

Assessing Police Precincts of Taipei City Using Data Envelopment Analysis

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Abstract

Data Envelopment Analysis (DEA) is used to measure the relative efficiency of the fourteen police precincts in Taipei city, Taiwan. Our results indicate how DEA may be used to measure these police precincts from commonly available police statistical data for the years 1994, 1995, and 1996. To sharpen our efficiency estimates, we use window analysis, slack variable analysis, and output-oriented DEA models with both constant and variable returns to scale. The problem of the presence of non-discretionary input variables is explicitly treated in the models used. Potential improvements in technical efficiency of police precincts are examined by readjusting the particular output/input indicators. The analysis indicates that differences in operating environments, such as resident population and location factors, do not have a significant influence upon the efficiency of police precincts.

Keywords: Data Envelopment Analysis; Performance measurement; Police

1. Introduction

The purpose of this paper is to measure the relative efficiency of the Taipei Municipal Police Precincts in 1994-1996, using a two-stage procedure. In the first stage, Data Envelopment Analysis (DEA) as put forward by Charnes *et al.* [7] in 1978 is used to construct a scalar measure of efficiency for all police precincts. In the second stage, multiple regression is used to analyze external factors or operating environments which might explain the variation in technical efficiencies across police precincts. The results of this study can be used to assist the Taipei Municipal Police Department in delivering better and efficient services to the community.

The inexorable rise in reported crime and expenditure for police service in recent years – 96810 reported crime cases in 2000 in Taipei city, up 103% on 1991 and increased expenditure for police service NT\$ 1290564 reported in 2000 in this city, up 64.5% from 1992 – has brought crime to the forefront of public debate. A study of analyzing police performance would be a useful object for improving these efforts of crime management. To date, none of these studies undertaken by the Police Department have helped police managers and officers identify how management systems can be changed to improve factors which drive the efficiency of our police operations?

Since the police force's operations represent a significant spending of tax-payers' money, it is vital for the Police Department to ensure the economic, effective and efficient provision of police services. However, due to the complexity of police operations, traditional performance measurement techniques have not been very effective in identifying and disseminating best practices throughout the police force. This paper will address these above-stated concerns. In particular, we report on a developmental study of DEA as a method for evaluating the relative efficiency of police precincts in Taipei city. A precinct refers to the management of police units in a specific administration district of Taipei city, which is responsible for the prevention and investigation of crime. To the best of our knowledge, this research is the first DEA study of police forces in Taiwan.

DEA has many desirable features which is why it was used to measure the relative efficiency of 14 Taipei Municipal Police Precincts.

- (1) it provides a single aggregate measure of the relative efficiencies of these police precincts in terms of their utilization of input factors to produce desired outputs;
- (2) it can handle non-commensurate multiple outputs and multiple input factors;
- (3) it can adjust for factor outside the control of the unit being evaluated;
- (4) it is not dependent on a set of *a priori* weights for the inputs or the outputs;
- (5) it can provide targets for increasing outputs and /or conserving inputs for an inefficient police precinct to become efficient; and

(6) it maintains equity in performance assessment.

Furthermore, it is theory-based, transparent and is a reproducible computational procedure. It has several advantages over traditional approaches such as ratio analysis and regression analysis (see Sherman [13]). A major advantage is that DEA has been empirically validated many times over. As Golany [10] points out, DEA is emerging as the leading method for efficient evaluation, in terms of both the number of research papers published and the number applications to real world problems. We shall assume throughout this paper some knowledge of DEA. Readers not familiar with DEA are referred to Charnes *et al.* [8] and Charnes *et al.* [9].

Given our aim above, we investigate the following research questions:

- (1) What are the input and output measures that we can use to assess performance of these police precincts?
- (2) Which precincts are most efficient?
- (3) What suggestions can we provide for inefficient precincts to improve their efficiency?
- (4) Do differences in operating environments, such as location and socioeconomic factors, have a significant influence upon the efficiency of police precincts?

The paper is organized as follows. It first discusses related prior studies which have influenced this paper. Next, a preliminary data analysis regarding the selection of input and output measures that can be used in a DEA model is presented. There then follows a section introducing the methodology used in the evaluation of the performance of police precincts. The empirical results obtained from the DEA assessment are presented and discussed. The paper concludes with a summary of our findings and use of DEA to improve the performance of police services.

2. Review of Literature

In the last decade, several DEA based police performance studies that described practical implementations in the U.K. and Australia have been reported in public publications (i.e. Audition Commission [1]; NSW Treasury [12]). Published applications of DEA to police services can be found in Thanassoulis [17] and Carrington *et al.* [5]. These papers have provided important contributions to this area and furthered our understanding the problem of police performance and the use of DEA to estimate efficiency. We briefly outline these prior studies in terms of their production model, sample size and limitations.

Thanassoulis [17] used an output orientated CCR model (Charnes, Cooper and Rhodes [7]) to analyze forty-one police forces in England and Wales using data for the years 1992-1993. The production model consisted of four inputs: police officers employed at each force, number of violent crimes, burglaries, other crimes recorded; and three outputs: number of “clear ups” of violent crime, burglary and other crime recorded. For a closer view of the performance, he examined “manpower efficiency” and “clear up efficiency”. Manpower efficiency was measured using one input (officers) and three outputs (number of violent crimes, burglaries, other crimes recorded). Clear up efficiency was measured with three inputs (number of violent crimes, burglaries, other crimes recorded; and three outputs (number of clear ups of violent crime, burglary, and other crime recorded). He concluded that raising staffing levels would lead to more crimes being cleared. It is important to highlight his attempt to capture in the production model the input-output weights and the identification of efficient peer forces for each inefficient force. However, these appear to be certain weaknesses in the assessment. Chief among these was the fact that the efficiency ratings of some forces could be based on a downgrading of the importance of certain output variables, often in a counter-intuitive way. Another weakness was that many inefficient forces had dissimilar policing environment to those of their efficient peers and so were not strictly comparable to one another. Also, from a technical point of view, the CCR model used could not examine whether technical and scale efficiencies existed for any other police forces (see, Banker *et al.* [2]). Specifically, increasing or decreasing returns as well as constant returns to scale were not identified (see Banker and Thrall [4]) for discussion).

Carrington *et al.* [5] examined the technical efficiency of the NSW Police Service in 1994-1995, using a two-stage procedure. In the first stage, input orientated CCR and BCC (Banker, Charnes and Cooper [2]) models were used to compute the technical efficiencies at 163 police patrols. The production model consisted of three inputs (police officers, civilian employees and police cars) and five outputs (number of offences, arrests, summons, major car accidents recorded and kilometers traveled by police cars). In the second stage, Tobit regression was used to analyze external factors or operating environments of patrols (i.e. proportion of young people, proportion of government housing and location). Returns to scale were also addressed in their paper. The authors concluded that (1) NSW police patrols could, on average, reduce input usage by 13.5 percent through better management, and by 6 percent if the patrols could be restructured to achieve the optimal scale; and (2) differences in operating environments, such as location and socioeconomic factors, did not have a significant influence on the efficiency of police patrols. Carrington *et al.* [5] enhanced their study by addressing technical and scale efficiencies for police patrols, the possibility of increasing or decreasing returns to scale, and analyzing operating environments which might have explain the variation in technical efficiencies across police patrols. However, their study has several limitations. First, they did not provide a statistical justification for the use of input and outputs in the DEA model. Second, their results suggest that to be efficient, an inefficient police patrol must reduce its number of input usage by a certain percentage. It seems somewhat paradoxical. Why is not to increase its levels of outputs? Is it because that

an input orientated model was used in their study? Finally, the identification of inefficient units and their efficient peers were not covered in their assessment.

In conducting our study, we provide a statistical justification for the inputs and outputs used in the DEA model. We use output orientated CCR and BCC models to examine the overall, technical, and scale efficiencies for all police precincts; identify inefficient units and their efficient peers; deal with the possibility of increasing or decreasing returns to scale; and specify potential improvements in technical efficiency of these precincts. Finally, multiple regression is used to investigate the influence of operating environments upon the technical efficiency of police precincts.

3. Preliminary Data Analysis

The first step in applying DEA is to identify the set of input and output measures to be included in the analysis. The objective is to select a set of inputs and outputs that are relevant to performance appraisal and for which a moderate statistical relationship exists. In some cases the appropriate factors can be identified by experienced police administrators or from prior research. In other situations, when data are available, a multivariate statistical analysis may be necessary to determine:

- (1) which outputs are intercorrelated—some of the outputs can be deleted from the model if statistical analysis shows them to be redundant;
- (2) which inputs are intercorrelated—some of the inputs can be deleted if they are redundant;
- (3) which inputs and outputs are related; and
- (4) the direction of the relationship, i.e. whether it is positive or negative.

Conceptual input/ output measures

Prior studies of police performance suggest us following inputs and outputs for police precincts that could be used in our study as follows.

- (1) input measures:
 - number of various criminal activities recorded, e.g. number of burglaries;
 - number of police officer employed;
 - number of civilian employees;
 - amount of expenditure for a police precinct; and
 - capital equipment used for police activities, e.g. number of police cars and computers;
 - and
 - other inputs, e.g. civilian employees.
- (2) output measures:
 - number of various crime clear up;
 - number of various non-crime activities recorded, e.g. activities for traffic control and emergency first aid care;
 - number of police activities involved to prevent crime and investigate criminal cases, e.g. patrol and official inspection; and
 - other outputs, e.g. quality of services.

Available input/output measures

In an ideal world with no data limitations, our DEA model of police precincts would include all the inputs a police precinct use and all the outputs it produces to deliver service to the public. Since it was difficult to obtain the first hand data from the Police Department, we then only used the secondary data for our study.

Law and order is a high priority of the Taipei City Government. The Police Department has developed several objectives for its services:

- to prevent crime;
- to enforce the law; and
- to protect, help and reassure the public.

In particular the Department aims at preventing crime and bring down high crime rates as major tasks in order to protect public safety. Consequently, the number of crimes recorded and the number of crimes cleared up were considered to be important inputs and outputs. However, there is a large variety of crimes ranging from multiple murder to vandalism. Retention of numerous crime categories would overcomplicate the analysis, obscuring an overview of the performance of each Precinct. For the purpose of building a simple and yet fair picture of crime levels and clear up at each Precinct, we use the group crimes categorized by the Police Department in police statistics publications. Group crimes consist of three types of crime:

- offence (felonious and violent),

- burglary, and
- ‘other’.

Information on numbers of civilian employees, capital equipment used, and various non-crime activities recorded were not available. While information on expenditure for police services was available, the amount budgeted for an included police precinct was not specified. Therefore, these input and output variables were excluded from the DEA model.

A crime was deemed “cleared up” if it had resulted in a summons or charge, caution, no further action deemed appropriate or was deemed to have been ‘taken into consideration’ with some other cleared up offence. Using these three crime categories and available information conveying input the following variables were specified for assessing the performance of police precincts:

- (1) input variables:
 - number of police officers employed (X_1);
 - number of burglaries recorded (X_2);
 - number of offence crimes recorded (X_3); and
 - number of other crimes recorded (X_4).
- (2) output variables:
 - number of burglary clear ups (Y_1);
 - number of offence crime clear ups (Y_2); and
 - number of other crimes clear ups (Y_3).

We used annual data for the years 1994, 1995, and 1996. Table 1 presents descriptive statistics for the data set. The input and output data are reported as the total number throughout the year and can be found in the *Taipei Municipal Police Department Statistics* ([14], [15], [16]) We did not use data covering the years 1996, 1997, 1998, and 1999, because annual statistical data for these police precincts published by Taipei City Government [18] was not available. Only annual data for the Police Department was reported.

TABLE 1 INSERTED HERE

Correlation and regression analysis

As an initial step correlations were calculated to analyze the candidate set of inputs and outputs and identify variables which are highly interrelated. Table 2 shows correlations among all the input and output variables. The following are some of key intercorrelations obtained:

- (1) $R = 0.78$ for ‘the number of police officers’ and ‘the number of other crimes recorded’.
- (2) $R = 0.83$ for ‘the number of offences crime recorded’ and ‘the number of other crimes recorded’.
- (3) $R = 0.90$ for ‘the number of burglary clear ups’ and ‘the number of other crimes clear ups’. Clearly, police precincts that do well on burglary clears up also do well on other crimes clear ups. This finding is consistent with Thanassoulis’s finding [17].
- (4) $R = 0.90$ for ‘the number of offences crime clear ups’ and ‘the number of burglary clear ups’.
- (5) $R = 0.87$ for ‘the number of police officers’ and ‘the number of burglary clear ups’.
- (6) $R = 0.91$ for ‘the number of offences crime clear ups’ and ‘the number of offences crime recorded’.
- (7) $R = 0.91$ for ‘the number of offence crimes clear ups’ and ‘the number of other crimes recorded’.
- (8) $R = 0.94$ for ‘the number of other crimes clear ups’ and ‘the number of other crimes recorded’.

TABLE 2 INSERTED HERE

The next step was an examination of the relations between inputs and outputs, and the direction of the relationships (i.e. positive or negative). To determine the appropriate specification of the model, multiple regression was utilized. The regression results in Table 3 show that a plausible, but not proven, production relationship exists between the input and output measures. We do however note that it is conceptual incomplete, since some data for inputs and outputs simply could not be obtained.

TABLE 3 INSERTED HERE

The input variables explained 87.4% of the variations in the output of burglary clear ups; 92.44% of the variations in the output of offence crimes clear ups; and 91.87% of the variations in the output of burglary clear ups. The results in Table 3 suggest that the inputs related to police officers and on crimes can be viewed as positive factors; that is, increasing the input factor generally led to an increase in an output factor. For the other inputs, number of burglaries recorded and officers, the relationships are weaker. These results provide some assurance that our model using 4 inputs and 3 outputs alone is a good represent of police performance.

4. Methodology

Consistent with managerial goals, our study focuses exclusively on the performance of police officers employed at a police precinct. From a technical perspective, we use some important extensions to DEA models in our study. In particular, we perform window analysis (see Charnes *et al.* [6]) to deal with the degrees of freedom problems with using 7 measures to evaluate 14 precincts/decision making units (DMUs). To perform the efficiency analysis we used a three-year window. Each DMU is represented as if it were a different DMU for each of the three successive years in a window (94, 95, 96), and an analysis of the 42 ($=3 \times 14$) DMUs. As Klopp [11] points out, window analysis can be used to analyze trends and potential stability problems which are also considered in this paper.

Some of the input variables are non-discretionary. They are in the forms of (1) burglaries, (2) offence crime, and (3) other crime. Only the number of police officers in each precinct is discretionary. For these we use the modified DEA mode proposed by Banker and Morey [3].

We use CCR and BCC models to measure overall, technical, and scale efficiencies for these precincts. To investigate returns to scale (RTS), we calculate the sum of all lambdas for each precinct to determine the type of scale efficiency affect these precincts, whether increasing or decreasing returns to scale. According to Banker and Thrall [4], the sum of all lambdas for a DMU is greater than 1 then there is decreasing return to scale (DRS), if the sum of all lambdas for a DMU is less than 1 there is increasing return to scale (IRS). Constant return to scale occurred when the sum of lambdas for a DMU is one. A single source for all of the above references can be found in Cooper *et al.* [9].

Although the efficiency scores obtained from solving linear programming problems for DEA models represent the ability of management to convert inputs into outputs at the current scale of operation, it is possible that some other external factors beyond the control of the management may affect their efficiency. Our interest is to determine which external factors have influence upon variations in technical efficiency across police precincts and in which direction. Multiple regression analysis is used to estimate the relationship between technical efficiency scores and operating environmental factors. Specifically, we estimate the following model:

$$TE = \alpha + Z\beta + u$$

where TE is a vector ($J \times 1$) of technical efficiency for J police precincts, the scalar α and the ($R \times 1$) vector β are unknown parameters to be estimated, Z is a ($J \times R$) matrix of environmental factors and u is ($J \times 1$) vector of residuals.

Production model

Based upon the preliminary analysis, we consider a production model incorporating all 4 inputs and 3 outputs to measure the relative efficiency of police precincts in Taipei city.

The set of input-out variables was used so that the efficiencies obtained would reflect the extent to which clear ups in a precinct could rise given its crime levels and manpower if the precincts were to perform as well as the best precincts found. The data reflecting computers, cars, etc. was ignored, since capital equipment employed by all police precincts are fairly homogeneous. In addition, the data was also not available. The assessment adopted the output orientation, consistent with the notion that crime levels are largely outside the control of the police and efficient operations should, at least in the short, result in higher clear ups rather than lower crime level.

The assessment of police precinct performance in this paper is similar to that in Thanassoulis [17] in that the focus is on the crime clear ups. In running the assessment, we also assumed constant returns to scale hold in converting crimes to clear ups. As Thanassoulis [17] points out, this assumption is likely to be safe if there is no reason to believe that proportion of harder to clear cases depends on the actual portion of cases cleared. Harder to clear cases may be proportionately more the larger the proportion of crimes cases cleared.

Throughout the study, we use output-oriented DEA models. The CCR model is used to examine relative efficiency while the BCC model is used to estimate technical and scale efficiencies. Frontier Analyst, a DEA-based software package developed by Banxia Software Ltd is used for mathematical computations.

The sample

The sample consists of fourteen police precincts in Taipei city; these are all the police precincts in the city. Figure 1 is a map of Taipei city showing the locations of the fourteen police precincts. Other police agencies, such as Criminal Investigation Corps, Police Mobile Unit, Traffic Police Corps, Juvenile Police Corps, and Policewoman Corps are excluded from the study, since these police forces are separate individual police forces.

FIGURE 1 INSERTED HERE

5. Results

Window analysis

Table 4 represents a window analysis of overall, technical, and scale efficiencies, as well as RTS results for these precincts. Table 4 shows that (1) almost 76% of the 42 DMUs were overall inefficient with average overall efficiency score 86.97; (2) approximately 48% of the 42 DMUs were technically inefficient with average technical efficiency score 92.61; (3) nearly 76% of the 42 DMUs were scale inefficient with average scale efficiency score 93.83; and (4) the returns to scale categories for IRS, CRS, and DRS are 32, 10, and 0 DMUs respectively. The resulting overall efficiency ratings of 100, 100 and 100 for three separate DEA evaluations indicate that Chungshan Precinct and Chungcheng 2nd Precinct were overall efficient across the three successive years. Both Chungshan Precinct and Chungcheng 2nd Precinct were also technically efficient and scale efficient; Taan Precinct was technically efficient over the three years.

TABLE 4 INSERTED HERE

As can be seen in Table 4 the DEA assessment yields 10 out of the 42 DMUs have an overall efficiency rating of 100%. The efficient police precincts are Nankang Precinct (1994), Chungcheng 1st Precinct (1994, 1996), Chungcheng 2nd Precinct (1994, 1995), Chungshan Precinct, (1994, 1995, 1996), Neihu Precinct (1996) and Tatung Precinct (1994). The other precincts are overall inefficient, since their efficiency ratings are less than 1. For technical efficiency, 20 out of the 42 DMUs have a technical efficiency rating of 100%. The efficient police precincts are Chungcheng 1st Precinct (1994, 1996), Chungcheng 2nd Precinct (1994) Chungshan Precinct (1994, 1995, 1996), Nankang Precinct (1994, 1995), Neihu Precinct (1996), Shihlin Precinct (1996), Sungshan Precinct (1996), Taan Precinct (1994, 1995, 1996), Tatung Precinct (1994), Wanhua Precinct (1994), Wenshan 1st Precinct (1994) and Wenshan 2nd Precinct (1994, 1995). The other precincts are technically inefficient.

From Table 4 we also observe that the average scale efficiency of 93.83 suggests further potential output improvement of 6.23% if it is possible for a police precinct to operate at constant returns to scale technology. Investigating the distribution of scale in Table 4 reveals that 10 DMUs: Chengcheng 1st Precinct (1994, 1996) Chengcheng 2nd Precinct (1994, 1995), Chungshan Precinct (1994, 1995, 1996), Nankang Precinct (1994), Neihu Precinct (1994), and Tatung Precinct (1994) already operate at the appropriate level. On the other hand, 32 DMUs are experiencing increasing return to scale. This suggests that these inefficient precincts could improve performance, if current operating output levels of these inefficient precincts were increased.

Table 4 lends itself to a study of trends and the potential problems within the window. Consider, for instance, the 78.86 overall efficiency score shown for Wenshan 1st Precinct in 1994. This value differs considerably from 65.46 (-16%) and 60.88 (-23%) efficiency values presented in the 1995 and 1996 evaluations. Given that the relative efficiency ratings for Wenshan 1st Precinct are generally low and declining, further investigation should be considered. Neihu Precinct has 74.80 overall efficiency value exhibited for in the 1994 evaluation. This value differs very much from 80.08 (+7%) and 100 (+34.80%) efficiency values presented in the 1995 and 1996 evaluations. The overall efficiency ratings for Neihu Precinct exhibit an upward trend, especially in the latter part of the three-year period and this, too, is potentially useful for evaluating its behavior. Similarly, one can analyze the trends and potential stability problems using technical and scale efficiency ratings obtained for these precincts.

Table 5 summarizes the results in Table 4 in yet another way. Note, for example, that Wenshan 1st Precinct has the lowest mean value of 68.40 and it also has a high variance in its overall efficiency ratings. Part of the latter maybe due to the unusually low overall efficiency rating of 60.88 in the 1996 evaluation of this DMU, as we previously observed, should be set aside for further examination. On the other hand, low means tend to be accompanied by high variances in Table 5, with the possible exception of Peitou Precinct. The latter, which also appears in group I, the very low variance group for Table 5, has the overall efficiency rating of 79.17 for this DMU in the 1994 evaluation. This value does not differ very much from 80.08 (+1%) and 78.55 (-0.7%) efficiency values presented in the 1995 and 1996 evaluations — see Table 4 — and this, too, should be investigated in more detail.

TABLE 5 INSERTED HERE

Chengcheng 2nd Precinct, Wenshan 1st Precinct, and Wenshan 2nd Precinct have the high mean technical efficiency values of 94.45, 94.21 and 93.39. Each of these precincts also has a high variance in its overall efficiency ratings. For these three precincts, the high variance in their efficiency ratings may be due to the low ratings of 83.35 for Chengcheng 2nd Precinct, 83.09 for Wenshan 1st Precinct, and 80.16 for Wenshan 2nd in the 1996 evaluation of these DMUs. The rest of the empirical results is focused on technical efficiency and is presented in the following sections.

Peer References

An inspection was next made of how frequently each efficient Precinct was used as a comparator of ‘efficient peer’ for inefficient Precincts. The purpose of this inspection was to identify an exemplar of good performance according to the number of times efficient Precincts appeared in the reference set. The reference sets and their frequencies for the 42 DMUs precincts are given in Table 6. The most frequent efficient peers are Taan Precinct (1994), Tatung Precinct (1994), Chungshan Precinct (1995) and Chungcheng 2nd Precinct (1995). This means that these four have the most usual mixes of crime levels, officers strength and clear ups and that is why they are used so often as comparators for inefficient Precincts. These four police precincts were ‘good performers’ in terms of all their input-output levels.

TABLE 6 INSERTED HERE

In order to gain a better insight into the performance of Precincts, we looked at the correlation between inputs and their technical efficiency scores. Three inputs are positively associated with efficiency scores. Higher manpower levels were weakly associated with higher efficiency ratings. This finding is consistent with Thanassoulis [17]. The lowest correlation coefficient is 0.04, found between police officer levels and efficiency scores. The correlation coefficient is 0.11, found between offence crime levels and efficiency scores. The correlation coefficient is 0.14, found between burglary levels and efficiency scores and between other crime levels and efficiency scores.

Input and output contributions

A good view of the performance of each inefficient Precinct can be gained when its input-output contributions are contrasted with those of its efficient peer references unit, identified in Table 6. Input/output contribution can be measured on how much input/output of a DMU have been used in determining efficiency. The values are ‘normalized’ to show a percentage of the overall input and output contribution and are obtained through the following computational procedure:

Step 1. For the efficient unit(s) calculate input/output variables times lambda for each input/output variable;

Step 2. Take the answer from 1, for each variable and divide it by the largest value for each variable for the inefficient unit; and

Step 3. Multiply by 100 to get the percentage value for the inefficient.

Table 7 shows the input/output contributions of the 42 DMUs. Thus, one may make comparisons of an inefficient unit and its reference set using tables such as Table 8.

TABLE 7 INSERTED HERE

Table 8 relates to inefficient DMU8-94: Shinyi Precinct (1994). The column headed ‘DMU8-94’ shows its ‘normalized’ input/output contributions. The input/output contributions under DMU1-94: Tatung Precinct (1994) are its normalized input/output contributions so that one of its input contributions (police officers) is higher than that of Shinyi Precinct (1994) while none of the rest of its input contributions is higher than the corresponding contribution of Shinyi Precinct (1994). The input-output contributions of the rest of the efficient peers have been normalized in a similar manner. This makes it easy to compare Shinyi Precinct (1994) with its peers as we can now focus on output contributions only.

If Shinyi Precinct (1994) to be deemed to have equivalent performance to that of its efficient peers, its output contributions must be at least as good as those of efficient peers. In fact, Shinyi Precinct (1994) has better output contribution (burglary clear ups) than Chungcheng 1st Precinct (1994), Chungcheng 2nd Precinct (1996), Taan Precinct (1994), and Tatung Precinct (1994). It also has better output contribution (offences crime clear ups) than peer references, with exception of Chungcheng 1st Precinct (1994). Finally, it has better output contribution (other crimes clear ups) than Chungshan Precinct (1994), Chungcheng 1st Precinct (1994, 1996), and Chungcheng 2nd Precinct (1996). Tables such as Table 8 can be used to review the performance of other inefficient Precincts.

TABLE 8 INSERTED HERE

Slack analysis

In order to find important information indicating by how much and in what areas an inefficient unit needs to improve in order to be efficient, a non-zero slack analysis was used. Non-zero slack analysis can identify marginal contributions in efficiency ratings with an additional increase in specific output amounts or with an addition decrease in specific input amounts. Table 9 represents results of the slack analysis.

Among the input measures, the number of burglaries recorded has the greatest number of non-zero slacks 14 while the highest number of non-zero slacks for output measures is 32. Holding the level of police services constant, on average, six DMUs could reduce the number of police officers by 26.56 officers; fourteen DMUs could reduce the number of burglaries by 239.04; thirteen DMUs could reduce the number of offences by 25.88; one DMU could reduce the number of other crimes by 74; and 32 DMUs could increase the number of burglary clear ups by 49.24,

the number of offence crime clear ups by 11.98, and the number of other crime clear ups by 115.94. Those having zero slack of course require no such addition to achieve their value if efficient. These estimated reductions in inputs would not in themselves suffice. They would also need to be accompanied by the estimated increases in outputs if an inefficient precinct were to achieve 100% efficiency.

TABLE 9 INSERTED HERE

The solution of the DEA models yields target input and output level which would render inefficient precincts efficient, if not already so (see Charnes et al. [7]). Information on target levels is given in Table 10. This information can be used to provide the Police Department important implications for improving performance of these inefficient units.

The TARGET column shows the amount of inputs and outputs that an inefficient Precinct should be using or producing in order to be efficient while POTENTIAL IMPROVEMENT column shows how much, in percentage terms, an inefficient Precinct' use of inputs or production of output needs to change by in order for it to be efficient. For example, DMU8-94: Shinyi Precinct in the 1994 evaluation could increase the number of burglary clear ups from 246 to 334 (an addition of 48.26%), the number of offence clear ups from 73 to 90.44 (an addition of 48.26%) and the number of other crime clear ups from 664 to 984.46 (an addition of 48.26%), in order to become efficient as its peer references.

Care is needed in interpreting target crime levels. One should be aware that crime levels are beyond the control of any police precincts in a large extent. It can only be influenced by crime prevention measures and crime will be deterred by high detection levels. The crime target levels indicate any reductions in crime levels that could take place before they begin to imply that corresponding reductions in clear up level are justifiable if a police precinct is efficient.

TABLE 10 INSERTED HERE

Multiple regression analysis

As discussed in the methodological section, the regression procedure is used in the second-stage analysis to explain the variation in DEA technical efficiency scores from the first stage. Based on previous police reports (i.e. [14, 15, 16]), we identified several environmental variables, or noncontrollable inputs, that may affect the efficiency of a police precinct which are beyond the control of management. Police observe most offenders are young people aged between 15 to 29 years. A higher population of young people that live in a police jurisdiction is likely to respond to more incidents compared to a lower population of young people in a police jurisdiction. Further, a precinct with a higher population of residents in its jurisdiction is likely to respond to more crime compared to a similar precinct having a lower population of residents. A precinct covering a larger jurisdiction area requires additional police officers above the level of resources justified the services they provide to the community. A precinct with a wider jurisdiction is likely to respond to more crimes compared to a similar precinct having a smaller jurisdiction due to lack of sufficient staff. Finally, a police precinct located in downtown area is likely to respond to more crime compared to a similar precinct located in suburban area, since there are more luxurious private housing estates located in downtown area. People living in luxurious housing are financially better off than the rest of the community and have more infrastructure and amenities to support and entertain their community.

The jurisdiction area of a police precinct, the population of residents that live in a police jurisdiction and the population of young people that live in a police jurisdiction are derived from 1994-1996 statistical data reported in [14, 15, 16]. A dummy variable is used to specify the location of a police precinct, where a value of one indicates a precinct is located in the downtown and a value of zero indicate a precinct is located in the suburb. Precincts with a higher population of young people or a higher population of residents are expected to appear more efficient than similar with lower populations of these socioeconomic conditions in their jurisdiction because they are relative busy responding to more crime (i.e. they have less idle time). Nevertheless, we still expect police precincts located in the downtown to have higher measured outputs because the Department located in the downtown could have a closer supervision on them than those precincts located in the suburban. Precincts with larger jurisdiction are expected relative inefficient compared to precincts with smaller jurisdiction because they require more inputs to provide an effective service.

To determine whether environmental factors affect the efficiency of police precincts, the technical efficiency score are regressed against the location of a police precinct, the jurisdiction area of a police precinct, the population of residents that live in a police jurisdiction and the population of young people that live in a police jurisdiction. The regression results in Table 11 explains about 6 percent of the variation in technical efficiency scores and none of the coefficients of the explanatory variables are significant at the 5 percent level of significance. Consequently, we conclude that the efficiency of police precincts are not influenced by these environmental variables. Our finding is consistent with Carrington *et al.* [5].

TABLE 11 INSERTED HERE

6. Conclusions

This paper has given an account of a DEA application to the assessment of policing performance. Chungshan Precinct was rated as the most efficient unit in terms of overall, technical, and scale efficiencies for the years 1994-1996 using police statistical data.

We have shown that police precincts can be investigated in terms of their relative efficiency. The overall performance of these precincts was assessed by setting their clear up levels against their crime and manning levels. This identified potentially weak and strong precincts on performance, their efficient peers and the levels of clear ups that would render inefficient precincts efficient. In particular, Chengcheng 1st Precinct (1994, 1996), Chengcheng 2nd Precinct (1994, 1995), Chungshan Precinct (1994, 1995, 1996), Nankang Precinct (1994), Neihu Precinct (1994), and Tatung Precinct (1994) already operate at the appropriate level. The other precincts are experiencing increasing return to scale and could improve their output levels to be efficient. There is a weak suggestion that higher manpower levels were associated with higher performance efficiency. Nevertheless, our analysis indicated that differences in operating environments and socioeconomic factors do not have a significant influence upon the efficiency of police precincts.

A few notes of caution are in order here. Our study is in terms of highly aggregated measures of output and inputs. There are important qualitative dimensions of outputs that are not taken into account. For example, measuring the quality of police work and the quality of police officers. It would be desirable to treat these outputs explicitly in the models used in this study. Our basic methodology would still remain valid, however.

Finally, it is important to note that the findings discussed in this paper are indicators of relative efficiency (or inefficiency) which are a means to an end—efficient operations— and not the end in themselves. As such, the information serves as a guide to the Police Department for additional investigation into enhancing a police precinct's performance efficiency.

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Note: Tables will be provided for conference attendees

Table 4. Efficiency of the fourteen police precincts

Precinct	Term	DMU Code	Efficiency Measures (%)			RTS
			Overall	Technical	Scale	
Tatung	1994	1-94	100	100	100	CRS
	1995	1-95	92.31	92.40	99.90	IRS
Wanhua	1996	1-96	88.95	89.13	99.80	IRS
	1994	2-94	99.92	100	99.92	IRS
	1995	2-95	84.71	86.06	98.43	IRS
Chungshan	1996	2-96	91.47	93.98	97.33	IRS
	1994	3-94	100	100	100	CRS
	1995	3-95	100	100	100	CRS
Taan	1996	3-96	100	100	100	CRS
	1994	4-94	99.33	100	99.33	IRS
	1995	4-95	94.25	100	94.25	IRS
Chungcheng 1st	1996	4-96	93.38	100	93.38	IRS
	1994	5-94	100	100	100	CRS
	1995	5-95	98.45	98.58	98.45	IRS
Chungcheng 2nd	1996	5-96	100	100	100	CRS
	1994	6-94	100	100	100	CRS
	1995	6-95	100	100	100	IRS
Sunqshan	1996	6-96	82.85	83.35	99.40	IRS
	1994	7-94	91.83	92.36	99.43	IRS
	1995	7-95	80.74	82.25	98.16	IRS
Shinyi	1996	7-96	98.35	100	98.35	IRS
	1994	8-94	77.51	67.45	96.83	IRS
	1995	8-95	71.71	74.30	96.51	IRS
Shihlin	1996	8-96	79.80	84.99	93.89	IRS
	1994	9-94	77.51	80.85	95.87	IRS
	1995	9-95	81.87	87.99	93.04	IRS
Peitou	1996	9-96	94.42	100	94.42	IRS
	1994	10-94	79.17	83.75	94.53	IRS
	1995	10-95	80.05	88.49	90.46	IRS
Wenshan 1st	1996	10-96	78.55	84.33	93.15	IRS
	1994	11-94	78.86	100	78.86	IRS
	1995	11-95	65.46	99.53	65.77	IRS
Wenshan 2nd	1996	11-96	60.88	83.09	73.27	IRS
	1994	12-94	89.10	100	89.10	IRS
	1995	12-95	84.73	100	84.73	IRS
Nankang	1996	12-96	69.49	80.16	80.45	IRS
	1994	13-94	100	100	100	CRS
	1995	13-95	71.47	100	71.47	IRS
Neihu	1996	13-96	73.10	99.12	73.75	IRS
	1994	14-94	74.80	76.21	98.15	IRS
	1995	14-95	80.08	81.16	99.05	IRS
	1996	14-96	100	100	100	CRS
Mean			86.97	92.61	93.83	



Figure 1: A map of Taipei city showing the locations of the fourteen police precincts