comparison of performance provide the means by which such encouragement is given" (para. 10). As an example of this drive for efficiency and VFM, since the fiscal year 1998/99, the Home Secretary has set targets such that each police force must identify efficiency gains of at least 2% year-on-year and channel these funds into their front-line delivery.

The initial 'modern' review of police efficiency, under the Conservatives, resulted in several publications including: Audit Commission (1990); Home Office (1993); Police Research Group (1993) and the Sheehy (1993) report which led to recommendations included in The Police and Magistrates' Courts' Act 1994. One of the main recommendations of the Sheehy Report was to change the nature of police management from a public to a business-orientated organisation and to introduce efficiency targets co-ordinated with Local Police Authorities (known as Key Performance Indicators (KPIs)). These KPIs were refocused under the new Labour government in 1998/99 to include; youth offending; local partnerships to enable a reduction in crime; and reducing drug related crime, which came about as a result of the Crime and Disorder Act 1998. Since 1999. these KPIs have been updated in response to the Macpherson Report on the death of Stephen Lawrence. The new updated KPIs to be implemented after June 2000 include the additional aim to increase the "trust and confidence in policing amongst minority ethnic communities" (Report of Her Majesty's Chief Inspector of Constabulary 1999/2000).

Recently, the issue of police force efficiency has assumed considerable importance in respect of police funding, as outlined in the Public Services Productivity Panel (PSP) (2000) report "Improving Police Performance".[1] In this report it was argued that the "top performers should get a tangible reward," such that they are given

[1] Both authors of this paper were advisers on drafts of the Public Services Productivity Panel report.

"preferential access to discretionary funding mechanisms, such as the Crime Fighting Fund. This type of approach would also ensure that the extra funding available would be going to those forces that have the track record to show that they could do the most with it." (page. 39). It was also argued that non-parametric techniques, such as Data Envelopment Analysis (DEA), and parametric cost function models, such as the Stochastic Frontier Approach (SFA), should be used in tandem. The results from these models are to be utilised in order to rank forces and hence provide a basis for distributing extra funds to efficient forces. The results will also enable HMIC investigators to assess those forces which lag, in efficiency terms, behind their peers. Indeed, the across the board 2% efficiency gains introduced by the Home Secretary are to be phased out in April 2002 and replaced by differential targets set for individual forces.

It is the aim of this paper to introduce a little used method of efficiency measurement that can complement, and overcome problems inherent in, some of the methods proposed in the PSP (2000). In this study, therefore, we analyse police force efficiency using the distance function concept first introduced by Shepherd (1970), rather than the cost function approach favoured in PSP (2000). We maintain that the distance function approach is highly appropriate for the analysis of the efficiency of public sector services as it permits relative efficiency analysis in a multi-input, multi-output context.

In contrast, the cost function approach requires information on input prices as well as total costs and outputs, and data on the former are generally difficult to obtain for public services such as policing. In calculating a premises related input price for a public sector service such as the police force, for example, a general difficulty arises in respect of the valuation of the capital stock or fixed assets, used in the denominator in the calculation of the price variable. Prior to 1992, almost all buildings used by police forces were owned by local councils. After the Sheehy report, however, many forces took over the assets once in control of local authorities, but these properties were typically not re-valued, and many would distort a capital price variable because of the age and prime site location of many of the inherited buildings, (see Audit Commission (1999)).

The distance function approach utilised in this paper overcomes these difficulties by requiring data on inputs and outputs, but not input prices. Furthermore, our use of the distance function concept allows us to contrast the results from non-parametric approaches, such as Data Envelopment Analysis (DEA), with those of a parametric technique, Stochastic Frontier Analysis (SFA), as recommended in the PSP (2000) report. In contrast to the PSP report, however, we advocate the use of SFA with a parametric distance function rather than a parametric cost function.

The remainder of the paper is organised as follows. In Section 2 we introduce the four distance function methods utilised to estimate efficiency measurement of police forces. The data utilised in this paper is presented in Section 3, together with a discussion of the difficulties of measuring police inputs and outputs. The results from the four models are presented in Section 4 and we conclude with Section 5.

2. Methodology

Although both stochastic production functions and stochastic cost functions have been widely used in empirical research, both have drawbacks with respect to measuring relative efficiency in the provision of public sector services such as policing. The stochastic production frontier approach has the disadvantage that, as output is the dependent variable, only a single output production process can be modelled. This is clearly not appropriate in policing as police forces deliver a range of services or outcomes. Furthermore, it would be very difficult to construct an appropriate composite output (outcome) measure.

The usual solution to this problem in empirical applications is to make use of the duality between cost and production functions and to specify and estimate a stochastic cost frontier. This permits the modelling of a multi-input, multi-output production process. A particular drawback in utilising a cost function specification to model public sector services such as policing, however, is that this requires data on total costs, outputs and input prices. While the latter are generally available for some inputs such as labour (staff), they are typically not available for capital inputs as this requires data on both capital expenditure and the units of capital utilised (see Drake and Simper (1999b)). A further potential drawback of the stochastic cost frontier approach is that any non-random deviations above the cost frontier will be associated with both allocative and technical inefficiency. In contrast, the relative efficiency measures derived from the non-parametric methodologies such as DEA and Free Disposal Hull (FDH) typically relate only to technical efficiency. Hence, the relative efficiency measures derived from parametric and non-parametric approaches are often not directly comparable.

A potential solution to these problems, but one which has not been widely used empirically, it to employ a parametric approach, but to specify and estimate a stochastic distance frontier rather than a stochastic cost or production frontier. The distance function specification has the advantages of permitting the modelling of a multi-input, multi-output production process, and being a function only of outputs and inputs. Hence, the distance function does not require data on input prices. Furthermore, as it is a function of outputs and inputs, the stochastic distance frontier produces a relative efficiency measure that is directly comparable to the measure of technical efficiency produced by Data Envelopment Analysis (DEA) and/or Free Disposal Hull (FDH). For an introduction to the distance function concept see Cornes (1992), and for an empirical application see Coelli and Perlman (1999).

The input oriented distance function can be interpreted as the greatest radial contraction of the input vector, with the output vector held fixed, such that the input vector still remains in the input requirement set V(y).

$$D_I(x, y) = \max\{\rho : (x/\rho) \in V(y)\} \tag{1}$$

The distance function $D_I(x, y)$ will take a value which is greater than or equal to unity if the input vector, *x*, is an element of the feasible input set, and will take a value of unity if x is located on the inner boundary of the input requirement set. In order to be consistent with the subsequent DEA and FDH analysis, we employ the input orientated distance function. As this produces a measure which is the inverse of the Farrell (DEA) efficiency measure, however, we report the reciprocal of the input distance function measure in order that the results are directly comparable with the DEA measures, which are defined to lie between zero and unity, or between zero and 100. As the latter facilitates a percentage inefficiency interpretation, all subsequent efficiency measures will be expressed relative to a maximum score of 100 rather than unity.

Stochastic Input Distance Frontier (SIDF).

In this paper we employ the popular Translog flexible functional form, where the input distance function with 4 outputs and 3 inputs can be expressed as:

$$\ln D_{Ii} = const + \sum_{i=1}^{4} a_i \ln y_i + \tfrac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4} s_{ij} \ln y_i \ln y_j + \sum_{m=1}^{3} b_m \ln x_m$$

$$+ \tfrac{1}{2}\sum_{m=1}^{3}\sum_{n=1}^{3} \gamma_{mn} \ln x_m \ln x_n + \tfrac{1}{2}\sum_{i=1}^{4}\sum_{m=1}^{3} \delta_{im} \ln y_i \ln x_m + \ln \varepsilon_i \qquad (2)$$

Young's theorem requires that the second order parameters of the cost function must be symmetric, that is, $\sigma_{ij} = \sigma_{ji}$ for all i, j, and $\gamma_{mn} = \gamma_{nm}$ for all m, n. A convenient method of imposing homogeneity upon the Translog distance function is to follow Lovell et al (1994) and observe that homogeneity implies that:

$$D_I(\omega x, y) = \omega D_I(x, y) \text{ for any } \omega \succ 0 \qquad (3)$$

Hence, if we arbitrarily choose the Mth input, and set $w = 1/xM$ then, using TL(.) to represent the Translog function, we can express the input distance function as:

$$\ln(D_{Ii}/xM_i) = TL(y_i, x_i/xM_i, const, a, b, g, d)$$

$$i = 1,2,...,N \qquad (4)$$

or $$\ln D_{Ii} - \ln(xM_i) = TL(y_i, x_i/xM_i, const, a, b, g, d)$$

$$i = 1,2,...,N \qquad (5)$$

It follows that we can re-write this Translog distance function as:

$$-\ln(xM_i) = TL(y_i, x_i/xM_i, a, b, g, d) - \ln(D_{Ii})$$

$$i = 1,2,...,N \qquad (6)$$

Hence, if we append a symmetric error term, υ_i to account for statistical noise, and re-write $\ln(D_{Ii})$ as μ_i, we can obtain the stochastic input distance function, with the usual composite error term, $\varepsilon_i = \upsilon i - \mu_i$.

$$-\ln(xM_i) = TL(y_i, x_i / xM_i, \alpha, \beta, \gamma, \delta) + \upsilon_i - \mu_i$$

$$i = 1,2,...,N \qquad (7)$$

We make the standard assumptions that the ν_i are normally distributed random variables while the μ_i are assumed to have a truncated normal distribution.

As is usual in the stochastic frontier approach, the predicted value of the output distance function for the ith firm, $D_{Ii} = \exp(-m_i)$, is not directly observable, but must be derived from the composed error term, ε_i. Hence, predictions for D_{Ii} are obtained using Coelli's Frontier 4.1 programme, based on the conditional expectation:

$$D_{Ii} = E[(-m_i)|e_i] \qquad (8)$$

Data Envelopment Analysis (DEA).

The non-parametric efficiency approach was originally developed by Farrell (1957) and later elaborated by Banker, Charnes and Cooper (1984) and Fare, Grosskopf and Lovell (1985). The constructed relative efficiency frontiers are non-statistical or nonparametric in the sense that they are constructed through the envelopment of the decision making units (DMUs) with the "best practice" DMUs forming the non-parametric frontier. This non-parametric technique was referred to as Data Envelopment Analysis (DEA) by Charnes et at (1978). For a previous example and justification for using DEA with police data, see Drake and Simper (2000). The present study differs from the latter due to the use of a different data sample (Audit Commission data), and the use of an input distance function approach.

A particular advantage of non-parametric techniques such as DEA, relative to statistical or parametric techniques such as stochastic frontier analysis (see Drake and

Weyman-Jones (1996) and Ferrier and Lovell (1990)), is that the latter must assume a particular functional form which characterises the relevant economic production function, cost function, or distance function. Hence, any resultant efficiency scores will be partially dependent on how accurately the chosen functional form represents the true production relationship (i.e., the relationship between inputs/resources and outputs). As DEA is non-parametric and envelops the input/output data of the DMUs under consideration, the derived efficiency results do not suffer from this problem of functional form dependency.

For each DMU in turn, using x and y, to represent its particular observed inputs and outputs, pure technical efficiency is calculated by solving the problem of finding the lowest multiplicative factor, θ, which must be applied to the firm's use of inputs, x, to ensure it is still a member of the input requirements set or reference technology. That is, choose

$$\{\theta,\lambda\} \text{ to : } \min \theta \text{ such that: } \theta x \geq \lambda' X$$
$$y \leq \lambda' Y$$
$$\lambda^i \geq 0, \ \Sigma\lambda^i = 1, \ i = 1,..., n \tag{9}$$

Hence, in (9) we assume a variable returns to scale reference technology and concentrate exclusively on technical efficiency, ie, the efficiency of translating inputs into outputs at the given scale of production. Due to the difficulties in accurately measuring all input prices in public sector services such as the police force, this paper does not consider allocative efficiency.

A potential criticism, given the non-parametric nature of the DEA approach, is that any deviations from the efficient frontier are interpreted as inefficiencies given the absence of a random error term. Hence, there is the possibility that DEA actually overstates inefficiency levels by failing to allow for "bad luck", measurement error, etc. DEA efficiency measurements can also be sensitive to outliers. This possibility arises from the fact that the efficient frontier is itself derived from the actual input/output configurations of the sample firms/units. Hence, the level of efficiency may be largely self determined in the case of outliers as there may be no similar units in the relevant input/output region from which to form the efficient production frontier. It is for these reasons, together with the other well known pros and cons of non-parametric versus parametric efficiency measurement techniques, that it is important to contrast the results obtained from DEA with a comparison parametric approach. Furthermore, by utilising the distance function concept we can ensure that the parametric and non-parametric efficiency results are both consistent and comparable.

Super-Efficiency DEA (SDEA)

Aside from the non-stochastic nature of DEA, a further potential drawback of this non-parametric technique, particularly when contrasting the results with those obtained from parametric measures, is that DEA ranks all efficient units equal to unity (or 100). Furthermore, it may be the case that there are a large number of such efficient DMUs in a particular data sample and hence no further discrimination between these DMUs is possible. In contrast, parametric methods such as the stochastic frontier approach typically do not assign identical efficiency scores to different observations, nor do they tend to produce relative efficiency scores of unity (or 100) unless they are normalised relative to the most efficient unit, as in the distribution free approach (see Berger, 1993).

Anderson and Peterson (1993), however, have developed a relatively straightforward approach that can be used for ranking efficient units within the context of the linear programming problem detailed in (9) above. Specifically, rather than evaluating each DMU in turn with a linear combination of all units in the sample (including the DMU in question), the DMU is evaluated against a linear combination of all other units, i.e., the DMU itself is excluded from the reference set. As Anderson and Peterson (1993) argue: "It is conceivable that an efficient DMU may increase its input vector proportionally while preserving efficiency. The unit obtains in that case an efficiency score above one. The score reflects the radial distance from the DMU under evaluation to the production frontier estimated with that DMU excluded from the sample, i.e., the maximum proportional increase in inputs preserving efficiency." (p. 1262)

It follows that DMUs initially identified as efficient by DEA, and having a score of unity (or 100), will have a score of greater than unity (greater than 100) when their efficiency is reassessed using the Anderson and Peterson approach. In contrast, inefficient units not on the frontier, and with an initial DEA score of less than unity (or 100), would find their relative efficiency score unaffected by their exclusion from the reference set of DMUs.

The Free Disposal Hull Technique (FDH).

It is clear from the previous analysis that, in respect of the inputs required to produce given output levels, DEA assumes convexity such that linear substitution is possible between the observed input combinations on an isoquant. In turn, these isoquants are derived in a piecewise linear fashion from the DMUs in the sample which form the efficient frontier. Hence, in DEA each DMU is evaluated in turn relative to this piecewise linear isoquant or efficient frontier. An alternative non-parametric approach to DEA, however, is the Free Disposal Hull (FDH) approach. FDH does not assume convexity and hence does not permit such linear input substitution. Hence, the isoquant is represented by a step function through the observed input combinations. In the words of Berger and Humphrey (1997): "The free disposal hull approach (FDH) is a special case of the DEA model where the points on lines connecting the DEA vertices are not included in the frontier. Instead, the FDH production possibilities set is composed only of the DEA vertices and the free disposal hull points interior to these vertices". (P.177)

The next section outlines the data used in the estimation of the four efficiency techniques outlined.

3. Data.

In the measurement of police force efficiency there are inherent problems in the choice of inputs and outputs, see Drake and Simper (1999a and 2000), and in respect of input prices in cost function estimation, see Drake and Simper (1999b). However, in this study we follow the aims and objectives of the PSP (2000) report in using their preferred BVPIs as outputs, but utilise a greater number of inputs. For example, in the PSP report they prefer that a "net revenue expenditure" measure be utilised, incorporating staff and operating and other costs in police forces. However, the grouping of inputs can lead to an loss of information in respect of the interactions and differential mixes between inputs in the provision of the policing service function. It may also result in an aggregation bias in the stated results.

We therefore utilise a more general set of inputs and assume that these can be grouped as if the police service was an economic firm. Hence, the specified inputs include labour and various forms of capital input. Specifically, we break down the inputs of each police force into three distinct categories, as outlined in the Chartered Institute of Public Finance and Accountancy Police Force Statistics (following Drake and Simper (2000)). The first input in our estimation methodology is labour, and is proxied by employment costs calculated as the total cost of each force's employed staff, which includes all police officer ranks, traffic wardens, civilian staff and other staff development expenses.

We have included civilian staff in the summation of police staff costs because the demarcation between the police function and the civilian involvement in policing has become ever more blurred over time. In a recent HMIC report, for example, the employment of civilian staff was thought to lead to an enhancement of "efficiency and effectiveness," and the report revealed that civilian staff represented approximately 30% of total staff employed in the service in 1995/96 (HMIC (1998)). Furthermore, the report argued that "the classification of roles into police/civilian was in itself a redundant concept. Instead, it would be more appropriate to shift the focus to the actual cost of delivering a service function,…." (HMIC (1998) para. 2.48). However, following Drake and Simper (2000) and, as advocated by the PSP report, we exclude pension costs from labour expenses.[2]

The second input is capital expenses which covers general running costs including repair and maintenance, capital financing costs and all those costs associated with equipment bought for internal use such as IT, and communications, etc. Indeed, as argued in Drake and Simper (2000) this could lead to greater pressure on future capital expenditure due to the need to update IT facilities in order that forces have the latest equipment. In the summer of 2000, for example, the Home Office made available £157

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[2] The PSP report argues that pension costs "relate to past wage structures and demographic factors entirely outside a force's control. Removing uncontrollable pension costs would avoid the possibility of efficiency measures being unduly influenced by these factors." Page. 15.

million under the Capital Modernisation Fund to 'provide the service with the equipment to make it as effective in reducing crime as possible.' The final input is total transport costs, and this includes any transport related expenses including the running costs and repairs of police vehicles.

A major problem inherent in measuring the efficiency of the police service is how to quantify the role of the police in society. That is, given the wide range of public service outcomes, from investigating murders to breathalysing motorists, which ones should be chosen in an efficiency measurement strategy. Indeed, there are a large number of BVPIs which police forces measure and these have to be reduced to the core objectives of policing, see DETR (1999). The PSP (2000) report argues that "as far as possible, the outcomes measures for efficiency estimation should come from this Best Value suite." (page. 16). In the report they initially present the possible outcome measures as shown in Table 1, with 3 possible additions from the British Crime Survey (BCS) (2001) (level of crime; fear of crime; and feelings of public safety). The main BVPIs listed in Table 1, follow the response/reactive approach to policing, while the new BCS (2001) BVPIs following the proactive/preventive methodology.

INSERT TABLE 1

This so-called response/reactive methodology of measuring policing outputs/outcomes can be found in a number of studies, including Todd and Ramanathan (1994) and Drake and Simper (2000). Byrne et al (1996) argue that, even though half of the police's community work cannot be modelled, a production function can still be estimated. They break down police activities into crime prevention "where crime is contemplated but not committed", and crime repression, where the "crime has occurred," and use an argument from Schmidt and Witte (1984) that any criminal is likely to assess the probability of getting caught after committing a crime. It is argued that the probability of arrest is linked to the number of arrests in a police force, and in particular to the number of convictions. Recently, the Home Office Minister Charles Clarke reiterated that the response/reactive variables should be used as a measure of police performance. "The most important aim of the Home Office is the reduction in crime and my role is to do everything possible to support you in achieving that." (Policing Today, Summer 2000, page. 21).

The data on outputs utilised in this study is taken from the Audit Commission reports on BVPIs in policing (various years). This report gives results for many of the BVPIs shown in Table 1, but in addition breaks them up into variables which can be manipulated to provide more informative measures. For example, in the Audit Commission report there are figures for total crimes per 1,000 population and the number of total crimes detected. Given the population figures stated in the CIPFA report above, the manipulation of these 3 variables allows us to calculate our first output variable, the total number of cleared up crimes. The second and third output variables in our models are; the number of cleared up violent crimes; and the number of cleared up burglaries.[3]

The first three outputs should provide a good proxy for the crime prevention and repression activities of the police. In addition, using the population in each police force area, implicitly acknowledges the role of public financed policing. Since the Police and Magistrates Courts Act (PMCA) (1994), a police authority, in conjunction with the chief constable develops a yearly Local Policing Plan (LPP) to cost local activities and national objectives in crime reduction, see Loveday (1996). However, before the PMCA introduced the Police Funding Formula in April 1995, which allocates revenues to Local Police Authorities (LPA's), revenues were based on a "cash limited system using a population based formula to assess relative need." (Home Office (1998) para. 1.3). The formula was extended after the PMCA to include characteristics of the area (for example number of unemployed, daytime population and rural sparsity) and its population.

Our final output variable relates to the problems of drink driving and the effect on police resources. In recent years the UK government has implemented a strict drink driving campaign, which can take up police time in respect of breathalysing drivers. In fact, there has been a 76% increase in breathalyser tests since 1988 and the 781,100 breath tests carried out by police in 1996/97 was the largest number of tests since breathalyser tests were introduced in 1967 (source: Home Office). We would expect that,

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[3] We also estimated the models excluding total cleared up crimes, but there was no difference in the levels or ranks of the results found.

as more people are breathalysed, serious road accidents would be likely to drop thereby freeing up more police time for other activities. Following the methodology of Byrne et al (1996), this action can be classified as a reactive approach to reducing car accidents, and so total breathalyser tests constitutes our final output variable.

For consistency, the same 4 outputs are specified in both the parametric and nonparametric efficiency analyses. In the next section, we present the results from the various models and contrast the relative efficiency scores.

4. Results.

The overall mean yearly pooled results for the 4 models are presented in Table 2, and the results from individual years are presented in the Appendix, Table 1A. In each column, the leftmost figure represents the actual efficiency estimate obtained for that model, while the adjacent figure is the rank of the police force in the overall sample. It is noticeable from Table 2, that the FDH model produces considerably more fully efficient forces (scores of 100) than DEA. Furthermore, as alluded to previously, both FDH and DEA tend to produce a number of units ranked as 100% efficient, i.e., located on the efficient frontier, whereas SIDF tends to produce relative efficiency measures between zero and unity or 100. This contrast is reflected in a comparison of the overall means for the complete sample, where the FDH mean score is 96.67, the DEA mean is 81.50 and the SIDF mean is equal to 69.92.

INSERT TABLE 2

As a check of whether the efficiency results from DEA and SIDF (the main models under consideration) are drawn from the same distribution, we estimated a paired samples t – test, which gave a significant t - statistic equal to –3.11. We can therefore conclude that the results from the two approaches are distinct. Hence, these two approaches to relative efficiency should be used in tandem as, individually, they may produce conflicting efficiency scores and consequently lead to erroneous policy actions.[4]

It is interesting to note that there is a strong positive relationship between the nonparametric and parametric results, where Figure 1 presents a scatter diagram of the DEA and SIDF results (we have omitted the FDH results as there are a large number of forces (29) on the frontier). Indeed, the relationship between the estimates from the 3 models is positive, with a Spearman's rank correlation coefficient between DEA and SIDF equal to 0.67 (significant at the 1% level), DEA and FDH equal to 0.39 and SIDF and FDH equal to 0.34 (both significant at the 5% level),. These results give credence to the PSP report conclusion that nonparametric and parametric models should be used in tandem to obtain efficiency rankings of police forces as they are strongly positively correlated, but reveal the potential for inconsistencies at the level of the individual police force. As an example, it is clear from Figure 1 that, for those forces ranked as efficient by DEA (DEA score = 100), the SIDF scores range from 97.67 (Gwent) to 62.13 (West Yorkshire). Similarly, in respect of non-efficient forces, the West Midlands has a DEA score of 82, but an SIDF score of only 52. Hence, this force represents a clear outlier in respect of Figure 1.

INSERT FIGURE 1

In terms of the individual analysis of the various police forces, we obtain 6 police forces on the frontier with DEA, relative to 29 with FDH. The SIDF results show a wide spread of efficiency scores ranging from the Surrey at 49.22 to the Gwent at 97.69. This corresponds well with the results of Drake and Simper (2000) who found, using a sample from 1992/93 to 1996/97, that the overall mean DEA pure technical efficiency estimates for the Surrey and Gwent forces was 69.34 and 100, respectively. Indeed, the Surrey was found to be one of the least efficient non-metropolitan police forces in England and Wales, and this is confirmed in this current study using a new data set and a more recent sample. In DEA and SIDF terms,. the Surrey should be able to reduce their use of inputs

[4] As we would expect from examining the frequencies of the DEA, FDH and SIDF estimates, there is a greater level of negative skewness for the former two, -0.26 and –3.03 (although insignificant), whereas the SIDF is slightly positively skewed equal to 0.20 (although insignificant).

by around 39% and 51% respectively, without adversely affecting the capacity of the force to deliver the 4 outputs.

An additional interesting feature of the results presented in this paper is that we can provide some further analysis of the DEA results for those police forces that are located on the efficient frontier. As outlined previously, we do this by employing the SDEA technique developed by Anderson and Peterson (1993). For example in 1996/97, in descending order, the SDEA scores are, Cleveland 152.22, Greater Manchester 144.70, West Yorkshire 134.92, Gwent 121.11, Dyfed-Powys 104.83 and Derbyshire 100.43. This implies, for example, that the Cleveland force, with an initial DEA score of 100, could have its inputs increased by around 52% and still remain on the efficient frontier. The Derbyshire force, on the other hand, is not as "super-efficient" as an increase in its inputs of less than 0.5% would be sufficient to move this force away from the efficient frontier.

Hence, it would appear that the SDEA approach offers a very useful means of ranking those units which appear to be jointly efficient according to DEA. This is clearly very important in cases where rank ordering and relative efficiencies/inefficiencies are important (for funding decisions, etc), and where DEA tends to produce a number of units rated as 100% efficient. It should be noted, however, that, although SDEA may produce measures of "super-efficiency" in some cases, in others it may simply reflect the DEA outlier problem noted previously. A good example of this is the case of the Metropolitan force which is an outlier by virtue of it's a-typically large size. It can be seen from Table 2 and Table A1 that the SDEA score for the Metropolitan for 1997/98 is defined as "big". This implies that an arbitrarily large increase could be imposed on this force's inputs, yet it would still remain on the efficient DEA frontier. This would seem to indicate that this force is extremely "super-efficient". If we contrast this result with that of the parametric SIDF approach, however, which would be expected to be less susceptible to outliers, we find that the Metropolitan is ranked 27th ,with an efficiency score of only 66.14.

Similarly, in the case of the 1996/97 SDEA scores referred to previously (Cleveland 152.22, Greater Manchester 144.70, West Yorkshire 134.92, Gwent 121.11, Dyfed-Powys 104.83 and Derbyshire 100.43), Greater Manchester has an SIDF score of

67.94 (rank 26), and West Yorkshire has an SIDF score of 62.13 (rank 32). Hence, these forces represent other possible examples of potential outlier problems where it would be unwise to rely exclusively on the DEA or SDEA relative efficiency results or rankings. With respect to some of the other forces, however, there is a very good correspondence between the SDEA and the SIDF results. Gwent, for example, has an SIDF score of 97.37 (rank 1), while Cleveland has an SIDF score of 81.5 (rank 4). Furthermore, this correspondence is even stronger for the pooled sample results shown in Table 2. According to SDEA and SIDF respectively, Gwent is ranked (3,1), Cleveland (1,4) and Derbyshire (8,10).

Hence, these results serve to confirm that non-parametric and parametric approaches can prove to be powerful complementary relative efficiency methodologies and underline the view in PSP (2000) that it would be unwise to rely solely on non-parametric approaches such as DEA and SDEA, particularly in respect of some of the large metropolitan forces. This claim is underlined by the finding that in 1998/99, over half of the metropolitan police forces are on the DEA efficient frontier with scores equal to 100, correspondingly high SDEA scores, but low SIDF ranks. Specifically the efficiency scores are: Greater Manchester 160.43 SDEA and 71.33 SIDF (rank 26); West Midlands 207.89 SDEA and 56.78 SIDF (rank 40); West Yorkshire 109.54 (SDEA) and 65.96 SIDF (rank 32); and the Metropolitan 'big' SDEA and 69.59 SIDF (rank 27).

The results discussed so far strongly suggest that the parametric and non-parametric approaches be used in tandem, but that SDEA may not provide a reliable method of discriminating between DEA efficient units. Hence, given that the SIDF measure does not tend to rank units at 100, a simple way of combining the non-parametric and parametric approaches, and of avoiding units being jointly ranked as efficient, would be to rank units on the basis of their mean DEA and SIDF efficiency scores. This is done in respect of the pooled sample in Table 3. It is clear that, under this approach, we obtain a relatively smooth discrete ordering of police forces ranging from the most efficient, the Gwent with a mean score of 98.84, to the Hertfordshire with a mean score of 53.82.

INSERT TABLE 3

One of the major aims of the new efficiency modelling strategy advocated in PSP (2000) is to facilitate the grouping of police forces. Once this is done, on the basis of their efficiency scores from DEA and a stochastic model, the forces assigned to these groups could be given an overall efficiency target to achieve. Figure 2, presents the overall efficiency score for English and Welsh police forces using the combined DEA and SIDF mean value. The forces are ranked from the most efficient, Gwent at 98.84, to the least efficient, the Hertfordshire at 53.82, and the four groups represent an equal efficiency score spread across maximum to minimum efficiency scores (group 1 is from 100 to 88.25, group 2 from 88.25 to 76.50, group 3 from 76.50 to 64.75, and group 4 from 64.75 to 53.00). In this case there are unequal groups, with group 1 having 8 forces, group 2 with 15, group 3 with 10 forces, and group 4 with 9 forces.

INSERT FIGURE 2

It is interesting to note that there is a clear break between the first and second group's border (the break is between Suffolk (88.78) and Cumbria (84.44)), and on the third and forth border (between West Midlands (67.21) and West Mercia (64.21)). Although the demarcation between groups 2 and 3 is not so clear cut, there is a clear plateau at around 76.50, and we have elected to place these marginal forces in group 2. There is then a discrete break to the Norfolk at 75.33 in group 3. In summary, the results from Table 3 and Figure 2 show that the Gwent is a clear outlier in terms of efficiency, and a group consisting of Lincolnshire, Cleveland, Northamptonshire and Dyfed-Powys are clearly in the same efficiency group band. On the other hand, in the fourth group, the least efficient police forces are represented by Merseyside, Sussex, Surrey, Essex and the Hertfordshire.

As alluded to previously, it is an aim of the PSP (2000) report to determine which forces are efficient and should be given extra funds, and those that should be inspected with a view to increasing efficiency. If all forces are to be given a target to improve within a band or group as is suggested in the report, it is necessary to determine whether there is any statistical difference between these groups. In other words, can police forces be legitimately placed in distinct efficiency bands. The PSP (2000) report argues that, "while the boundaries of the bands should be chosen on sensible demarcations of the results, statistical tests can be completed on the bands. These tests can establish, for example, whether there is a statistically significant difference between the average of the scores of the forces in each band." (page. 33).

A method of determining this mean difference is a One - Way ANOVA. In the calculation of the ANOVA, we have split the results into the four groups based on Figure 2 and Table 3. The F – test for the combined DEA and SIDF estimates is equal to 154.11 (significant at the 1% critical level), and hence there is a significant difference between the efficiency groups. A post-hypothesis testing analysis, shows that all groups were significantly different from each other at the 1% critical level.[5] Hence, in the context of this study we can conclude that it would not be arbitrary to enforce efficiency improvements based on these scores and police force groupings.

Conclusions.

This paper is the first to utilise both parametric and non-parametric distance function models to analyse English and Welsh police force efficiency, and is also one of the first to estimate a stochastic distance function using a flexible functional form such as the Translog. Furthermore, the results obtained provide some important insights not only in terms of the relative efficiency of police forces, but also in respect of the practical application of the various alternative methodologies in the assessment of efficiency in public sector services.

The results obtained from the four models estimated exhibited a strong positive relationship, and this strong positive correlation was particularly apparent in respect of DEA and SIDF. Hence, this cross-verification provides a strong endorsement for the two main distance function measures considered in the paper and suggests that both are credible relative efficiency measurement techniques. With respect to the remaining two

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[5] This was estimated in SPSS V. 10, and all tests showed a significant mean difference, e.g., Tukey HSD, Bonferroni, and Dunnett T3 and Tamhane (when we do not expect a constant variance).

techniques considered, the very high proportion of efficient police forces established under FDH suggests that this technique will be of limited practical application in policing, particularly when the emphasis is on the accurate determination of relative efficiency bands, as suggested in PSP (2000). In contrast, SDEA appears to offer a simple means of discriminating between efficient DEA units. However, our results suggest that, while the technique may identify "superefficient" units in some cases, in others the DEA outlier problem may result in some units being erroneously classified as "superefficient". In reality, these units may appear on the DEA frontier simply by virtue of their outlier status, i.e., they are self identified as efficient, and hence should not be termed superefficient.

Although the DEA and SIDF results showed a strong, and statistically significant, positive relationship, some diversity was apparent across police forces, both in terms of the relative efficiency scores and the corresponding efficiency rankings. This, together with the well know relative pros and cons of the non-parametric and parametric techniques, suggests that it would be unwise to rely exclusively on either one of these approaches. In this paper we utilise a very simple approach to combining the two sets of results, based on the mean of the DEA and SIDF scores, and find that this produces a relatively smooth discrete ordering of police forces with no forces ranked as jointly efficient, as is the case with DEA. Furthermore, these combined results serve to illustrate the considerable disparity in efficiency levels across police forces in England and Wales with the mean scores ranging from the most efficient, the Gwent with a mean score of 98.84, to the Hertfordshire with a mean score of 53.82.

Finally, in respect of the practicalities of efficiency enhancement, the PSP (2000) report places a great deal of emphasis on identifying relative efficiency bands in order that individual forces may be set realistic efficiency improvement targets relative to their own efficiency band. Our results confirm that this is feasible and that the combined DEA/SIDF scores do provide four distinct police force relative efficiency bands with statistically significantly different mean efficiency levels. Furthermore, the fact that these bands are constructed on the basis of parametric and non-parametric relative efficiency techniques, both of which are modelled in a consistent fashion, serves to alleviate the potential concern that some forces are advantaged or disadvantaged by one particular technique.

In conclusion, our results provide strong support for the joint use of parametric and non-parametric relative efficiency techniques, provided that they are modelled in a consistent fashion. This is ensured in this paper as both our techniques employ the distance function concept and have identical inputs and outputs. It is typically not the case, however, when the stochastic cost frontier approach is utilised in conjunction with DEA. Hence, an important agenda for future research will be to employ this innovative approach using the improved data sets which should emerge in the wake of the PSP (2000) report.

Table 1.

BVPIs Outcome Measures in PSP (2000) Report

Code:	Efficiency Measure
BV125R	Total crimes per 1,000 population
BV125D	Total crime, % detected
BV126	Burglaries per 1,000 households
BV128	Violent crime per 1,000 population
BV129	Number of offenders dealt with for supply offences in respect of class A drugs per 1,000 population
BV130	Public disorder incident count per 1,000 population
BV132	Number of road traffic collisions involving death or serious injury per 1,000 population

Figure 1.

Correlation Between DEA and SIDF Estimates.

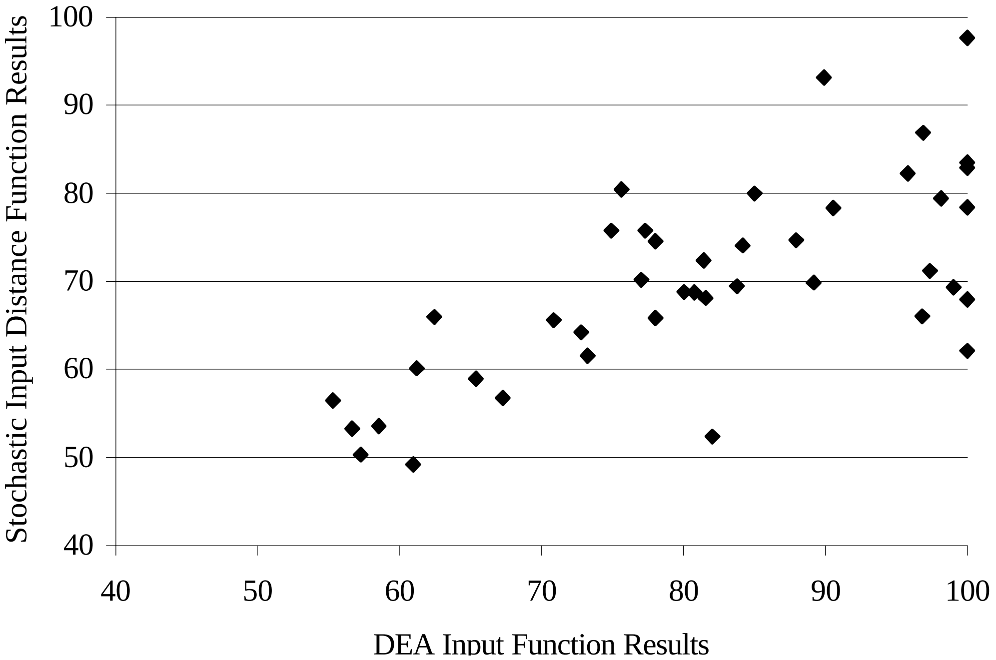

Figure 2.

Efficiency Ranking of English and Welsh Police Forces.

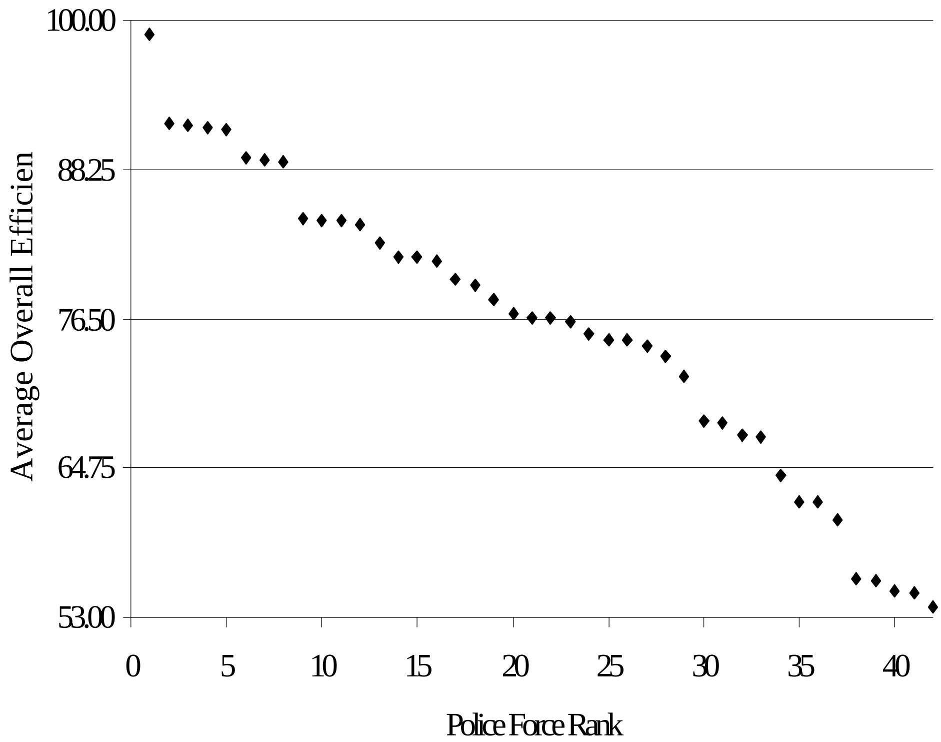

Table 2. 1996/99 Overall Mean English and Welsh Police Force Efficiency Results.

	DEA		**SDEA**		**FDH**		**SIDF**	
Avon and Somerset	80.78	18	104.03	12	100	1	68.74	24
Bedfordshire	95.79	7			100	1	82.25	6
Cambridgeshire	89.17	10			100	1	69.90	20
Cheshire	77.29	22			100	1	75.80	12
Cleveland	100	1	142.00	5	100	1	83.50	4
Cumbria	90.56	8			100	1	78.33	11
Derbyshire	100	1	114.05	8	100	1	78.41	10
Devon and Cornwall	61.22	32			83.61	11	60.17	34
Dorset	81.55	16			95.68	5	68.11	25
Durham	78.01	20			83.47	12	65.83	29
Essex	56.65	36			100	1	53.31	39
Gloucestershire	97.35	4			100	1	71.21	18
Hampshire	73.24	26			94.68	7	61.56	33
Hertfordshire	57.28	35			64.13	14	50.37	41
Humberside	78.01	21			100	1	74.56	15
Kent	72.82	27			100	1	64.22	31
Lancashire	70.86	28			100	1	65.58	30
Leicestershire	85.00	12			100	1	79.99	8
Lincolnshire	96.87	5	114.00	9	100	1	86.87	3
Norfolk	74.91	25			91.61	9	75.74	13
Northamptonshire	89.88	9			99.59	2	93.12	2
North Yorkshire	77.05	23			90.94	10	70.17	19
Nottinghamshire	83.79	14			100	1	69.48	21
Staffordshire	81.44	17			100	1	72.43	17
Suffolk	98.16	3	121.20	6	100	1	79.41	9
Surrey	60.98	33			70.50	13	49.22	42
Sussex	55.31	37			100	1	56.45	37
Thames Valley	67.26	29			100	1	56.77	36
Warwickshire	99.01	2	107.43	11	100	1	69.32	22
West Mercia	62.44	31			97.58	4	65.98	28
Wiltshire	87.93	11			98.39	3	74.70	14
Dyfed-Powys	100	1	108.45	10	100	1	82.91	5
Gwent	100	1	149.08	3	100	1	97.67	1
North Wales	80.04	19			95.20	6	68.80	23
South Wales	84.16	13			100	1	74.11	16
Greater Manchester	100	1	148.13	4	100	1	67.94	26
Merseyside	58.53	34			100	1	53.62	38
Northumbria	75.62	24			100	1	80.46	7
South Yorkshire	65.39	30			100	1	58.91	35
West Midlands	82.04	15	207.89	2	94.55	8	52.38	40
West Yorkshire	100	1	116.60	7	100	1	62.13	32
Metropolitan	96.81	6	big	1	100	1	66.05	27

Table 3.

English and Welsh Police Force Overall Efficiency Scores (OES) and Rankings.

Rank		OES	Rank		OES
1 (1st)	Gwent	98.84	14 (2nd)	Cheshire	76.54
2 (1st)	Lincolnshire	91.87	15 (2nd)	Humberside	76.28
3 (1st)	Cleveland	91.75	16 (2nd)	Norfolk	75.33
4 (1st)	Northamptonshire	91.50	17 (2nd)	Dorset	74.83
5 (1st)	Dyfed-Powys	91.46	18 (2nd)	Avon & Somerset	74.76
6 (1st)	Derbyshire	89.20	19 (2nd)	North Wales	74.42
7 (1st)	Bedfordshire	89.02	1 (3rd)	North Yorkshire	73.61
8 (1st)	Suffolk	88.78	2 (3rd)	Durham	71.92
1 (2nd)	Cumbria	84.44	3 (3rd)	Kent	68.52
2 (2nd)	Gloucestershire	84.28	4 (3rd)	Lancashire	68.22
3 (2nd)	Warwickshire	84.17	5 (3rd)	Hampshire	67.40
4 (2nd)	Greater Manchester	83.97	6 (3rd)	West Midlands	67.21
5 (2nd)	Leicestershire	82.50	7 (3rd)	West Mercia	64.21
6 (2nd)	Metropolitan	81.43	8 (3rd)	South Yorkshire	62.15
7 (2nd)	Wiltshire	81.32	9 (3rd)	Thames Valley	62.01
8 (2nd)	West Yorkshire	81.07	1 (4th)	Devon and Cornwall	60.70
9 (2nd)	Cambridgeshire	79.54	2 (4th)	Merseyside	56.07
10 (2nd)	South Wales	79.14	3 (4th)	Sussex	55.88
11 (2nd)	Northumbria	78.04	4 (4th)	Surrey	55.10
12 (2nd)	Staffordshire	76.93	5 (4th)	Essex	54.98
13 (2nd)	Nottinghamshire	76.63	6 (4th)	Hertfordshire	53.82

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Table A1. 1996/97 English and Welsh Police Force Efficiency Results.

	DEA		SDEA		FDH		SDIF	
Avon and Somerset	80.60	16			100	1	65.32	24
Bedfordshire	94.38	7			100	1	80.11	6
Cambridgeshire	88.11	11			100	1	66.58	20
Cheshire	73.55	24			100	1	73.01	12
Cleveland	100	1	152.22	1	100	1	81.50	4
Cumbria	88.48	10			100	1	75.79	11
Derbyshire	100	1	100.43	6	100	1	75.88	10
Devon and Cornwall	53.83	35			69.08	10	56.13	34
Dorset	77.30	20			87.94	5	64.64	25
Durham	83.65	14			87.38	6	62.19	29
Essex	56.56	31			100	1	48.89	39
Gloucestershire	98.69	3			100	1	68.00	18
Hampshire	61.85	28			84.03	7	57.61	33
Hertfordshire	51.89	36			54.59	12	45.82	41
Humberside	81.53	15			100	1	71.65	15
Kent	68.76	26			100	1	60.45	31
Lancashire	74.17	22			100	1	61.92	30
Leicestershire	77.94	17			100	1	77.62	8
Lincolnshire	90.61	8			100	1	85.24	3
Norfolk	73.62	23			80.36	9	72.95	13
Northamptonshire	87.44	12			98.96	2	92.25	2
North Yorkshire	77.34	19			91.09	3	66.88	19
Nottinghamshire	99.24	2			100	1	66.13	21
Staffordshire	86.59	13			100	1	69.33	17
Suffolk	94.47	6			100	1	76.98	9
Surrey	56.17	33			65.91	11	44.63	42
Sussex	51.67	37			100	1	52.19	37
Thames Valley	69.56	25			100	1	52.52	36
Warwickshire	97.04	4			100	1	65.95	22
West Mercia	61.13	29			100	1	62.34	28
Wiltshire	95.85	5			100	1	71.81	14
Dyfed-Powys	100	1	104.83	5	100	1	80.85	5
Gwent	100	1	121.11	4	100	1	97.37	1
North Wales	75.96	21			89.53	4	65.39	23
South Wales	77.81	18			100	1	71.16	16
Greater Manchester	100	1	144.70	2	100	1	64.46	26
Merseyside	54.40	34			100	1	49.21	38
Northumbria	64.02	27			100	1	78.14	7
South Yorkshire	59.06	30			100	1	54.79	35
West Midlands	56.32	32			83.64	8	47.91	40
West Yorkshire	100	1	134.92	3	100	1	58.22	32
Metropolitan	90.42	9			100	1	62.42	27

Table A1. 1997/98 English and Welsh Police Force Efficiency Results.

	DEA		SDEA		FDH		SIDF	
Avon and Somerset	78.74	13			100	1	68.83	24
Bedfordshire	100	1	104.03	11	100	1	82.32	6
Cambridgeshire	99.86	3			100	1	69.99	20
Cheshire	83.58	10			100	1	75.89	12
Cleveland	100	1	117.29	4	100	1	83.57	4
Cumbria	96.20	5			100	1	78.41	11
Derbyshire	100	1	112.79	5	100	1	78.49	10
Devon and Cornwall	57.87	31			81.75	6	60.25	34
Dorset	87.26	8			99.09	2	68.20	25
Durham	76.89	16			81.50	7	65.92	29
Essex	58.26	30			100	1	53.38	39
Gloucestershire	99.93	2			100	1	71.30	18
Hampshire	67.34	23			100	1	61.65	33
Hertfordshire	63.25	27			72.51	9	50.43	41
Humberside	78.79	12			100	1	74.64	15
Kent	66.72	24			100	1	64.31	31
Lancashire	71.50	20			100	1	65.67	30
Leicestershire	77.77	14			100	1	80.07	8
Lincolnshire	100	1	105.97	7	100	1	86.93	3
Norfolk	76.37	18			94.46	4	75.83	13
Northamptonshire	96.88	4			100	1	93.16	2
North Yorkshire	79.29	11			92.03	5	70.26	19
Nottinghamshire	75.43	19			100	1	69.57	21
Staffordshire	77.44	15			100	1	72.52	17
Suffolk	100	1	105.07	9	100	1	79.49	9
Surrey	68.63	21			73.14	8	49.28	42
Sussex	59.76	29			100	1	56.53	37
Thames Valley	68.56	22			100	1	56.84	36
Warwickshire	100	1	111.24	6	100	1	69.41	22
West Mercia	61.33	28			100	1	66.07	28
Wiltshire	91.39	6			100	1	74.79	14
Dyfed-Powys	100	1	104.25	10	100	1	82.98	5
Gwent	100	1	119.28	3	100	1	97.69	1
North Wales	84.23	9			96.07	3	68.89	23
South Wales	76.77	17			100	1	74.20	16
Greater Manchester	100	1	139.26	2	100	1	68.03	26
Merseyside	53.56	32			100	1	53.69	38
Northumbria	65.16	26			100	1	80.54	7
South Yorkshire	66.29	25			100	1	58.99	35
West Midlands	89.81	7			100	1	52.44	40
West Yorkshire	100	1	105.34	8	100	1	62.22	32
Metropolitan	100	1	big	1	100	1	66.14	27

Table A1. 1998/99 English and Welsh Police Force Efficiency Results.

	DEA		SDEA		FDH		SIDF	
Avon and Somerset	82.99	10			100	1	72.06	24
Bedfordshire	92.98	6			100	1	84.31	6
Cambridgeshire	79.55	15			100	1	73.13	20
Cheshire	74.74	19			100	1	78.50	12
Cleveland	100	1	156.50	5	100	1	85.43	4
Cumbria	87.00	8			100	1	80.79	11
Derbyshire	100	23	128.94	7	100	1	80.86	10
Devon and Cornwall	71.97	1			100	1	64.13	34
Dorset	80.10	13			100	1	71.48	25
Durham	73.50	22			81.54	6	69.39	29
Essex	55.14	31			100	1	57.66	39
Gloucestershire	93.42	5			100	1	74.32	18
Hampshire	90.52	7			100	1	65.43	33
Hertfordshire	56.70	30			65.28	8	54.86	41
Humberside	73.71	21			100	1	77.37	15
Kent	82.99	11			100	1	67.89	31
Lancashire	66.91	26			100	1	69.16	30
Leicestershire	99.30	2			100	1	82.28	8
Lincolnshire	100	1	122.03	8	100	1	88.43	3
Norfolk	74.75	18			100	1	78.45	13
Northamptonshire	85.33	9			99.80	2	93.97	2
North Yorkshire	74.53	20			89.69	5	73.38	19
Nottinghamshire	76.69	16			100	1	72.74	21
Staffordshire	80.28	12			100	1	75.44	17
Suffolk	100	1	137.32	6	100	1	81.76	9
Surrey	58.14	29			72.46	7	53.76	42
Sussex	54.50	32			100	1	60.64	37
Thames Valley	63.66	28			100	1	60.93	36
Warwickshire	100	1	103.61	11	100	1	72.60	22
West Mercia	64.87	27			92.75	4	69.52	28
Wiltshire	76.56	17			95.18	3	77.50	14
Dyfed-Powys	100	1	116.28	9	100	1	84.90	5
Gwent	100	1	206.84	3	100	1	97.97	1
North Wales	79.92	14			100	1	72.12	23
South Wales	97.91	3			100	1	76.97	16
Greater Manchester	100	1	160.43	4	100	1	71.33	26
Merseyside	67.64	25			100	1	57.95	38
Northumbria	97.67	4			100	1	82.70	7
South Yorkshire	70.83	24			100	1	62.95	35
West Midlands	100	1	207.89	2	100	1	56.78	40
West Yorkshire	100	1	109.54	10	100	1	65.96	32
Metropolitan	100	1	big	1	100	1	69.59	27