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by

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Abstract

Data envelopment analysis (DEA) is used to measure the technical and scale efficiency of the domestic waste management function in 103 New South Wales' local governments. After allowance is made for nondiscretionary environmental factors which may affect the provision of these local public services, such as congestion and the inability to operate machinery in densely-populated urban areas, comparison of efficiency across geographic/demographic criteria is made. The results suggests that, on average, waste management inputs could be reduced to just over 65 percent of the current level based upon observable best-practice whilst productivity losses due to scale effects account for slightly over 15 percent of total inputs. The results also indicate that inefficiency in urban developed councils is largely the result of congestion and other collection difficulties encountered in densely-populated areas, whilst inefficiency in regional and rural councils stems from an inability to attain an optimal scale of operations.

Key Words: Local government services; technical and scale efficiency; data envelopment analysis

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Public sector reform has now become an established dimension of policymaking in many developed countries, including Australia. Although the ongoing program of public sector reform in Australia has focused mainly on the Commonwealth government and some state governments, especially Victoria, it is now being applied to local government. Key aspects of this process have been administrative reforms (compulsory competitive tendering and contracting-out), structural reforms (local council consolidations), legislative reforms (fiscal transparency and accountability), and workplace reform (labour market deregulation). Another part of this process has been the collection of new ideas associated with what has come to be known as the 'New Public Management'. Central ingredients in this movement have been the notion of explicit standards and measures of performance in the public sector, the greater emphasis on outputs rather than inputs, the shift to greater competition in the public sector, an emphasis on private-sector styles of management practice (i.e. 'letting managers manage') and a stress on greater discipline and parsimony in resource use (Hood, 1991). Finally, there is a greater awareness on the behalf of the Commonwealth government of the desirability of promoting efficiency through the system of intergovernmental financial assistance. In common with the other pressures for greater efficiency and effectiveness in local public service provision, this process can be used for accurate and meaningful measures of local government efficiency for the purposes of comparative performance assessment and process benchmarking.

This paper is centrally concerned with the evaluation of technical and scale efficiency in New South Wales (NSW) local governments using the nonparametric approach to efficiency measurement. We examine technical and scale efficiency for a single function of Australian local government: namely, domestic waste management services. The paper itself is divided into four main parts. The first section outlines the nonparametric approach to efficiency measurement for local public services and provides the formulation of the model employed. The second section provides the specification of inputs and outputs for domestic waste management services, both discretionary and nondiscretionary. The results obtained from this analysis are discussed in the third section. The paper ends with some brief concluding remarks.

Model Formulation

The method used to measure efficiency at the local level is based upon data envelopment analysis (DEA), a mathematical programming approach to frontier estimation pioneered in Charnes, Cooper & Rhodes (1978), extended in Banker, Charnes & Cooper (1984) and outlined in Färe *et al*. (1994). There are several advantages of the DEA approach in evaluating the efficiency of government service providers (Worthington & Dollery, 2000). These include *inter alia* its ability to handle the multiple inputs and outputs characteristic of public sector production, especially where it is difficult or impossible to assign prices to many of these factors and its capacity to incorporate differences in operating environments beyond management control, particularly for the purposes of comparative performance assessment and process benchmarking (SCRSCCP, 1997). Measuring efficiency in this manner is consistent with both the literature associated with the efficiency analysis of government service providers in general, such as Ganley & Cubbin (1992), Kittelson & Forsund (1992), Mensah & Li (1993), and Carrington *et al*. (1997), and with the majority of past empirical approaches to efficiency measurement in the local public sector, notably Charnes, Cooper & Li (1989), Cook, Roll & Kazakov (1990), Grosskopf & Yaisawarng (1990), Deller (1992), Vanden Eeckaut, Tulkens & Jamar (1993), and De Borger & Kerstens (1996a).

Figure 1
Technical and Scale Efficiency in Local Government

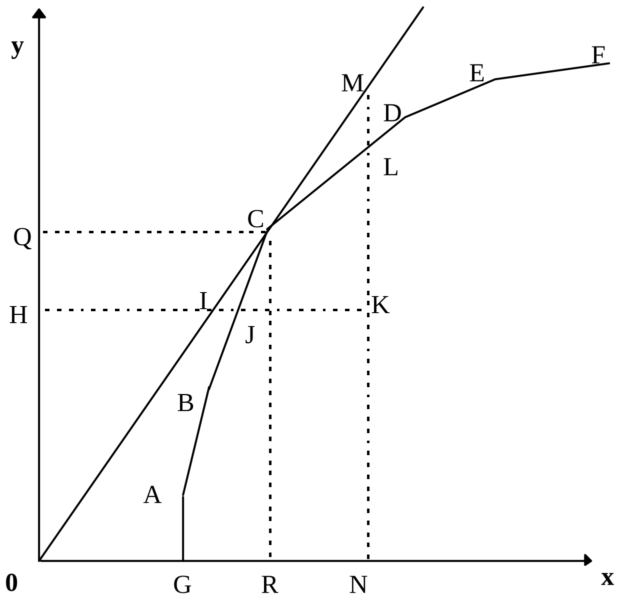

Figure 1 illustrates the derivation of the efficiency measures found in DEA in the single-input (x), single-output (y) case. As shown, these envelopment surfaces may be either linear, as in the constant returns-to-scale (CRS) case, or convex as with variable returns-to-scale (VRS). The CRS and VRS cases are detailed: the CRS surface is the straight line 0*ICM* and the VRS surface is *GABCDEF*. For ease of exposition, the interior (or inefficient) councils are represented by point *K*. The efficiency of any interior point (such as *K*) is intuitively indicated by the distance between the envelope and itself. In the case of an input orientation, focus falls on maximal movement toward the frontier through the proportional reduction of inputs. For example, using an input orientation and the council depicted by point *K*, the measure of technical efficiency will be given by *hi/hk* in the CRS case, and by *hj/hk* in the VRS case. A measure of scale efficiency is provided by the ratio *hi/hj*. Using an output orientation, the technical efficiency of point K would be given as *nk/nm* in the CRS case, *nk/nl* in the VRS case, and the scale efficiency would be provided by *nl/nm*. Finally, for a council on the envelope surface, as denoted by *C*, the technical efficiency ratio would be *qc/qc* for technical efficiency under both

VRS and CRS with an input orientation (a value of unity), and the scale efficiency measure in this case would also be *qc/qc*.

The specific extension of DEA to the multiple-input, multiple-output case was first introduced by Charnes *et al*. (1978) and extended in Seiford & Thrall (1990). Consider N local councils each producing M different outputs using K different inputs. The *envelopment* form of the input-orientated DEA linear programming problem is specified as follows:

$$\begin{aligned} &\min_{q,l} q \\ \text{s.t.}\ &-y_i + Yl \geq 0 \\ &q x_i - Xl \geq 0 \\ &l \geq 0 \end{aligned} \qquad (1)$$

where y_i is the vector of outputs produced by the *i*th council, x_i is the vector of inputs used by the *i*th council, Y is the $M \times N$ output matrix for all N councils, X is a $K \times N$ input matrix for all N councils, i runs from 1 to N, q is a scalar and l is a $N \times 1$ vector of constants. The value of q will be the efficiency score for a particular council. It will satisfy $q \leq 1$, with a value of 1 indicating a point on the frontier, and hence a technically efficient council.

One problem with this linear program [as discussed by Ali & Seiford (1993) and Coelli *et al*. (1997), amongst others] is that it may not always identify all *efficiency slacks* (for example, whether some inputs could be reduced further and still produce the same output). One suggestion is the use of a second-stage linear programming problem to ensure the identification of an efficient frontier point by maximising the sum of slacks required to move from the first-stage projected point to a Koopmans efficient frontier point:

$$\begin{aligned} &\min_{l,s^+,s^-} -(M1's^+ + K1's^-) \\ \text{s.t.}\ &-y_i + Yl - s^+ = 0 \\ &q x_i - Xl - s^- = 0 \\ &l, s^+, s^- \geq 0 \end{aligned} \qquad (2)$$

where s^+ is an $M \times 1$ vector of output slacks, s^- is a $K \times 1$ vector of input slacks, and $M1$ and $K1$ are $M \times 1$ and $K \times 1$ vectors of one, respectively, and all other variables are as previously defined (in this second-stage linear program q is not a variable, its value is taken from the first-stage results) (Coelli *et al*., 1997). The non-zero slacks and the value of $\theta \leq 1$ together identify the sources and amount of any inefficiencies that may be present. There are at least three assumptions underlying these formulations that require further elaboration.

Firstly, these programs provide the input-orientated constant returns-to-scale envelopment surface, and a measure of overall technical efficiency (T_s). That is, emphasis is placed on the equiproportionate reduction of local government inputs. An input orientation is adopted since it is assumed that local governments take outputs as exogenous and have a larger degree of control over the level of inputs, especially within functional areas. In particular, one would expect that for a local government in Australia, the imposition of rate capping and other constraints on revenue raising would tend to restrict the amount of output possible in any one time period. Hence, a suitable behavioural objective for these institutions would be that of input minimisation, rather than output maximisation. The input measures thus provided can then detect failures to minimise inputs resulting from discretionary power and incomplete monitoring, and thereby provide an indication of possible gains from exploiting technical and scale efficiencies (De Borger & Kerstens, 1996a, p. 11).

For example, Ganley & Cubbin (1992) used an input-orientation to study the efficiency of U.K. local education authorities (LEAs). They argued *inter alia* that the initial emphasis in government policy is usually on the input dimension, since inputs are more amenable to scrutiny whereas outputs are often disputed (Ganley & Cubbin, 1992, p. 45). Other local public sector studies which employed an input-orientated approach include Pestieau & Tulkens' (1990; 1993), Rouse, Putterill & Ryan's (1995), and Ruggiero's (1996) respective studies of Belgian, New Zealand and New York State local authorities.

Secondly, the measure of technical efficiency detailed in (1) also assumes that any scaled-up or scaled-down versions of the input combinations are also included in the production possibility set. Overall technical efficiency can then be further divided into pure technical (PT_s) and scale efficiency (S_s). Adding the convexity constraint ($N1'\lambda=1$) to (1) allows for variable returns-to-scale and provides a measure of pure technical efficiency (PT_s), whilst dividing overall technical efficiency by pure technical efficiency yields a measure of scale efficiency ($S_s= T_s/PT_s$). One shortcoming of this measure of scale efficiency is that its value does not indicate whether the council is operating in an area of increasing or decreasing returns to scale. This may be determined by imposing non-increasing returns-to-scale in (1) by replacing the $N1'\boldsymbol{l}=1$ restraint with $N1'\boldsymbol{l}\leq 1$ (Färe *et. al.*, 1983; Färe & Grosskopf, 1994). The NIRS surface is represented by *0CDEFI* in Figure 1. If the technical efficiency score under an assumption of non-increasing returns-to-scale is equal to the score obtained under variable returns-to-scale then decreasing returns to scale apply. If they are unequal (as for point *K* in Figure 1) then increasing returns-to-scale exist for that council.

Lastly, the model formulation detailed in (1) also implicitly assumes that all inputs and outputs are discretionary, i.e. controlled by the management of each council and varied at its discretion. However, in most circumstances there may exist exogenously fixed or non-discretionary inputs and/or outputs that are beyond managerial control [see, for example, Golany & Roll (1993)]. In the case of the input-orientated models we have discussed, it is not relevant to maximise the proportional decrease in the entire input vector: rather maximisations should only be determined with respect to the sub-vector that is composed of discretionary inputs. Examples in the Australian local public sector include the regulatory constraints imposed by state-based legislation, the geographic, socioeconomic and demographic characteristics of a given local government area and its citizenry, and accounting standards. The specific formulation employed to incorporate non-discretionary variables in the input-oriented model may be found in Charnes, *et al*. (1993) and Ali & Seiford (1993).

An important task that arises after the calculation of the DEA measures is to attribute variations in efficiency to specific characteristics of local councils and the environment in which they operate. Several linear regression models have been employed to examine these relationships. In the first approach a logistic regression of general form:

$$l_i^* = z_i^{'}\boldsymbol{b} + e_i \qquad (3)$$

is estimated, where $l_i = 1$ if the *i*th council is efficient on the basis of a DEA measure of pure technical, scale or overall technical efficiency ($\boldsymbol{q}=1$), and $l_i = 0$ is the *i*th firm is inefficient ($\boldsymbol{q}$ <1). Past approaches that have employed nonparametric techniques to measure government service efficiency followed by parametric techniques to assign variation in efficiency include

Bjurek, Kjulin & Gustafsson (1992), De Borger, Kerstens, Moesen & Vanneste (1994) and De Borger & Kerstens (1996a; 1996b). One alternative to the logistic model used in this study is tobit regression. Future work in this area could usefully employ such an approach given the loss of valuable information in a logistic regression.

The second regression approach seeks to explain the slack inefficiency in each council: that is, slack in the form of excessive utilisation of specific resources or underprovision of outputs. This analysis is likely to illuminate areas of particular concern to management, and has been employed by Fried *et al*. (1993, 1996) in the analysis of efficiency in U.S. credit unions. This requires estimation of ordinary least squares (OLS) equations of the form:

$$s_i^{+,-} = z_i^{'}\boldsymbol{b} + e_i \qquad (4)$$

where s_i is the total slack (both radial and non-radial) in the output (+) or input (-), and all other variables are as previously defined.

Specification of Inputs and Outputs

The variables used to provide efficiency measures using the non-parametric methodology are outlined in Table 1. Following Smith & Mayston (1987), Valdmanis (1992), Kooreman (1993), Thanassoulis & Dunstan (1994), and Thanassoulis *et al*. (1996), a single function is employed to evaluate DEA as a tool of efficiency analysis in government service provision. The activity selected in the current study is the provision of domestic waste management and recycling services by New South Wales (NSW) local governments. All data corresponds to the year ending 31 December 1993 (the first year in which statements were prepared under *AAS27 Financial Reporting by Local Government*) and is obtained from the NSW Department of Local Government (NSWDLG), the NSW Local Government Grants Commission (NSWLGGC) and the Australian Bureau of Statistics (ABS). Descriptive statistics are also provided in Table 1.

The model used to conceptualise local council behaviour is a traditional production-based approach. Table 1 details the inputs (both discretionary and nondiscretionary) and outputs for the provision of domestic waste management and recycling services in NSW local government councils. The provision of these services is generally classified as a 'community-related' function. This function is also usually acknowledged as a core service of local government, especially since the provision of waste services usually involves a significant proportion of councils' total resources (NSWDLG, 1998). Within the context of NSW local governments' responsibilities, waste is recognised as being composed of four components: (i) domestic waste, (ii) council operational waste, (iii) commercial and industrial waste, and (iv) construction and demolition waste (IPART, 1997, p. 90). While local councils have an important role in managing all four waste streams, they have a primary responsibility in providing what is referred to as the domestic waste management service (DWMS).

An important consideration is that all waste activities in NSW are now subject to the *Waste Minimisation and Management Act 1995*. The underlying principles of the Act are: (i) a 60% reduction in waste disposal by the end of the year 2000 (per capita reduction on 1990 disposal rates); and (ii) the establishment of a waste management hierarchy of the following order: (a) avoidance, (b) re-use, (c) recycling and reprocessing, and (d) disposal. The Act also provides that waste services should be co-ordinated in nominated waste management regions, that councils should adopt efficient waste management practices and policies, and councils should also operate in accordance with the principles of ecologically sustainable development.[1]

Two problems immediately arise when calculating the efficiency of DWMS for local governments. Firstly, one problem that may potentially arise here is that waste management services is one of the most frequently 'contracted-out' services in the Australian local public sector. However, the shift to accrual accounting and the adoption of a common accounting standard in the form of *AAS27* has ensured that all current and capital costs are recognised within the reporting period, whether provided 'in-house' or purchased via contract [the Independent Pricing and Regulatory Tribunal (IPART) (1997) report suggests that where waste services are not contracted out, labour, capital (equipment utilised), overheads, and other costs would add additional dimensions to council performance]. Secondly, whereas all or nearly local councils in NSW operate waste collection services, only those councils covered by the Waste Recycling and Processing Service NSW (WRPS) have information collected on recyclable material collected and disposal costs. The total sample of 173 NSW local governments is accordingly reduced to 103 individual councils.

A large number of factors are thought to have an impact on the efficiency of waste collection. In common with other local government functions, these may be broadly grouped as: (i) characteristics of the existing service (such as frequency of service); (ii) the community's service requirements (including the manner of collection); (iii) limitations on the service posed by the environment (such as complexities posed by population density and topography and the influence of garden area, family size, household income, and restaurant usage); (iv) council's utilisation of various productive factors (including the degree of automation); and (v) other factors (including the extent of green space, and street sweeping and litter bin services) (IPART, 1997). However, the recent IPART (1997, p. 90) inquiry has identified a number of conflicts that make the measurement of efficiency in DWMS particularly problematic.

Table 1
Variables and Descriptive Statistics, Domestic Waste Management Services

Variable	Description	Mean	Std. dev.	Min.	Max.
Non-discretionary inputs					
x_1	Properties receiving DWMS	16218	17943	283	68500
x_2	Occupancy rate	2.6689	0.5250	1.2337	4.3353
x_3	Population density	26.959	27.124	1.2557	189.93
x_4	Population distribution	9.6493	19.387	0.000	100.75
x_5	Cost of disposal index	27.197	8.789	17.462	49.718
Discretionary inputs					
x_6	Collection expenditure	1.21E+06	1.46E+06	1.10E+04	7.43E+06
Discretionary outputs					
y_1	Total garbage collected	1.75E+07	1.86E+07	1.10E+05	7.43E+07
y_2	Total recyclables collected	2.12E+06	2.56E+06	1.00E+03	1.22E+07
y_3	Implied recycling rate	0.1504	0.1513	0.0008	0.3254
Australian Classification of Local Governments					
z_1	Urban, metropolitan developed (UCC, UDV, UDL, UDM, UDS)				32
z_2	Urban, fringe (UFV, UFL, UFM, UFS)				10
z_3	Urban, regional town/city (URV, URL, URM, URS)				22
z_4	Rural, significant growth (RSG)				2
z_5	Rural, agriculture (RAV, RAL, RAM, RAS)				37

One example is that there may be a degree of conflict between strictly efficient performance and compliance with the *Waste Minimisation and Management Act* if the cheapest method of waste management is disposal to landfill, yet the Act seeks to minimise disposal to landfill. Another example is associated with councils' recycling efforts and involves ownership of recyclable material. The IPART (1997, p. 90) inquiry notes that where a council maintains ownership, any proceeds from the sale of recycled material will offset costs to some degree. Alternatively, where ownership is transferred to a collection contractor, the proceeds should be considered in deriving the cost of the recycling service. Unfortunately, there is no dataset available reflecting all factors relevant to calculating DWMS efficiency at the present time.

In terms of non-discretionary inputs, eight categories are employed. These are: the number of properties receiving DWMS (x_1); the occupancy rate (x_2) (council population divided by the number of serviced properties); urban density (x_3) (urban population divided by the urban residential area); population distribution (x_4) (the sum of population centres greater than 200 multiplied by their distance from council headquarters divided by the number of urban properties); and an index of waste disposal costs (x_5) (based on the standardised tonnage of garbage collected, the cartage distance to the receiving depot, and the receiving charge at that depot). Once again these measures are identical to those employed by the NSWLGGC to calculate expenditure disability factors in DWMS [see NSWLGGC (1994)]. The occupancy measure recognises the variation in DWMS expenditures required for households with a higher than average occupancy rate, the urban density measure indicates the constraints placed on operating machinery in densely populated areas, while the measure of population distribution indicates costs associated with travel and duplication of services in local government areas (LGAs) where population is widely dispersed. As an example, narrow streets (associated with high urban density) may reduce the ability to use large, specialised equipment. Similarly, the extent of on-street parking may reduce the ability to use some automated collection equipment and accordingly increase manual labour requirements. According to the NSWLGGC (1994, p. 55) methodology for calculating standardised unit expenditure for residential garbage services, the largest marginal input requirement for a one percent increase in the contextual variable is for the occupancy rate, followed by disposal costs, and lastly, urban density and population distribution.

A comparable study of U.K. local authorities by Domberger, Meadowcroft & Thompson (1986) used similar variables to add additional dimensions to DWMS efficiency. In their cost function approach, Domberger *et al*. (1986) employed frequency of collection, density of population units, and distance to disposal points. In common with the present study, Domberger *et al* (1986, p. 74) used the number of units serviced rather than population, arguing that "population served seemed less appropriate on *a priori* grounds (the number of pick-up points is likely to be a more important determinant of costs than the number of people served by the collection service) and this was confirmed by our analysis". However, in contrast with the present study, Domberger *et al*. (1986, p. 75) argued that "the density of units is likely to have a negative effect on total cost; the proximity of pick-up points and shorter walking distances in areas of high density would suggest that costs should be lower in these areas".

Of these nondiscretionary inputs, one of the most important is the index of waste disposal costs. Given that most Australian garbage is disposed of in landfill sites near or beyond the urban fringe, the cost of transport will vary slightly with the distance of a local council from the landfill site. This may result in some geographic differences in the level of disposal costs (Neutze, 1997, p. 174). However, a more significant contributor to differences in the cost of disposal is the charges at the landfill site. Ideally, these would include the value of the site used for landfill, the environmental impact of these operations, and a scarcity rent associated with the exhaustible nature of these sites. It is also possible that this measure would provide some indication of the propensity of a council's ratepayers to engage in illegal dumping. All other things being equal, higher charges for dumping domestic waste, and the greater the distance to a collection site, the more likely illegal dumping will occur. A commensurate increase in the cost of surveillance by the council could also be expected (Neutze, 1997).

As with the contextual inputs, problems arise when obtaining reliable data on discretionary DWMS inputs and outputs for local councils. The principal difficulty is that the available data is usually not sufficiently disaggregated for the purposes of the analysis. For example, total costs for labour and capital could be listed as separate items, and variables identifying whether the service is provided 'in-house' or by 'contract', and the degree of automation could also be used. Moreover, there is also considerable diversity among the waste management practices of councils, which in turn influences the specification of outputs. For instance, in 1992 (the latest year for which these figures were collected) of the 72 percent of councils which offered DWMS, 72 percent provided ‘big bins’ (240 litre bins, sometimes referred to as ‘wheelie’ bins), 18 percent provided ‘normal/other bins’ (55 litre or any other than ‘big’ bins) and 38 percent both ‘big’ and ‘normal/other’ bins (NSWDLG, 1993, p. 19).

Similarly, the recycling services offered by councils vary considerably, a condition which may have a dramatic influence on the rate of recycling. For example, the average rate of recycling in urban metropolitan councils was 23.09 percent, compared to 11.35 percent in urban fringe councils, 11.43 percent in urban rural councils, 11.46 percent in rural agricultural councils, and 10.42 in rural councils with significant growth. As discussed, one reason for this may be differences in the recycling services offered. For instance, of the 23 percent of councils offering a recycling service, 78 percent were collected weekly, 10 percent fortnightly and 2 percent monthly (NSWDLG, 1993, p. 19). In ideal circumstances, the vector of discretionary outputs would also include collection quantities, the frequency of garbage service, and place of pick-up (street-front or within the residence) (IPART, 1997, p. 92). Reliable data on these variables is not available.

Accordingly, the discretionary input employed in DWMS is total collection cost (x_6), whereas the three measures of discretionary outputs are the amount of garbage collected in kilograms (y_1); the amount of recyclables collected (y_2) (also in kilograms); and the implied recyclable rate (y_3) (recyclable material as a proportion of total garbage collection). Although the specification of these variables is not ideal, especially that concerning outputs, it does effectively serve two purposes.

First, to some extent the collection of garbage is exogenously imposed upon a council by legal requirements. Increasing the volume of garbage collected thereby tends to provide some indication of the councils success in deterring illegal dumping by providing timely and effective collection services, and accordingly maintaining the quality of the environment (Neutze, 1997). Second, the distinction between ‘recyclable’ and ‘nonrecyclable’ domestic waste highlights efforts by councils to constrain the high costs associated with landfill site or incineration, and promote local environmental objectives. Moreover, the absence of a charging system for household garbage that relates to volume has meant that the primary means of limiting the demand for garbage collection in recent years has been education. Neutze (1997, p. 95) has argued that this is an appropriate method for discouraging the excessive use of public disposal facilities since it:

> [T]akes advantage of the interest of individuals in protecting the natural environment and emphasises a range of options including composting organic wastes and recycling paper, some plastics, glass and metal cans. In addition, recycling has been encouraged by the free provision of containers for, and free collection of, recyclable materials, and free or subsidised provision of compost containers.

A similar argument has been advanced by Domberger *et al*. (1986) when the amount of waste paper reclaimed was used as an output in a study of U.K. DWMS cost efficiency. The implied recyclable rate therefore indicates efforts the council has made to promote the recycling of domestic waste, both in the provision of separate collection services and promotion of these services amongst the community.

The final set of variables (z_1 – z_5) detailed in Table 1 relate to the Australian Classification of Local Government (ACLG) categories, which are in turn based upon objective geographic/demographic criteria. It is argued that other considerations may still have an influence on a council's efforts to attain an efficient outcome, even after the vector of non-discretionary inputs is taken into account. For example, in waste management services there may be additional complexities relating to the distance to waste disposal facilities or proximity of this facility to residential areas. If the vector of dummy variables in either of these cases proves to be an insignificant influence on efficient outcomes, then local governments across New South Wales should be able to be compared solely on the basis of the input/output vector and individual disability factors. Alternatively, evidence of a systematic relationship between one or more ACLG categories may focus the search for excluded disability factors, or analysis of managerial conditions unique to that local government classification.

Empirical Results

The results of the analysis of technical and scale efficiency using local governments' waste management and recycling function is presented in Table 2. The non-discretionary inputs posited to exert an influence on performance include the number of properties receiving the service, population density and occupancy rate. The discretionary input is total collection expenditure, whilst the discretionary outputs are the total tonnage of garbage and recyclable material collected and the implied rate of recycling. This particular model includes nondiscretionary inputs in the efficiency calculations themselves, however an alternative for future work would be to leave the nondiscretionary variables out of the DEA model and examine them in more detail in a second-stage regression.

Table 2.
Waste Management and Recycling Services Efficiency Indices

	Technical efficiency		**Pure technical efficiency**		**Scale efficiency**	
	All councils	*Inefficient councils*	*All councils*	*Inefficient councils*	*All councils*	*Inefficient councils*
Number	103	76	103	61	103	66
Mean	0.5614	0.4056	0.6712	0.4449	0.8453	0.7585
Standard deviation	0.3272	0.2275	0.3277	0.2342	0.2416	0.2652
Lowest quartile	0.2710	0.2321	0.3292	0.2535	0.8009	0.5281
Next to lowest quartile	0.4960	0.3392	0.7445	0.3682	0.9734	0.8986
Next to highest quartile	1.0000	0.5676	1.0000	0.5790	1.0000	0.9643
Highest quartile	1.0000	0.9150	1.0000	0.9799	1.0000	0.9994

As indicated, of the 103 councils examined, 42 councils (or 41 percent) are judged purely technical efficient, whilst 37 councils (some 36 percent) are scale efficient. The results for pure technical efficiency indicate that, on average, inputs could be reduced to 67.12 percent of the current level based upon observable best-practice, whilst the results for scale efficiency suggest that productivity losses due to scale effects account for 15.47 percent of inputs. However, more councils are either scale efficient or nearly so, with 75 percent of councils have an efficiency score greater than 97.34 percent. On the other hand, 50 percent of councils are less than 75 percent purely technically efficient when compared to best practice.

The results for waste management and recycling services indicate that the larger portion of overall technical efficiency is the result of purely technical inefficiency, rather than scale effects. That scale inefficiency which does exist is largely the result of operating at a smaller than optimal scale (53 councils subject to increasing returns-to-scale) as against scale diseconomies. Banker's (1996) tests of returns-to-scale reject the null hypothesis of constant returns-to-scale, and we may conclude that the provision of waste management and recycling services is subject to variable returns-to-scale.

Table 3
Waste Management and Recycling Services Efficiency by ACLG Category

		Pure technical efficiency				Scale efficiency			
ACLG	*Total*	*Mean*	*Std. dev*	*# Eff.*	*% Eff.*	*Mean*	*Std. dev*	*# Eff.*	*% Eff.*
UCC	1	1.0000	0.0000	1	100	0.0961	0.0000		
UDS	5	0.5181	0.2876	1	20	0.9447	0.0815	1	20
UDM	13	0.5986	0.2718	2	15	0.9520	0.0524	1	8
UDL	6	0.4647	0.2960	1	16	0.9633	0.0454	1	16
UDV	7	0.8663	0.2568	4	57	0.9343	0.0994	4	57
URS	10	0.6860	0.3388	4	40	0.7795	0.2697	3	30
URM	8	0.7181	0.3908	5	62	1.0000	0.0000	8	100
URL	1	1.0000	0.0000	1	100	1.0000	0.0000	1	100
URV	3	1.0000	0.0000	3	100	0.9476	0.0605	2	66
UFS	1	1.0000	0.0000	1	100	0.6050	0.0000		
UFM	2	0.1903	0.0242			0.9869	0.0184	1	50
UFL	2	0.7172	0.3999	1	50	0.9997	0.0004	1	50
UFV	5	0.7536	0.3571	3	60	0.8978	0.1960	2	40
RSG	2	1.0000	0.0000	2	100	0.2492	0.0119		
RAM	16	0.7085	0.3530	8	16	0.6805	0.3037	4	25
RAL	10	0.5627	0.3667	3	30	0.7222	0.2659	2	20
RAV	11	0.6143	0.2888	2	18	0.9566	0.8599	6	55
State	103	0.6712	0.3277	42	41	0.8453	0.2416	37	36

Notes: Urban (U), capital city (CC), metropolitan developed (D), part of an urban centre >1 million population or population density > 600 persons per sq. km), regional towns/city (R), part of an urban centre with population <1 million and predominately urban in nature, fringe (F), a developing LGA on the margin of a developed or regional urban centre, very large (V) (>120000 persons) large (L) (70001–120000) medium (M) (30001–70000) small (S) (<30000),

Rural (R), significant growth (SG), average annual population growth >3%, population >5000 and not remote, agricultural (A), population density <30 persons per sq. km, very large (V) (10001–20000 persons) large (L) (5001–10000) medium (M) (2001–5000) small (S) (<2000)

The distribution of waste management and recycling efficiency across the narrowest definition of ACLG categories is presented in Table 3. It should be emphasised that the sample of 103 councils used in this analysis comprises only 59 percent of all NSW local governments, and relates only to those councils covered by the Waste Recycling and Processing Service NSW (WRPS).

There is also significant variation in the average level of technical and scale efficiency (in brackets respectively) across the broader ACLG categories; urban developed (UD) (0.5757/0.9223), urban fringe (UF) (0.5718/0.9067), urban regional (UR) ((0.6756/0.8950), rural significant growth (RSG) (0.2492/0.2492) and rural agricultural (RA) (0.4951/0.7645).

Combined with Table 3 there is the suggestion that urban developed councils are generally less efficient, either purely or nearly so, compared to urban regional councils, with regard to both technical and scale efficiencies. Further, scale efficiencies are generally higher in urban fringe councils and lower in rural councils with significant growth, and technical efficiency is highest in urban rural councils and lowest in rural councils with significant growth.

Table 4
Summary of Statistical Test Results, Waste Management Services

Test procedure	Hypothesis	Group A	Group B	Pure technical	Scale efficiency
Welch	$H_0: \sigma^2_A = \sigma^2_B$ $H_1: \sigma^2_A \neq \sigma^2_B$	UD	All	-0.8504	2.6248***
	$T_W \sim N(0, \sigma^2)$	UR	All	2.5616**	1.2101
		UF	All	-0.1155	1.1160
		RSG	All	10.2630***	-25.5103***
		RA	All	-0.2793	-3.3397***
Mann-Whitney	$H_0: \sigma^2_A = \sigma^2_B$ $H_1: \sigma^2_A \neq \sigma^2_B$	UD	All	0.0888	0.3085
	$T_{MW} \sim N(0, \sigma^2)$	UR	All	3.0855***	3.0806***
		UF	All	-1.5204	-2.9636***
		RSG	All	0.8277	-0.8194
		RA	All	0.4992	0.01177
Banker’s asymptotic	$H_0: \sigma^2_A = \sigma^2_B$ $H_1: \sigma^2_A > \sigma^2_B$	RA	RSG	0.0855	0.0857
test (exponential)	$T_{EXP} \sim F(2N_A, 2N_B)$	RA	UR	1.4093	1.4045
		UF	UR	0.9087	0.9115
		UF	UD	3.1386***	3.1825***
		UR	UF	1.1004	1.0969
		UR	UD	2.8522***	2.9011***
Banker’s asymptotic	$H_0: \sigma^2_A = \sigma^2_B$ $H_1: \sigma^2_A > \sigma^2_B$	RA	RSG	0.0854	0.0855
test (half-normal)	$T_{EXP} \sim F(N_A, N_B)$	RA	UR	1.4102	1.4075
		UF	UR	0.9084	0.9095
		UF	UD	3.1389***	3.1971***
		UR	UF	1.1008	1.0995
		UR	UD	2.8514***	2.9077***

Notes: Asterisks represent significance at the * – .10, ** – .05 and *** – .01 level for t-tests; F-tests undertaken at .01 level only; UD – urban developed, UR – urban regional, UF – urban fringe, RSG – rural significant growth, RA – rural agricultural; “All” indicates all groups (exclusive of Group A).

However, these results are not supported on the basis of the statistical tests detailed in Table 4. The Welch test indicates that the distribution of pure technical efficiency varies from the overall population for urban regional and rural significant growth councils, whereas the Mann-Whitney test provides support on this basis only for urban regional councils. On the other hand, Banker’s (1996) asymptotic tests for both an assumption of exponential and half-normal distributions support the hypothesis that urban fringe councils are less scale and purely technically efficient than urban regional councils, which are in turn less efficient on average than urban developed councils. Examples of purely technically efficient councils are spread across a number of categories. Examples include Gunnedah, Scone and Tamworth (RA), Manly and North Sydney (UD), and Penrith (UF). However, scale efficient councils tend to be concentrated in the larger urban and regional developed categories. These include Blacktown, Mosman and Bankstown in the former, and Newcastle and Lake Macquarie in the latter.

Table 5
Determinants of Waste Management and Recycling Services Efficiency Variation

	Pure technical efficiency		**Scale efficiency**	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*
UD	-0.9382***	(0.3931)	-1.2730***	(0.4276)
UF	-0.74E-16	(0.6324)	-0.4054	(0.6455)
UR	0.3677	(0.4336)	0.5596	(0.4432)
RSG	27.8800	(0.35E+06)	-26.583	(0.36E+06)
RA	-0.6131*	(0.3443)	-0.7339**	(0.3511)

Notes: Asterisks represent significance at the * – .10, ** – .05 and *** – .01 level; figures in brackets are the corresponding standard errors; UD – urban developed, UR – urban regional, UF – urban fringe, RSG – rural significant growth, RA – rural agricultural.

The components of overall efficiency are examined using efficiency scores and total slacks (radial and non-radial) in Tables 5 and 6 respectively. The average level of slack across all geographic categories (as a percentage of the observed amount) is 56.7 percent for recyclables, 32.8 percent for expenditure and 13.9 percent for garbage. All other things being equal, urban developed councils have greater slacks in all three outputs (i.e. garbage, recyclables and the recycling rate), and the level of input (ie. collection expenditure). These results hold even after the vector of nondiscretionary inputs is taken into account, most of which is the result of congestion factors, rather than municipal size or geographic location. This would suggest that the impact of congestion, the inability to operate machinery, and difficulties in waste disposal in metropolitan areas, are significant influences on a council's ability to attain efficient outcomes. Moreover, it is only in the urban developed category that significant slacks in all discretionary inputs and outputs exist. Both urban regional and rural agricultural councils have substantial slacks in recyclables and the recycling rate, but both are relatively productive in collecting garbage within the constraints imposed by their respective local government areas.

Table 6
Determinants of Waste Management and Recycling Services Total Slacks

	Garbage slack		**Recyclable slack**		**Recycling rate slack**		**Expenditure slack**	
	Coefficient	*Elasticity*	*Coefficient*	*Elasticity*	*Coefficient*	*Elasticity*	*Coefficient*	*Elasticity*
UD	0.5932***	0.6261	8909*	0.2860	0.0229***	0.3783	0.69E+06***	0.6625
	(0.15E+06)		(0.48E+05)		(0.0070)		(0.95E+06)	
UF	0.23E+06	0.0767	1800.4	0.0018	0.0069	0.0359	0.55E+06***	0.1633
	(0.27E+06)		(0.85E+05)		(0.0125)		(0.17E+06)	
UR	28514	0.0207	0.19E+06***	0.4247	0.0248***	0.2823	0.19E+06***	0.1270
	(0.18E+06)		(0.57E+05)		(0.0084)		(0.11E+06)	
RSG	-0.22E+06	-0.0149	-77453	-0.0155	-0.0158	-0.0164	-43147	-0.0026
	(0.62E+06)		(0.19E+06)		(0.0288)		(0.39E+06)	
RA	0.22E+06	0.2915	77453*	0.3030	0.0158**	0.3199	43147	0.0499
	(0.14E+06)		(0.44E+05)		(0.0065)		(0.88E+05)	

Notes: Asterisks represent significance at the * – .10, ** – .05 and *** – .01 level; figures in brackets are the corresponding standard errors; elasticities calculated at means; dependent variable in least squares regression is total slack (residual and non-residual) from variable returns-to-scale model; UD – urban developed, UR – urban regional, UF – urban fringe, RSG – rural significant growth, RA – rural agricultural.

In terms of expenditure slack, urban regional and urban fringe councils tend to have higher expenditure slacks. The results indicate that the emphasis on improving productive performance in urban fringe councils should fall on reducing inputs, whereas urban regional and rural agricultural councils need to place more attention on promoting recycling and increasing the rate of recycling. Although the output weights used in DEA are derived from the sample itself, it would be possible to restrict weights in order to recognise the efforts by councils to promote recycling. Unfortunately, information of this type is not available for Australian local government.

However, the alternative logistic regression approach presented in Table 6 indicates that both urban developed and rural agricultural councils are generally less technically and scale efficient. A reason for this discrepancy would appear to be that while many urban developed and rural agricultural councils are not purely efficient in either respect, their relative efficiency scores are, on average, relatively high. The results in this section highlight the benefits of using a number of different approaches to interpret efficiency variation across groups of interest. Put differently, simple descriptive analysis, or an emphasis on the numbers of efficient councils alone, is likely to result in misleading inferences.

Concluding Remarks

The first section of this paper, focusing on technical and scale efficiency in local government, examined cross-sectional technical and scale efficiency at the municipal level using the mathematical programming approach to efficiency measurement. The approach selected directly incorporates the effect of nondiscretionary environmental factors on efficiency indices, and thereby allows the comparison of efficiency of public sector entities with different operating environments. The results indicate that technical and scale efficiency varies significantly across individual councils at the local level. The results also suggest that it is possible to construct a uniform framework for measuring efficiency in local public services, provided allowance is made for the nondiscretionary environmental or contextual factors which affect the production correspondence relating inputs to outputs. However, even after allowing for differences in councils' operating environments, variations in efficiency remain and these may be related to several imposed conditions.

The second section of the paper focused on the individual components that determine efficiency in local governments' waste management and recycling function. All other things being equal, urban developed councils have greater input slacks in expenditure, whilst regional and rural councils have greater output slacks in recycling programs. A number of promising areas for further research are highlighted by these results in particular. This includes using surveys of ratepayers/citizens to ascertain a jurisdiction's subjective preferences for local public services, and incorporating these into efficiency analyses. A further area is to utilise a more disaggregated data set to identify more specific sources of inefficiency in local public services. These additional variables may include information relating to the extent of contracting-out, the type and frequency of service delivery, and the degree of mechanisation.[2]

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Notes

[1] The empirical problem faced in this context is considerably complicated by the fact that NSW local governments are obliged under the *Waste Minimisation and Management Act 1995* to both reduce overall garbage collection and increase the rate of recycling. Alternative methodologies exist to that pursued in the paper. For example, a directional distance function could be used which could examine the output-orientated problem where garbage collection and garbage recycling are simultaneously decreased and increased respectively. Similarly, a cost indirect model could be employed in which an output-based measure is used subject to a budget constraint. This would allow for the identification of the efficient (in the sense of cost minimising) mix of inputs (Färe *et al*. 1983; Färe & Lovell, 1983; Färe *et. al*., 1988).

[2] Unfortunately, the NSW Department of Local Government's published *Comparative Information on New South Wales Local Government* does not include information on many of these variables, including the extent of contracting out. Accordingly, empirical work here would need to survey individual councils to collect this data.

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