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An Application to Out of Hours Primary Care Services on the Island of Ireland

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Abstract:

This paper is a cross border study that explores isolating the efficiency component and measuring its overall contribution to productivity in the case of out of hours (OOH) primary care services operating on the Island of Ireland. Out of hours GP care is supplied throughout the Island of Ireland by OOH co-operatives. Although Northern Ireland (NI) and the Republic of Ireland (ROI) have their own individual health systems the OOH organisations themselves are relatively homogenous in structure. The data for this study has been gathered and collated by the author and relates to six of twelve co-operatives operating in ROI and five of the seven co-operatives in NI. The primary aim of this paper is to estimate efficiency for these organisations using stochastic frontier analysis (SFA) SFA was chosen as the method for analysis as it allows distinction between 'noise' effects and efficiency effects. This paper outlines the means that SFA methodology can be used to derive sensible and robust efficiency estimates for OOH primary care organizations operating on the Island of Ireland. The paper also examines the sensitivity of these estimates to the choice of functional form for the health production function, the choice of error distribution for the efficiency terms and the means in which heterogeneity is incorporated into the analysis. Individual efficiency estimates, rankings, cross border rankings and comparisons are reported to allow recommendations to be made on how these organizations can improve their production process.

Keywords: Primary Care, Out of Hours, Efficiency, Stochastic Production Frontiers.

Introduction and Background:

Measuring efficiency using parametric methods has been a common theme in the literature in recent years with stochastic frontier analysis (SFA)[1] being the dominant parametric technique utilised since the seminal papers of Aigner, Lovell & Schmidt (1977) and Meeusen and Van den Broeck (1977). SFA employs multivariate statistical methods to explore output or cost variations between organizations and thereby produce efficiency scores for the entities under consideration. It is necessary in this scenario to choose an appropriate distribution assumption for the one sided error as well as a functional form.

This analysis considers a stochastic production frontier (SPF) approach to estimating efficiencies for organisations on the Island of Ireland that supply GP services outside of normal working hours. The aim of the work is two fold. Firstly, SFA is used to estimate the efficiencies of these out of hours (OOH) co-ops. The data is from the Republic of Ireland (ROI) and Northern Ireland (NI). Although NI and ROI have their own individual health systems, the OOH organisations themselves are relatively homogenous in structure, opening hours and facilities. Therefore this study will measure if there are any efficiency gains between OOH co-ops operating in NI as opposed to ROI. These gains may be due to cheaper remuneration of staff across borders or be linked to government influences. All OOH co-ops supply consultations for patients in their own home as well as in treatment centres. OOH co-ops may operate through doctor or nurse triaging. For organisations that operate via nurse triaging, two additional services of nurse advice and doctor advice are offered to their patients. In this instance the triager is a nurse. For the OOH co-op that operates via doctor triaging only doctor advice is supplied with the doctor being the triager. This work therefore has the unique opportunity of considering the differences in efficiency across these two types of triaging. Differences in efficiencies across borders or types of triaging will interest health policy makers and OOH management alike.

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[1] For a complete review of SFA the reader is referred to Kumbhaker and Lovell (2000)

> The second aim of this study is to consider the effects on efficiency scores of changes to the specification. That is the effects on the emanating efficiencies of varying the distributional assumption on the one sided error component and the functional form. A further complication exists when SFA is being employed to measure efficiency values for organisations working within the health services. In this scenario it is necessary to account for the immeasurable elements of quality of care and casemix as well as decide on suitable proxies to incorporate the latter. Therefore, the third specification change considered relates to the manner in which the immeasurable element of casemix is incorporated into the analysis. Changes in the efficiencies will be examined by considering the changes in the descriptive statistics, kernel densities and Spearman rank correlations from each model. Nested and non nested testing procedures are also utilised to decide on the most appropriate model. This allows the model that is believed to be theoretically correct to be compared to other models based on statistical merit and also allows conclusions to be drawn on the sensitivity of efficiency estimates to changes in the specification.

Considering the choice of functional form, the literature favours Cobb-Douglas (Puig-Junoy and Ortun (2004), Settlage et al. (2000)) and the more general translog functional form (Rosenman and Friesner (2004), Zuckerman (2004). Emerging evidence suggests that the former choices should not significantly affect the overall emanating efficiency results (Hollingsworth and Wildman 2002, Kumbhakar and Lovell 2000); however what the researcher gains in flexibility they may lose to multicollinearity. This work will re visit this topic and consider both the translog and Cobb-Douglas functional form as well as two reduced forms of the former.

Returning to placing a distributional assumption on the one sided error term, the literature is split on whether variation changes the efficiencies in a significant manner. For example, Hollingsworth and Wildman (2002) conclude that choice of efficiency distribution is not important versus Kumbhakar and Lovell (2000) who found significant impact to efficiency estimates and their ranks. This work will provide further evidence in this debate by comparing the Half Normal distribution (Aigner, Lovell & Schmidt (1977)), the exponential distribution, the gamma distribution (Greene 1980) and the truncated distribution (Stevenson 1980) for the one sided error in terms of their impact on efficiency estimates.

Whether casemix should be included in an equation that aims to estimate efficiency for an organisation providing a health service is a moot point, where these effects should be placed in the equation is less obvious. This work argues that the casemix effects should be placed in the variance of the one sided error term. It is also argued that the doctor triaging indicator should appear in this variance. Changes to this specification are considered by moving these effects to the variance of the symmetric component, moving these effects across both the variance of the one sided error and the variance of the symmetric component and moving all effects to the production function. This analysis may be seen as a contribution to the literature as no study has considered these four cases with respect to impact on the efficiencies.

The final feature of this work that is unique to the literature is the manner in which output is measured. That is, this analysis considers an approach where payroll is considered as an output in the health production function and services offered by the healthcare facility are seen as inputs. These services are generally modelled as outputs in the traditional production frontier approach. It is argued that this may be inappropriate when these services are exogenous and is even more troublesome with multiple output technology when a suitable aggregation method is not apparent. The objective of the function is then to minimise the payroll given the inputs. This approach is applied to micro panel data from primary care out of hours' services which operate on the Island of Ireland.

Sample and Data:

The models for this paper are estimated using daily data from out of hour's co-ops for the time period 01 May 2004 to 31st April 2005. The data were collected and collated by the author. OOH co-ops were set up on the island of Ireland to provide primary care services outside normal GP working hours. They are not an accident and emergency (A&E)

service although practically speaking their existence may have taken some load off A&E services by treating borderline or non-serious cases. There are 12 OOH co-ops operating in ROI and 8 of these are established in eight of the former health boards. These co-ops operate from 6pm-8am Monday to Friday and from 10am -8am Saturday and Sunday and consist of a call centre and a number of treatment centres. These centers have facilities similar to those expected from an in-hours GP service. The remaining four co-ops operate from 6pm-10pm Monday to Friday and 10am to 6pm Saturday and Sundays. These co-ops are based in Dublin and operate on a smaller scale consisting of one premises. This premises combines a treatment centre and a call centre. All co-ops in ROI were asked to contribute data to this study and 6 large and 2 small co-operatives agreed. The latter 2 co-operatives were dropped as the data quality differed from other OOH co-ops in terms of variables stored. In NI there are seven OOH co-ops located with four health boards. The Northern, Western and Southern boards each contain one co-operative and there are four co-operatives in the Eastern Board resulting in a total of 7 OOH co-ops serving the population of NI. Again, all 7 organisations were asked to contribute data and 5 agreed. This results in a sample of 11 out of hours co-operatives which serve approximately 55% of the population of the island of Ireland in terms of OOH primary care. The OOH co-ops in NI hold identical opening hours and structure to their ROI counterparts. OOH co-ops offer some or all of the following services:

a) A consultation with a GP in one of the co-ops treatment centers
b) A consultation with a GP in the patient's own home
c) Advice via telephone from a GP
d) Advice via telephone from a nurse

Nurse advice is only offered from OOH co-ops that practice nurse triaging, in this case 5 out of the six OOH co-ops that are included and operating in NI. All the remaining OOH co-ops practice doctor triaging. When patients initially contact an OOH co-op they are connected to the triage unit, where an operator takes their name and address. A triager[2] then discusses the purpose of the patients' call, their characteristics and their symptoms to

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[2] A doctor in the case of doctor triaging and a nurse in the case of nurse triaging

establish which service the patient needs. If a patient is to receive triage advice for their complaint it is provided by the triager at this point. For any of the other services the patient is referred to their nearest centre. The individual using the service is tracked from the point of original contact through to their final diagnosis and treatment.

The data are arranged in panel form with N=11 (number of co-ops) and T=365 (number of days). The dependant variable (output) is payroll and is calculated based on the quantity of nursing, medical and administrative staff employed daily by the centre multiplied by their price of labor[3]. The reasoning behind specifying payroll as the primary output is discussed in the next section. Four inputs are considered: quantity of home visits, quantity of treatment centre consultations, quantity of nurse advice and quantity of doctor advice for each day. An indicator is also created to indicate whether the OOH co-op practices nurse triaging or doctor triaging.

Additional variables are included in the model to account for patient casemix and quality of care of the centre. A clinical indicator which has been dubbed 'priority' indicates how serious the caller's complaint is. When a caller rings the triager places a marker on the individuals name indicating whether this caller is considered a priority or not. These indicators are aggregated to provide an estimate of the number of high priority cases daily. A second indicator considered is the quantity of calls received between 12am and 8am (red eye). It is argued that individuals would only ring during these late hours for urgent matters. Again, this indicator is aggregated to represent the number of 'redeye' calls received. Certain characteristics of the patients seen are also included as casemix proxies. Following the literature Sex is also included; the literature (Nolan and Nolan (2002)) suggests that females receive a higher quantity of primary care *cetrius paribus*,

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[3] For administrative, driving and nursing staff this is straightforward as these staff are paid hourly. For medical staff, locum staff are paid hourly whereas GP's are paid a fee for the quantity of home visits and treatment centre visits that they provide. This fee differs for public and private patients.

whether this translates to higher resources being consumed by females over males is left for the data to disentangle. Previous literature also suggests that both the quantity of toddlers (Szczepura (1993)) and the quantity of elderly (Johnson (2005), LiM (1996)) should also be included in this analysis for similar reasons. The variable representing the quantity of elderly people was defined as the total number of individuals greater than 75 seen daily and the toddler variable was described as the total number of children less than three years seen daily.

Four reaction variables are constructed to capture how fast the joint effort of the triage unit and the centre is to a patient's call. Relating to the doctor advice and nurse advice service the associated reaction variables are defined as the difference between the time the person rang and the time they received medical advice. Relating to home and treatment centre visits, two variables are constructed and are defined as the difference between the time the person rang and the time they received their direct consultation with a GP.

A set of eleven fixed effects are also constructed to indicate each individual OOH co-op. Descriptive statistics of these variables are documented in table 1:

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Quantity of Treatment Centre Visits (x1)	84.39	93.77	2.000	1210
Quantity of Home Visits (x2)	18.63	15.90	.0000	123
Quantity of Nurse Advice (x3)	22.90	36.58	.0000	298
Quantity of Doctor Advice (x4)	55.15	72.33	.0000	638
Nurse Advice Reaction Time (z1)	378	810	.0000	19737
Doctor Advice Reaction Time (z2)	598	968	.0000	26289
Treatment Centre Reaction Time (z3)	4282	8684	.0000	150758
Home Visit Reaction Time (z4)	958	1396	.0000	13797
Quantity of three year olds (j1)	30.05	31.27	.0000	251
Quantity of seventy five year olds (j2)	21.40	21.22	.0000	148
Quantity of severe patients (j3)	12.62	20.15	.0000	167
Quantity of Patients seen in the Red Eye (j4)	21.01	13.63	.0000	112
Quantity of Female Patients (j5)	111.76	109.20	.0000	925

Stochastic Production Frontier:

The traditional stochastic production frontier model (Aigner, Lovell & Schmidt (1977), Meeusen and Van den Broeck (1977)) can be represented by:

$$y_i = \alpha + \beta' x_i + v_i - u_i \qquad (1)$$

where y_i is the amount produced by the ith firm, x_i is a K * 1 vector of inputs and B is an unknown parameter vector to be estimated. Notably the error term has two components; the first is $v_i \sim N[0, \sigma_v^2]$ and is equivalent to the traditional stochastic error. The second is a one-sided error component u_i that allows a firm to lie away from the best practice frontier. In the seminal papers $u_i \sim N[0, \sigma_u^2]$ and both v_i and u_i are assumed to be uncorrelated. Alternatively u_i may follow an exponential, truncated normal (Stevenson (1980) or gamma (Greene (1980, 1990).

A firms' efficiency is calculated based on actual output produced divided by the level of output that would have ensued if technical inefficiency was zero. Equation 1 illustrates a stochastic production frontier for panel data with time invariant inefficiencies. The conditional distribution of u_i given e_i can be used estimate u_i for the normal-half normal stochastic production frontier[4] as originally proposed by Jondrow et al. (1982):

$$E[u_i \mid e_i] = \sigma_* [\frac{\phi(e_i \kappa / \sigma)}{1 - \Phi(-e_i k / \sigma)} + (e_i k / \sigma)$$

$$E[u_i \mid e_i] = [\frac{\sigma\lambda}{1+\lambda^2}][\tilde{\mu}_{it} + \frac{\phi(\tilde{u}_{it})}{\Phi(\tilde{u}_{it})}]$$

where

$$\varepsilon_i = y_i - B^{'} x_i = v_i - u_i$$

$$\tilde{\mu}_i = -\lambda \varepsilon_{it} / \sigma$$

$$\sigma = [\sigma_u^2 + \sigma_v^2]^{.5}$$

$$\lambda = \sigma_u / \sigma_v$$

Given $E[u_i \mid e_i]$ a firms' efficiency can be calculated as $\text{TE}_\text{i} = \exp(-u_i)$. Values for efficiency are between zero and one, a firm with a technical efficiency of one being fully efficient. The difference between 1 and the actual efficiency value obtained 'provides a measure of the shortfall of observed output from maximum feasible output' (Kumbhaker and Lovell 2000).

Measuring Output:

Before the framework described in equation 1 can be applied to the data it is necessary to decide on an appropriate measure for output. The natural choice in the healthcare literature may be to consider a measure of the service offered to patients, such as beds in the case of hospitals or the quantity of surgery visits in the case of measuring GP efficiency. This poses a problem in the current setting as the co-op's offers four very different types of services; treatment centre visits, home visits, nurse advice and doctor advice. A solution would be to consider a dual approach which involves estimation of a cost or profit function, and requires price data. It also assumes cost minimization or profit

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[4] Conditional estimators for the normal-exponential, normal-gamma models may be found in the quoted seminal papers.

maximization behavior. It is questionable if such assumptions are justified for health services, but this question is moot given that full price data are unavailable.

Alternatively, if a suitable aggregated measure exists it can be used to create a dependent variable for SFA. Initially an obvious choice is to consider the price of the service as an appropriate weight in which to aggregate services. However in the case of the OOH co-op doctor advice and nurse advice is free of charge and this does not reflect its value to the patient receiving it. Also, in ROI there are two different groups of patients who attend the co-ops, private and public, and these groups pay different charges[5] for the treatment centre and home visit services while in NI all services are provided free of charge by the National Health Service (NHS). Again, these discriminating prices do not fully reflect the value of these services to patients.

Ignoring the latter problems and assuming it is justified to aggregate services using price of service, to enforce the framework of equation one it is necessary to specify inputs. A natural choice for inputs is labour data, which is quantity of nurses, administration staff, medical staff and drivers employed by the co-op weighted by the price of labour. It follows we assume the latter are exogenous. This may not be a plausible assumption, the service itself is an emergency out of hours, and therefore the quantity of staff on a rota is a function of the quantity of calls received and the type of services provided daily and not vice versa. Therefore staffing levels are not theoretically exogenous to the equation.

This analysis considers an original approach where payroll is considered as an output in the health production function and services offered by the healthcare facility are seen as inputs. That is, in this case we postulate that the services offered to the patient are exogenous. The latter is true if and only if services offered to the patient are not determined by the co-op staff but are driven by factors outside the co-ops' control. In this instance, we argue that services are driven by the condition the patient reports when they first contact the co-op, their age, severity and possibly their sex.

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[5] A public patient in ROI does not pay for these services, whereas a private patient pays the fees as determined by the co-op.

Lordan (2006a) explores the latter by considering gastroenteritis patients that present to the co-op. This illness category is chosen as the case study as it covers a wide range of symptoms, can potentially affect all individuals in the population and its severity varies considerably with patient characteristics. Therefore it is expected that the services offered to the patient will also vary. The author considers a discrete choice approach when considering the factors that determine the service the patient receives. A multinomial logit is employed which allows for patient, call and co-op characteristics to affect the choice variable. The results indicate that patient and call characteristics are the elements that ultimately affect the service the patient receives and find co-op characteristics to be insignificant in this choice. Lordan (2006b) extends the latter analysis by considering a number of disease classes. The results again show that co-op characteristics are jointly insignificant in determining service choice.

Methodology:

Accepting the hypothesis that services are not determined by the co-op staff but are driven by exogenous factors we may extend equation 1 to allow for panel data and consider one modification:

$$y_{it} = \alpha_i + \beta' x_{it} + v_{it} + u_i \qquad (2)$$

In this case y_{it} represents the payroll of the i^{th} co-op for day t, x_{it} is a K * 1 vector of inputs corresponding to the quantity of treatment centre visits, the quantity of home visits, the quantity of nurse advice and the quantity of doctor advice dispensed by co-op i for day t. β is an unknown parameter vector to be estimated, $v_{it} \sim N[0, \sigma_v^2]$ and $u_i \sim N[0, \sigma_u^2]$. α_i represents the producer specific dummy variables, that is, equation 2 corresponds to a fixed effects stochastic frontier model. It should be noted that the latter differs from the dominant Schmidt and Sickles (1984) fixed effects estimator which takes the form:

$$y_{it} = (\alpha - u_i) + B' x_{it} + v_{it} \qquad (3)$$

$$= \alpha_i + B' x_{it} + v_{it}$$

$$u_i = \max_i(\alpha_i) - \alpha_i >= 0$$

The drawback of equation 3 is its failure to incorporate producer specific latent heterogeneity (see Greene 2002). Equation 2 overcomes this by incorporating a full set of producer specific dummies, which will catch producer specific heterogeneity. This approach is not widely used in the literature because the addition of dummies distinctly increases the number of parameters to be estimated and because of the incidental parameters problem (Neyman and Scott (1948)). With regard to the former given that the number of OOH co-ops is 11, it is envisaged that this is small enough not cause computational problems when producer specific dummies are introduced into the equation. Considering the incidental parameters problem occurs because the number of parameters to be estimated grows with N, it is expected this issue is only a concern when T is small (Greene (2002)), whereas in this instance T=365.

The primary aim of this analysis is to estimate efficiency values for OOH co-ops and provide an insight into how sensitive these estimates are to changes in the specification. In order to produce credible efficiency estimates from healthcare data it is necessary to look at incorporating both casemix and quality of care. Therefore the methodology will consider three aspects relating to specification. Firstly, it is necessary to choose an appropriate functional form for equation 2. As previously stated, the standard is to choose a translog or Cobb-Douglas. The dominance of the flexible translog in the literature, as well as evidence from the SFA literature suggesting that choices of the latter do not greatly affect efficiency results (Hollingsworth and Wildman 2002, Kumbhakar and Lovell 2000) abate concerns surrounding this choice. However multicollinearity is a major problem with the flexible translog. It is therefore worthwhile revisiting this issue by estimating the translog functional form, the Cobb-Douglas functional form as well as two reduced forms of the former to gauge their robustness in terms of efficiency values. These functional forms are described in equations 4, 5, 6 and 7 respectively. It is straightforward to choose between these forms as they are nested counterparts and standard likelihood ratio testing is applicable.

$$Lny_{it} = \alpha_i + \beta' \ln x_{it} + v_{it} + u_i \qquad (4)$$

$$Lny_{it} = \alpha_i + \beta' \ln x_{it} + .5\beta' \ln(x_{it})^2 + \ln x_{it} \ln x_{jt} + v_{it} + u_i \tag{5}$$

$$Lny_{it} = \alpha_i + \beta' \ln x_{it} + .5\beta' \ln(x_{it})^2 + v_{it} + u_i \tag{6}$$

$$Lny_{it} = \alpha_i + \beta' \ln x_{it} + \ln x_{it} \ln x_{jt} + v_{it} + u_i \tag{7}$$

So far, we have ignored the issues of incorporating quality of care and casemix into the analysis. The issue of the latter will be returned to letter, considering the former, a vector z contains the quality of care proxies relating to reaction times. Specifically, these variables correspond to the reaction time of the OOH co-op to supplying the services of nurse advice, doctor advice, treatment centre visits and home visits respectively. At a micro level these variables are measured as the time elapsed between a patient contacting the triage centre and receiving one of the latter services. Reasonably a centre that has the lowest reaction time is the least wasteful and the most efficient *cetrius paribus*. It seems logical that a high reaction time would result in a higher payroll *cetrius paribus* and a vice versa for a low reaction time. It was therefore decided to place these variables directly into the production function of equations 4 through 7.

Returning to placing a distributional assumption on u_i, evidence is mixed on the impact of favouring one distribution against another in the case of SFA. Hollingsworth and Wildman (2002) using WHO (2000) data modelled both half-normal and truncated-normal random effects. Based on their results the authors conclude that choice of efficiency distribution did not largely affect their results. Conversely, Kumbhakar and Lovell (2000) calculated rank correlation coefficients between pairs of efficiency estimates based on data of 124 U.S. electric utilities used in Greene (1990). The authors calculated these correlations for the half normal, truncated normal, exponential and gamma distributions and found the lowest rank correlation to be .7467 (between exponential and gamma). This analysis will consider the Normal-Half Normal Model

(Aigner, Lovell & Schmidt (1977)), the Normal-Exponential Model, the Normal-Truncated Normal Model (Stevenson 1980) and the Normal Gamma Model (Greene 1980)[6]. *A priori* expectations indicate that the latter choice should not affect the emanating efficiency results. Distinguishing the most appropriate distribution is done using testing procedures for non-nested models; namely the Vuong test statistic (1989) as well as AIC and BIC criteria.

Incorporating casemix into the model can be done in a number of ways. Specifically, these components can be allowed to shift the production function, the variance of the one sided inefficiency component or the variance of the symmetric component among other options. Because it is proxies that we are using as a measure casemix (and indeed vector z that represents quality of care) it should be noted that not all variation attributed to these components may be captured, nevertheless, it is an important question as to where they should appear in the model.

Considering the casemix proxies, a vector j is created which contains variables relating to the quantity of patients less than 3 and greater than 75 seen daily, the quantity of female patients seen daily, the number of cases seen in the redeye and the quantity of emergency and urgent cases seen by the OOH co-op. A casemix that contains more vulnerable and/or severe cases will affect the efficiency values. To argue in the other direction, ignoring casemix effects will ultimately dub OOH co-ops that treat a more severe casemix as less efficient than other OOH co-ops *cetrius paribus* by subsuming the effects into the error term from which the efficiencies are drawn. It is postulated that these variables should ideally affect the variance of the one-sided error, that is influence the efficiencies directly. It is also argued that whether or not an OOH co-op practices doctor triaging or nurse triaging has potential to affect this variance. These effects are incorporated through a dummy indicator of doctor triaging labelled DT. The extent of the latter effects is unknown prior to estimation and findings for a particular type of triaging will interest OOH co-op management and health policy makers. It is argued the most likely suited model for estimating efficiencies is:

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[6] Usually the Gamma (1980) distribution is a moot point in stochastic frontier analysis that utilises panel data, however because we are using a pooled version of fixed effects this option is open

$$\ln y_{it} = \alpha_i + \beta' x_{it} + B' z_{it} + v_{it} + u_i \qquad (8)$$

Where:

$v_{it} = N\left(0, \sigma_v^2\right)$

$u_i = N\left(0, \sigma_u^2\right)$

$Var[U_i \left| h_i \right.] = \sigma_u^2 gu(h_i, \tau) = \sigma_{ui}{}^2$

$g_u(h_i, 0) = 1$

$g_u(h_i, \tau) = [\exp(\tau^T h_i)]^2$

h contains vector j and DT

all other variables are consistent with previous definitions

The positioning of the z vector in the production function remains unchanged; however, this analysis considers the effect of changing the specification with respect to the positioning of the j vector and DT variable. Specifically, the analysis considers the affect of moving these variables into the production function, the symmetric component's variance and also a specification whereby DT is moved to the symmetric component's variance and the vector j remains in the variance of the one-sided error. The purpose of this exercise is to investigate how volatile the efficiency estimates are to changes to the positioning of these elements in terms of moments, kernels and ranks. These additional models are represented by equations 9, 10 and 11 respectively.

$$\ln y_{it} = \alpha_i + \beta' x_{it} + B' z_{it} + v_{it} + u_i \qquad (9)$$

where:

$v_{it} = N\left(0, \sigma_v^2\right)$

$u_i = N\left(0, \sigma_u^2\right)$

$Var[v_i \left| l_i \right.] = \sigma_v^2 g_v(l_i, \delta) = \sigma_{vi}{}^2$

$g_v(l_i, 0) = 1$
$g_v(l_i, \delta) = [\exp(\delta^T l_i)]^2$

l contains vector j and DT

$$\ln y_{it} = \alpha_i + \beta' x_{it} + B' z_{it} + v_{it} + u_i \tag{10}$$

where:

$v_{it} = N\left(0, \sigma_v^2\right)$

$u_i = N\left(0, \sigma_u^2\right)$

$Var[U_i \,|\, h_i] = \sigma_u^2 g_u(h_i, \tau) = \sigma_{ui}{}^2$

$g_u(h_i, 0) = 1$
$g_u(h_i, \tau) = [\exp(\tau^T h_i)]^2$

h contains vector j

$Var[v_i \,|\, l_i] = \sigma_v^2 g_v(l_i, \delta) = \sigma_{vi}{}^2$

$g_v(l_i, 0) = 1$
$g_v(l_i, \delta) = [\exp(\delta^T l_i)]^2$

l contains DT

$$\ln y_{it} = \alpha_i + \beta' x_{it} + \beta' z_{it} + \beta' j_{it} + \beta' DT_{it} + v_{it} + u_i \tag{11}$$

where:

$v_{it} = N\left(0, \sigma_v^2\right)$

$u_i = N\left(0, \sigma_u^2\right)$

Equations 8-11 are also estimated varying the functional form from Cobb-Douglas to translog to the two previously described reduced forms of translog. It is however not possible to vary the error distribution in equations 8-10 from half-normal. The most appropriate of models 8-11 are chosen using the Vuong test, AIC criterion and BIC criterion.

Results:

All models considered in this study are estimated using Limdep (Greene 2002). All models with the exception of the models with the gamma distribution are estimated using maximum likelihood. The gamma distribution models are estimated by the method of simulated maximum likelihood and 1000 Halton draws are used in estimation. +.001 was added to every variable in the dataset to eliminate zero values for creating logs. The results are presented in three sections. The first section considers the effects to efficiency values of changing the specification of the one sided error distribution and the functional form of the production function. The base case is:

$$Lny_{it} = \alpha_i + \beta' \ln x_{it} + B' z_{it} + v_{it} + u_i \qquad (12)$$

where:

$v_{it} = N\left(0, \sigma_v^2\right)$

$u_i = N\left(0, \sigma_u^2\right)$

And all variable definitions are consistent with those previously defined.

Results are presented for equation 12 and variations of the functional form, namely the translog and two reduced forms of the translog. In addition for each of the functional forms presented the error distribution is varied between a truncated, half-normal, exponential and gamma distribution for the efficiencies. This results in 16 models. The prime focus of this analysis is on the estimated efficiencies and therefore for all models the spearman rank correlation coefficients, simple correlations, and descriptive statistics are reported for the estimated efficiencies. In addition the results of likelihood ratio tests are presented to decide on the most functional form for models with the same one-sided error distribution. The results of Vuong tests and AIC and BIC criteria are documented to distinguish between models with a different distribution on the error term.

Section 2 presents the results for models that incorporate casemix and a doctor triaging dummy variable into the analysis as illustrated by equations 8-11. Including all variations of functional form there are 16 models. Again the prime focus is the efficiency estimates and the same statistics as section 1 will be reported. This will allow comparisons to be made on the effect on these estimates of ignoring casemix. Kernel densities are also illustrated. AIC, BIC and Voung statistics are used to distinguish between models.

Section 3 presents the parameter estimates from the most appropriate model and focuses on what the results mean in terms of policy measures for the OOH co-op. As stated *a priori* it is believed that model 8 is the most appropriate model. OOH co-ops will be ranked to see if differences in efficiency exist across NI/ROI and doctor triaging/nurse triaging. Parameter estimates are also reported as well as the average annual efficiency and rank for each OOH co-op.

Section 1:

Table 2 presents the descriptive statistics for the 16 models which, vary in error distribution and functional form. So far these models ignore the j vector and DT variable. This is necessary because the specifications that incorporate the latter are for the most part only relevant to the half-normal error distribution. Considering the descriptive statistics, a high variation is evident in the range of efficiency values produced from the various models. The most obvious differences are extreme minimum values emanating from the exponential distribution in ever case and the gamma in the case of the translog and the Cobb-Douglas functional form.

Table 2: Efficiency Estimates Descriptive Statistics: Various Distributions and Functional Forms

Distribution	Functional Form	Mean	Std Dev	Min	Max
Half Normal	**Translog**	.793	.069	.286	.944
Half Normal	**Reduced Translog: No Squares**	.704	.142	.399	.972
Half Normal	**Reduced Translog: No Cross Products**	.695	.146	.480	.973
Half Normal	**Cobb Douglas**	.744	.107	.627	.984
Truncated	**Translog**	.823	.094	.202	.957
Truncated	**Reduced Translog: No Squares**	.846	.070	.771	.993
Truncated	**Reduced Translog: No Cross Products**	.789	.103	.664	.987
Truncated	**Cobb Douglas**	.833	.073	.755	.992
Exponential	**Translog**	.823	.098	.035	.961
Exponential	**Reduced Translog: No Squares**	.734	.245	.056	.994
Exponential	**Reduced Translog: No Cross Products**	.717	.236	.044	.988
Exponential	**Cobb Douglas**	.699	.268	.052	.994
Gamma	**Translog**	.872	.100	.031	.993
Gamma	**Reduced Translog: No Squares**	.862	.067	.314	.999
Gamma	**Reduced Translog: No Cross Products**	.818	.098	.273	.999
Gamma	**Cobb Douglas**	.722	.278	.042	.997

To consider the degree to which the efficiency estimates vary across functional form and to get closer to choosing the most appropriate model table 3a, 3b, 3c and 3d document the simple correlations and spearman rank correlations across functional forms. From table 3a, strong correlations exist across all functional forms with a half normal distribution with exception of translog. Bizarrely, the translog has a strong negative correlation with all of the other models. This phenomenon is also consistent across tables 3b, 3c, 3d which illustrate the results from the truncated normal, exponential and gamma distributions. Investigating this further, the problem seems to stem from multi-collinearity. Symptoms include many variables that are significant in other models being insignificant in the translog specification and results varying wildly when a variable is excluded. All spearman rank correlations are high across all other functional forms in the case of table

3a, 3b, and 3c. The lowest value is .77. This is comforting, given the popularity (WHO 2000, Spottiswoode Report 2000 and Nera 2003) of using these estimates to rank firms. The gamma distribution is however less stable. Excluding the translog, Spearman rank correlations are still as low as .49. An obvious conclusion is that the gamma distribution is less stable than other distributions in this scenario given it is estimated by simulated maximum likelihood.

Because all models in table 3a through 3d are nested it is possible to use likelihood ratio testing to choose between them. Even though comparing the reduced form of the translog that ignores cross products and the version of the translog that ignores squares is not possible directly as they are non nested, it is possible to make judgment between these by process of elimination. Reading from the tables the clear favorite seems to be the reduced form of the translog which drops the square terms but retains the cross-products. It is this model that we will proceed with in section 2. Considering the choice of functional form, results indicate that stable efficiency estimates should ensue from all types of translog and its reduced forms in the absence of multi-collinearity.

Table 3a: Correlations and Test Results for Models with a half normal distribution and various functional forms

Functional Forms Being Compared		**Spearman Rank Correlation**	**Simple Correlation**	**LR Test Statistic**	**LR Test Conclusion**
TL	**TL**	1.00	1.00	N/A	N/A
TL	**RTNS**	-0.85	-0.76	11	RTNS Favored
TL	**RTNCP**	-0.63	-0.66	477	TL Favored
TL	**CD**	-0.24	-0.56	1120	TL Favored
RTNS	**TL**	-0.85	-0.75	11	RTNS Favored
RTNS	**RTNS**	1.00	1.00	N/A	N/A
RTNS	**RTNCP**	0.90	0.89	N/A	N/A
RTNS	**CD**	0.77	0.74	1139	RTNS Favored
RTNCP	**TL**	-0.63	-0.66	477	TL Favored
RTNCP	**RTNS**	0.90	0.89	N/A	N/A
RTNCP	**RTNCP**	1.00	1.00	N/A	N/A
RTNCP	**CD**	0.89	0.89	643	RTNCP Favored
CD	**TL**	-0.24	-0.56	1120	TL Favored
CD	**RTNS**	0.77	0.89	1139	RTNS Favored
CD	**RTNCP**	0.89	0.89	643	RTNCP Favored
CD	**CD**	1.00	1.00	N/A	N/A

Table 3b: Correlations and Test Results for Models with a truncated normal distribution and various functional forms

Functional Forms Being Compared		**Spearman Rank Correlation**	**Simple Correlation**	**LR Test Statistic**	**LR Test Conclusion**
TL	**TL**	1.00	1.00	N/A	N/A
TL	**RTNS**	-0.20	-0.48	10	RTNS Favored
TL	**RTNCP**	-0.24	-0.42	284	TL Favored
TL	**CD**	-0.98	-0.40	177	TL Favored
RTNS	**TL**	-0.20	-0.48	10	RTNS Favored
RTNS	**RTNS**	1.00	1.00	N/A	N/A
RTNS	**RTNCP**	0.91	0.88	N/A	N/A
RTNS	**CD**	0.88	0.80	1193	RTNS Favored
RTNCP	**TL**	-0.24	-0.42	284	TL Favored
RTNCP	**RTNS**	0.91	0.88	N/A	N/A
RTNCP	**RTNCP**	1.00	1.00	N/A	N/A
RTNCP	**CD**	0.93	0.90	284	RTNCP Favored
CD	**TL**	-0.98	-0.40	177	TL Favored
CD	**RTNS**	0.88	0.80	1193	RTNS Favored
CD	**RTNCP**	0.93	0.90	177	RTNCP Favored
CD	**CD**	1.00	1.00	N/A	N/A

Table 3c: Correlations and Test Results for Models with an exponential distribution and various functional forms

Functional Forms Being Compared		**Spearman Rank Correlation**	**Simple Correlation**	**LR Test Statistic**	**LR Test Conclusion**
TL	**TL**	1.00	1.00	N/A	N/A
TL	**RTNS**	-0.60	-0.38	10	RTNS Favored
TL	**RTNCP**	-0.57	-0.37	287	TL Favored
TL	**CD**	-0.50	-0.33	88	TL Favored
RTNS	**TL**	-0.60	-0.38	10	TL Favored
RTNS	**RTNS**	1.00	1.00	N/A	N/A
RTNS	**RTNCP**	0.91	0.97	N/A	N/A
RTNS	**CD**	0.86	0.93	1204	RTNS Favored
RTNCP	**TL**	-0.57	-0.37	287	RTNCP Favored
RTNCP	**RTNS**	0.91	0.97	N/A	N/A
RTNCP	**RTNCP**	1.00	1.00	N/A	N/A
RTNCP	**CD**	0.91	0.95	462	RTNCP Favored
CD	**TL**	-0.50	-0.33	88	TL Favored
CD	**RTNS**	0.86	0.93	1204	RTNS Favored
CD	**RTNCP**	0.91	0.95	462	RTNCP Favored
CD	**CD**	1.00	1.00	N/A	N/A

Table 3d: Correlations and Test Results for Models with a gamma distribution and various functional forms

Functional Forms Being Compared		Spearman Rank Correlation	Simple Correlation	LR Test Statistic	LR Test Conclusion
TL	**TL**	1.00	1.00	N/A	N/A
TL	**RTNS**	-0.90	-0.48	13	RTNS Favored
TL	**RTNCP**	-0.81	-0.45	924	TL Favored
TL	**CD**	-0.42	-0.26	84	TL Favored
RTNS	**TL**	-0.90	-0.48	13	RTNS Favored
RTNS	**RTNS**	1.00	1.00	N/A	N/A
RTNS	**RTNCP**	0.82	0.92	N/A	N/A
RTNS	**CD**	0.49	0.53	497	RTNS Favored
RTNCP	**TL**	-0.81	-0.45	924	RTNCP Favored
RTNCP	**RTNS**	0.82	0.92	N/A	N/A
RTNCP	**RTNCP**	1.00	1.00	N/A	N/A
RTNCP	**CD**	0.53	0.58	504	RTNCP Favored
CD	**TL**	-0.42	-0.26	84	TL Favored
CD	**RTNS**	0.49	0.53	497	RTNS Favored
CD	**RTNCP**	0.53	0.58	504	RTNCP Favored
CD	**CD**	1.00	1.00	N/A	N/A

Retaining the reduced form of the translog which ignores square terms as the preferential model, table 4 explores the effect on the efficiency values of varying the one sided error distribution in terms of the simple correlations and the spearman rank correlations. The Spearman rank correlation is always the more interesting assuming these results will be used to rank the organizations. Descriptive statistics relating to these efficiency values have been previously transcribed in table 2. Examining the Spearman rank correlations and simple correlations, the lowest values are .78 and .76 respectively with two exceptions. These exceptions are the correlations between the truncated-normal and gamma distributions and the correlations between the exponential distribution and the gamma distribution. The latter indicates instability in the gamma distribution in this scenario. Again, this may be due to the gamma models being estimated by different methods than the other models in the suite. Excluding the latter, results indicate a strong faith in efficiency ranks when the one sided error distribution is varied from half normal to truncated to exponential.

Vuong test statistics, AIC and BIC criterion are also provided to distinguish the most appropriate model from the other three. The results from AIC and BIC criterion favor the truncated normal in every case, however the Vuong test lends support to the hypothesis that choice between distributions (with the exception of gamma) is not likely to have great impact. In every case, the model fails to choose between the truncated, half-normal and exponential distribution. The test does however discriminate in the case of the gamma distribution, favoring the alternative in every case.

Table 4: Correlations and Test Results for Models with various one sided error distributions

Error Distributions Compared		**Spearman Rank Correlation**	**Simple Correlation**	**Vuong Statistics**	**Preferred Error DI**
HN	**HN**	1.00	1.00	N/A	N/A
HN	**TN**	0.78	0.76	-1.317	Inconclusive
HN	**EXP**	0.84	0.85	-1.121	Inconclusive
HN	**G**	0.90	0.76	191.92	Favors HN
TN	**HN**	0.78	0.76	1.317	Inconclusive
TN	**TN**	1.00	1.00	N/A	N/A
TN	**EXP**	0.89	0.82	1.089	Inconclusive
TN	**G**	0.65	0.45	96.85	Favors TN
Exp	**HN**	0.84	0.85	1.121	Inconclusive
Exp	**TN**	0.89	0.82	-1.089	Inconclusive
Exp	**EXP**	1.00	1.00	N/A	N/A
Exp	**G**	0.66	0.65	96.30	Favors Exp
G	**HN**	0.90	0.76	-191.92	Favors HN
G	**TN**	0.65	0.45	-96.85	Favors TN
G	**EXP**	0.66	0.65	-96.30	Favors Exp
G	**G**	1.00	1.00	N/A	N/A
Error Distribution	**AIC**	**Preferred Error DI**	**BIC**	**Preferred Error DI**	
HN	**1890**	TN	2178	TN	
TN	**1639**	TN	1933	TN	
EXP	**2621**	TN	2909	TN	
G	**3031**	TN	3325	TN	

Section 2:

This section is devoted to considering the effects of moving the vector j which contains the casemix proxies and the variable DT from the variance of the one-sided error term.

The variations considered are described in equations 9-11. In particular, the variations consider:

1) Moving vector j and DT into the variance of the symmetric component (VSE)
2) Moving DT into the variance of the symmetric component and retaining vector j in the variance of the one sided error (V1E & VSE)
3) Placing vector j and DT into the production function as independent variables (PF)

A priori the specification which puts all effects into the variance of the one sided error is theoretically favored. To examine the effects on the efficiencies of altering this specification to those listed above table 5 presents the descriptive statistics of the emanating efficiencies. The highest efficiency values are those associated with placing the effects in the variance of the one sided error component (V1E), these values also have the tightest range. This suggests that this model is best for explaining variation in the efficiencies. All of the other models have quite low values minimum efficiency values.

Table 5: Descriptive Statistics of Emanating Efficiencies from Models with various case mix specifications

J Vector and DT Placement in equation	**Mean**	**Std Dev**	**Min**	**Max**
Variance of one sided error component (V1E)	.825	.102	.689	.999
Variance of the symmetric component (VSE)	.782	.102	.271	.999
J in the variance of the one sided error component and DT is in the variance of the symmetric component (V1E&VSE)	.966	.083	.159	.999
Production Function (PF)	.751	.109	.378	.974

To get a true picture of the efficiencies, it is helpful to examine the kernel densities; these are illustrated in figures 1 through four.

Figure 1: Kernel Density Illustration for V1E

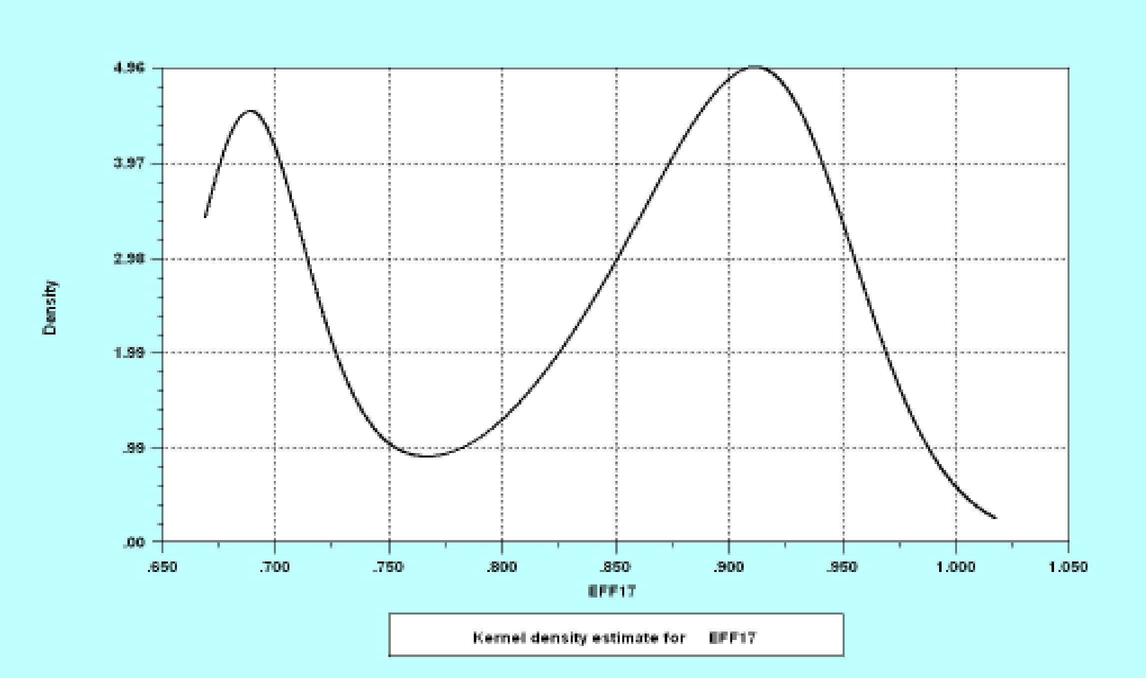


Figure 2: Kernel Density Illustration for VSE

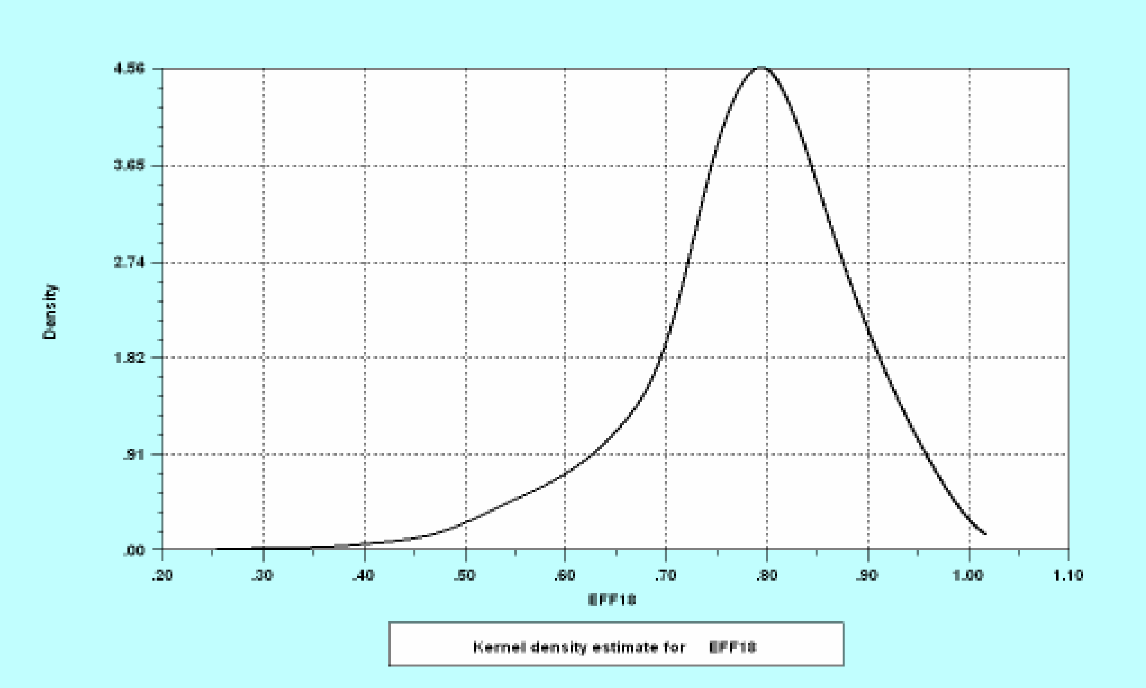


Figure 3: Kernel Density Illustration for V1E&VSE

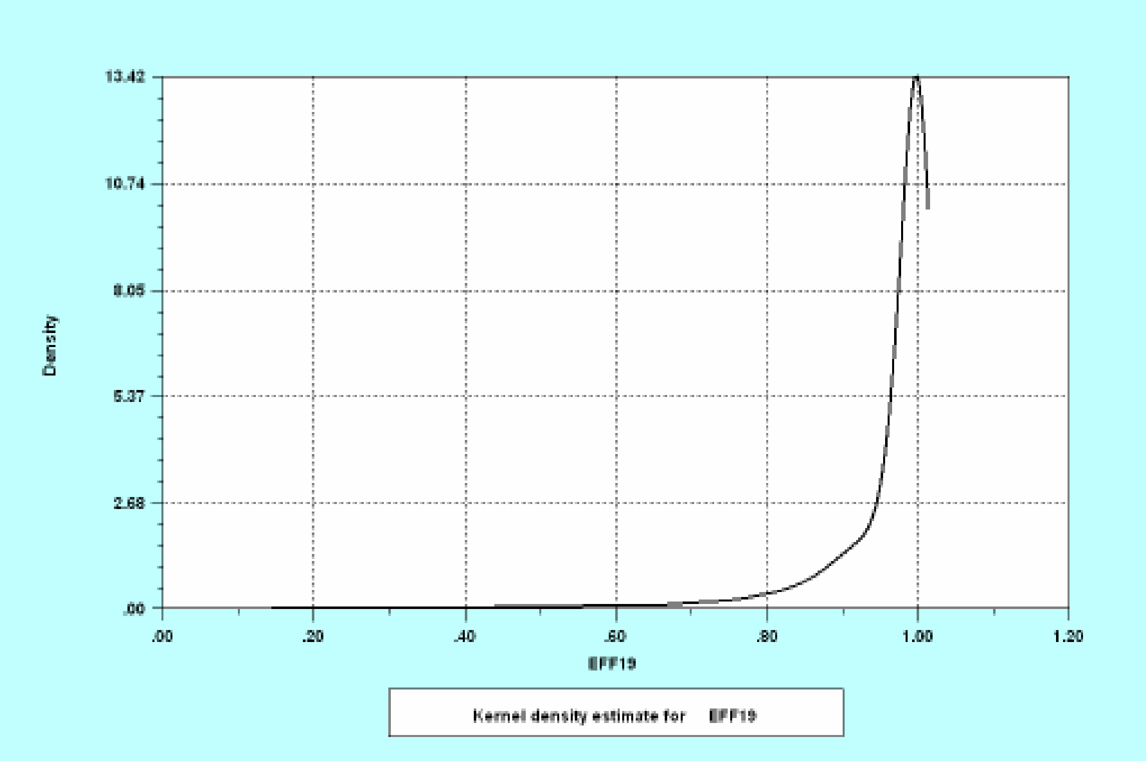
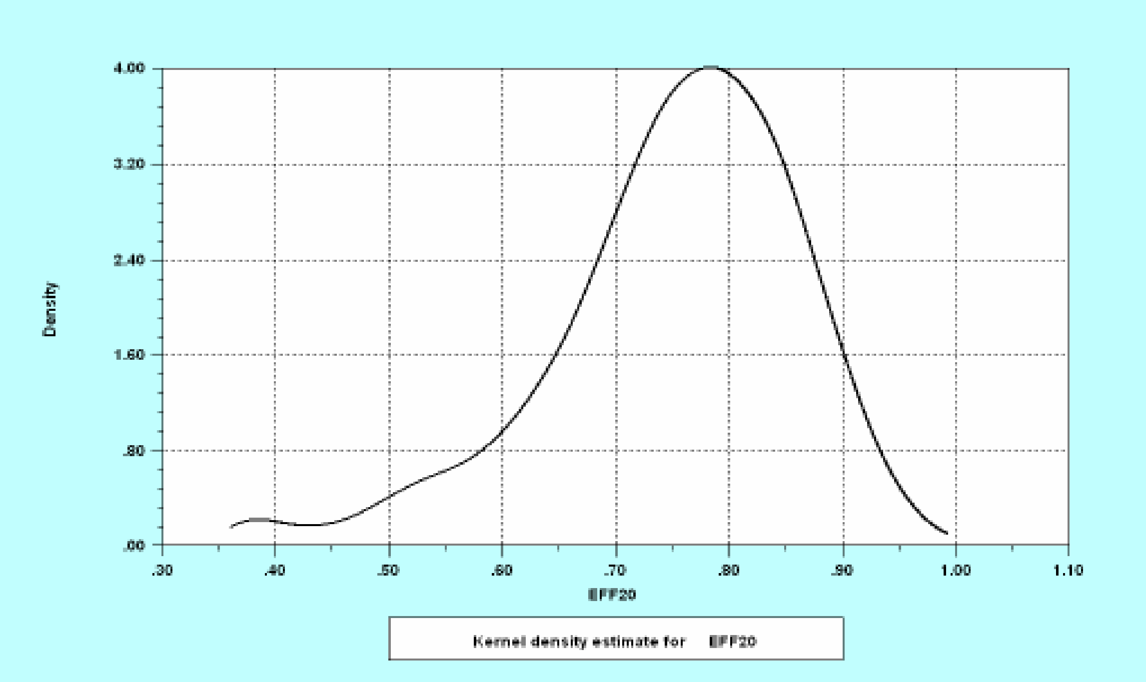


Figure 4: Kernel Density Illustration for PF



The kernel density attached to V1E is an unusual shape and graphed over a relatively tight spread of values. This picture is very different to the more regular shaped kernel density attached to VSE pictured below; however this graph illustrates unrealistically low efficiency values attached to some OOH co-ops. The same is true for the kernel attached to V1E & VSE. This picture is very unrealistic, with the majority of OOH co-ops at the top-end of the efficiency spectrum and a long tail representing OOH co-ops exhibiting efficiency values even lower than 20%. The kernel density illustration of PF visually resembles the kernel density of V1E in shape but it is graphed over a very different range and spread of values. To consider these two figures resemblance further and decide on the most appropriate model table 6 documents the Spearman rank correlations, simple correlations as well as results from non nested model testing procedures.

From table 6 even though VSE and PF have the closest kernel density shape wise the correlations between individual efficiency estimates indicate that V1E and VSE are the closest in terms of individual correlations. This is also true of the attached Spearman rank correlation coefficient of .67. PF and VSE exhibit a Spearman rank correlation of .62. While these are relatively high scores, it should be noted that the numbers are sufficiently different from 1 to indicate displacement in the ranks. All other correlations are poorer, the most notable being the correlations attached to V1E&VSE which are negative in every case. Clearly this model is very different from all other three models in every way with respect to efficiency values given the picture painted by its kernel density and its associated correlations.

To determine the most appropriate model it is useful to consider non nested testing procedures. The results of the AIC and BIC efficiency scores are lowest for the V1E model indicating that it is the most suitable. The latter criterion is supported by the Vuong test.

Table 6: Correlations and Test Results: Models with various case mix specifications

Positions of J and DT placement being Compared		**Spearman Rank Correlation**	**Simple Correlation**	**Vuong Test Statistic**	**Vuong Test Conclusion**
V1E	**V1E**	1.00	1.00	N/A	N/A
V1E	**VSE**	0.67	0.70	13.884	V1E Preferred
V1E	**VIE&VSE**	-0.24	-0.25	47.291	V1E Preferred
V1E	**PF**	0.49	0.40	89.246	V1E Preferred
VSE	**V1E**	0.67	0.70	-13.884	V1E Preferred
VSE	**VSE**	1.00	1.00	N/A	N/A
VSE	**VIE&VSE**	0.04	0.03	67.132	VSE Preferred
VSE	**PF**	0.62	0.45	127.433	VSE Preferred
VIE&VSE	**V1E**	-0.24	-0.25	-47.291	V1E Preferred
VIE&VSE	**VSE**	0.04	0.03	-67.132	VSE Preferred
VIE&VSE	**VIE&VSE**	1.00	1.00	N/A	N/A
VIE&VSE	**PF**	0.00	-0.03	74.058	V1E&VSE Preferred
PF	**V1E**	0.49	-0.40	-89.25	V1E Preferred
PF	**VSE**	0.62	0.45	-127.433	VSE Preferred
PF	**VIE&VSE**	0.00	-0.03	-74.058	V1E&VSE Preferred
PF	**PF**	1.00	1.00	N/A	N/A

Positions of J and DT placement being Compared	**AIC**	**Best Model Based on AIC**	**BIC**	**Best Model Based on BIC**
V1E	1022	V1E	1341	V1E
VSE	9705	V1E	2463	V1E
VIE&VSE	13361	V1E	6112	V1E
PF	8986	V1E	2157	V1E

Section 3:

Sections 1 and 2 have investigated the impact on efficiencies to changes to the specification. Section 1 concluded that efficiency results are fairly stable to choices of functional form in the absence of multi -collinearity. In this application, results emanating from the translog functional form were greatly affected by the latter. Using likelihood-ratio testing the preferred functional form was a translog form with the squares dropped. Section 1 also investigated the effects of changing the efficiency's distribution, on the emanating results. The findings indicated that the range, standard deviation, kernel densities and Spearman rank correlations are relatively stable to varying the choice of distribution from half normal to truncated normal to exponential. The gamma distribution however gave somewhat unstable results and was poorly correlated in terms of ranks with the other distributions emanating efficiencies. AIC and BIC criterion indicate that the most appropriate distribution is the truncated normal , however Vuong test statistic does not differ between the half normal and the truncated normal. Section 2 therefore used a model with a translog functional form with the squares dropped and a half normal distribution. The latter was used as it opens more options for dealing with heterogeneity. From the options considered in section two, Vuong statistics and AIC & BIC criterion preferred the V1E specification which placed the casemix proxies' vector j and triage indicator DT in the variance of the one-sided error. This section will concentrate on the latter model and consider its emanating results in terms of policy implications for OOH co-ops. In particular, it will investigate if efficiency differences exist between co-operatives operating in NI and ROI as well as seeing if the choice between doctor triaging and nurse triaging makes a difference.

Table 7 displays the emanating parameter estimates. All of the co-op coefficients have a positive relationship with payroll. With the exception of OOH co-op 7 all NI OOH co-ops (see table 8 for identifier) have substantially larger coefficients than their colleagues in ROI. This could be due to a number of operational factors and further analysis would be needed to disentangle exactly what is being picked up in these 'effects'. The quantity of treatment centre visits and home visits provided daily have a positive effect on payroll. Surprisingly, the effect of treatment centre visits on payroll is larger in magnitude than that of home visits given the latter certainly uses more resources, however these differences are explained by the higher numbers of treatment centre visits dispensed (see table 1 for average values) compared to home visits. The coefficient on nurse advice and doctor advice are negative and low, again this is to be expected because these services require far less resources than a face to face consultation. Doctor advice has the highest negative impact of the two advice services on payroll; this is explained perhaps by differences in remuneration between nurses and doctors.

The quality of care proxies are contained in the z vector which corresponds to the reaction time in minutes of nurse advice, doctor advice, treatment centre consultations and home visits respectively. The nurse advice reaction time actually has a negative coefficient indicating an efficient response time, all other coefficients are positive and interestingly doctor advice reaction time has the largest coefficient. It should be noted, that because nurse triaging OOH co-ops also supply doctor advice than this coefficient may be attributed to these organizations having a slow response with respect to the service of doctor advice rather than simply a doctor triaging effect. The interpretation of cross products is left for the interested reader.

Considering the coefficients on the variables that enter the variance of the one sided efficiencies, the most interesting is DT. This is because DT is a potential policy variable. That is, OOH co-ops could change at any time from doctor triaging to nurse triaging and vice versa. The coefficient itself is large and positive, indicating that doctor triaging is a higher driver of payroll than nurse triaging. The impacts of doctor triaging will be examined further later when the emanating ranks are considered alongside those of OOH co-ops which nurse triage.

The coefficients on quantity of three year olds (.518), quantity of seventy five year olds (1.823) and quantity of severe patients (.138) are all positive as expected. The sex coefficient is -.827, however as stated it was unclear what direction these effects would take. A puzzling negative coefficient of -1.605 is attached to cases seen in the redeye; it was thought that these would likely be more serious and therefore have a positive impact on the payroll of OOH co-ops. The latter can be explained if individuals who ring late at night have a tendency to receive the services of doctor advice and nurse advice, over and above, direct consultations which are more expensive to provide.

Table 7: Parameter Estimates

Parameter	Estimate	Std Error	Prob
Constant	7.156	0.0716	.0000
Co-op 1 Dum	1.231	0.1275	.0000
Co-op 2 Dum	1.104	0.1234	.0000
Co-op 3 Dum	1.306	0.1270	.0000
Co-op 4 Dum	1.316	0.0273	.0000
Co-op 5 Dum	1.431	0.1265	.0000
Co-op 6 Dum	1.140	0.1251	.0000
Co-op 7 Dum	0.900	0.1803	.0000
Co-op 8 Dum	1.466	0.0359	.0000
Co-op 9 Dum	7.754	0.0295	.0000
Co-op 10 Dum	21.11	0.0216	.0000
Co-op 11 Dum	Reference Case	Reference Case	Reference Case
Ln(x1)	0.526	0.0498	.2910
Ln(x2)	0.135	0.0621	.0302
Ln(x3)	-.01069	0.0412	.0103
Ln(x4)	-0.0381	0.0470	.0418
Ln(z1)	-0.5146	0.0144	.0004
Ln(z2)	0.1492	0.0327	.0000
Ln(z3)	0.0625	0.0123	.0000
Ln(z4)	0.01052	0.0192	.5837
Ln(x1)Ln(x2)	-0.0149	0.0120	.2148
Ln(x1)Ln(x3)	-0.0233	0.0124	.0596
Ln(x1)Ln(x4)	0.0049	0.0067	.4743
Ln(x2)Ln (x3)	-0.0271	0.0100	.0073
Ln(x2)Ln(x4)	0.0027	0.0096	.7754
Ln(z1)Ln(z2)	0.0029	0.0028	.3016
Ln(z1)Ln(z3)	0.0091	0.0444	.0408
Ln(z1)Ln(z4)	-0.009	0.0043	.0333
Ln(z2)Ln (z3)	0.0145	0.0025	.0000
Ln(z2)Ln(z4)	-0.0008	0.00123	.4991
Ln(z3)Ln(z4)	-0.0048	0.00353	.1775
Ln(x1)Ln(z1)	0.0327	0.00664	.0000
Ln(x1)Ln(z2)	-0.122	0.0032	.0002
Ln(x1)Ln(z3)	0.0165	0.0066	.0126
Ln(x1)Ln(z4)	0.0106	0.0042	.0109
Ln(x2)Ln(z1)	0.0150	0.0055	.0061
Ln(x2)Ln(z2)	0.0001	0.0023	.9665
Ln(x2)Ln(z3)	0.0109	0.0095	.2529
Ln(x2)Ln(z4)	0.0005	0.0009	.5702
Ln(x3)Ln(z1)	-0.0019	0.0065	.7653
Ln(x3)Ln(z2)	0.0010	0.0050	.8422
Ln(x3)Ln(z3)	0.0037	0.0088	.6729
Ln(x3)Ln(z4)	0.0351	0.0079	.0000
Ln(x4)Ln(z1)	-0.005	0.0046	2.966
Ln(x4)Ln(z2)	0.0013	0.0010	.2051
Ln(x4)Ln(z3)	-0.0170	0.0069	.0137
Ln(x4)Ln(z4)	-0.0032	0.0031	.3038
Parameters in variance of v (symmetric)			
Constant	-6.229	0.078	.0000
Parameters in variance of u (one sided)			
DT	1.017	0.056	.0000
Ln(j1)	0.518	0.041	.0000
Ln(j2)	1.823	0.033	.0000
Ln(j3)	0.138	0.004	.0000
Ln(j4)	-1.605	0.042	.0000
Ln(j5)	-0.827	0.040	.0000

Re-considering the efficiency values that emanate from the study, table 8 displays the average annual efficiency values for each of the 11 OOH co-ops. These are calculated by aggregating the daily efficiency scores achieved by each organization and dividing by the number of OOH co-ops. This table also displays the ranks of each co-op and an indicator as to whether the OOH co-op operates in NI or ROI or provides nurse triaging (NT) or doctor triaging (DT). The overall efficiency scores of the OOH co-ops are all fairly satisfactory with the lowest score being 70%. It should be noted however that the DT variable was high in magnitude and significant and therefore moved some of the variation out of the efficiencies already.

Considering the results of table 8, the average annual efficiency value for an OOH co-op who practices nurse triaging is 86% as opposed to 80% for OOH co-ops who practice doctor triaging. Given the latter and the magnitude of the DT variable it is clear that gains in efficiency are possible from adopting nurse triaging as opposed to doctor triaging. These gains are transferred to the OOH organization in terms of lower payroll and decreased reaction times among other things. The case of comparing NI to ROI is somewhat a moot point, given with the exception of one OOH co-op it is the same as the DT versus NT debate. The average annual NI efficiency is 82% as opposed to 83% in ROI, these differences are so marginal we cannot attribute them to differences in governments or structure, however, the fixed coefficients attached to each co-op is picking up latent heterogeneity across these two countries. As noted, NI seems to have significantly larger coefficients and therefore larger payrolls *cetrius paribus*. What these effects are is open to speculation and is a question for future research.

Table 8: Average Annual Efficiency %

OOH Co-op Number	Average Annual Efficiency %	Rank	DT/NT	NI/ROI
1	94%	1	NT	ROI
2	88%	4	NT	ROI
3	91%	3	NT	ROI
4	82%	6	NT	ROI
5	70%	10	DT	ROI
6	74%	9	NT	ROI
7	82%	6	DT	NI
8	92%	2	DT	NI
9	76%	8	DT	NI
10	77%	7	DT	NI
11	84%	5	DT	NI

Discussion:

This paper had two main aims. The first of which is to estimate efficiencies for OOH co-ops in NI and ROI and secondly to consider the effect on efficiency values of changes to model specification. The specification changes considered relate to distribution choice for the one sided error, functional form choice and placement of casemix variables in the model. This analysis used an approach SPF where payroll was modelled as the OOH co-ops output and services were seen as the inputs that produced payroll. It was argued that these services are exogenous.

Results from the analysis suggest that functional form choice does not greatly affect efficiency estimates except in the presence of multi-collinearity. Symptoms of the latter were found in the translog specification in this study. Likelihood ratio testing found in favour of a reduced version of the translog which ignored square terms. Results also suggested that rotating the half normal, truncated normal and exponential distributions of the one sided error term would not greatly impact the efficiency estimates. The exception was the gamma distribution. It is suggested that this is unstable perhaps due to it being estimated by simulated maximum likelihood.

The placement of the casemix vector and DT variables in the variance of the one sided error term, the variance of the symmetric component, a combination of the latter or the production function did affect emanating efficiencies. Kernels, ranks and descriptive statistics differed across models. The former model was favoured *a priori* and again statistically by the Vuong test, AIC and BIC criteria. Results from this model were further analysed in section 3. Particular attention was given to potential gains being had across NI/ROI and nurse triaging/doctor triaging. The findings suggest that ROI OOH co-ops have efficiency gains over their NI colleagues and nurse triaging has efficiency gains over doctor triaging. Further analysis is needed to dissect the exact nature of these gains. Another potential for future analysis is to disaggregate the data from OOH co-op level to centre level. That is, OOH co-ops run out of a number of centres encompassed within the OOH co-op. The latter would increase the number of firms and thereby degrees of freedom and perhaps alleviate the symptoms of multi-collinearity in the translog functional form. It would also allow the isolation of inefficient centres.

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