Cost efficiency in Australian non-bank financial institutions: A non-parametric approach

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Abstract

A two-stage procedure is employed to evaluate non-bank financial institution cost efficiency. In the first stage, data envelopment analysis is used to calculate technical, allocative and cost efficiency indices using a sample of two hundred Australian credit unions. The results indicate that a typical credit union's costs in 1997 were thirty percent above what could be considered efficient on the basis of observed best practice. The major source of overall cost inefficiency would appear to be allocative inefficiency, rather than technical inefficiency. The second stage uses limited dependent variable regression techniques to relate credit union efficiency scores to financial statement information. The results indicate that commercial lending activities, expenditures on information technology and marketing and promotion, the proportion of non-interest income, and association membership are a significant influence on the level of cost efficiency. The results are found to be invariant to alternative model specifications where input prices are first assumed to be different for each credit union and then assumed to be identical across the sample.

Key words: Data envelopment analysis; Technical, allocative and cost efficiency; Credit unions

JEL classification: C24; C61; D24; G21

1. Introduction

During the last two decades, sweeping changes to the restrictions governing deposit-taking institutions (DTIs) around the globe have been made. DTIs who previously operated within well-defined, institution-specific, regulatory sub-sectors have been forced to adapt to newly deregulated environments. A similar experience has occurred in Australia where regional and major joint-stock

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banks now compete on a largely equal regulatory footing with predominantly mutual credit unions and building societies. While the large commercial banks could be expected to be well placed for the newly-deregulated product markets, the fact that the overwhelmingly smaller credit unions have survived and competed in what is a highly competitive environment is most interesting. Moreover, given that certain credit union institutional characteristics are argued to constrain cost-effective behaviour, their ability to survive competition from non-member owned financial institutions presents an even more compelling area of inquiry.

Australian credit unions differ from non-member owned financial institutions in at least four respects. First, credit unions operate on a cooperative basis, principally by borrowing from and lending to their members. In principle, new members join on equal terms to existing members and the key principle of mutuality is maintained, implying ‘one member, one vote’. One aspect of this process is that an individual member can acquire only one vote regardless of the value of funds committed, and that credit unions cannot acquire shares in another. Hostile acquisition is therefore difficult, if not impossible, to achieve. Second, profits earned by the credit unions are not ordinarily distributed to members; rather they are accumulated and held perpetually in the form of reserves for the benefit of current and future members. The owner-members cannot sell their claims to any accumulated surplus on a secondary market and no claim can be made on this surplus if membership lapses.

Third, in spite of the erosion of some traditional objectives of credit unions, there is still an emphasis on the common associational bond or affinity that defines membership. For example, credit unions in Australia are restricted to three categories: namely, industrial (employee) groups; community-based (geographic) groups; and parish (religious) groups. This implies that credit unions are restricted (in principle) in many product markets. Finally, there is the suggestion that structural change in cooperative financial services is essentially restricted to ‘friendly’ mergers, and that there is a large degree of acquiescence by regulatory authorities in this matter. Furthermore, it is also the case that liquidation of Australian credit unions has been extremely rare, and it is widely understood that the exit of a credit union in financial distress is likely to occur through merger rather than liquidation (Brown *et al*., 1999).

Taken together, these characteristics generally imply that credit unions, in Australia and elsewhere, “…suffer from a particularly acute agency problem” (Thompson, 1997, p. 40). It is argued that the owner-members have no particular incentive to participate in decision-making or monitoring performance, and that regulatory intervention in the form of forced mergers effectively renders deposits risk-free. The democratic principle underlying voting procedures in credit unions further implies that it would be extremely difficult to build a voting coalition against incumbent management. When combined, the weak ownership claims and the absence of a secondary equity market appears to favour managerial control over depositor ownership. This has led Thompson (1997, p. 40), amongst others, "to conclude that the managers of financial mutuals engage in systematic expense preference-behaviour and/or departures from cost minimisation".

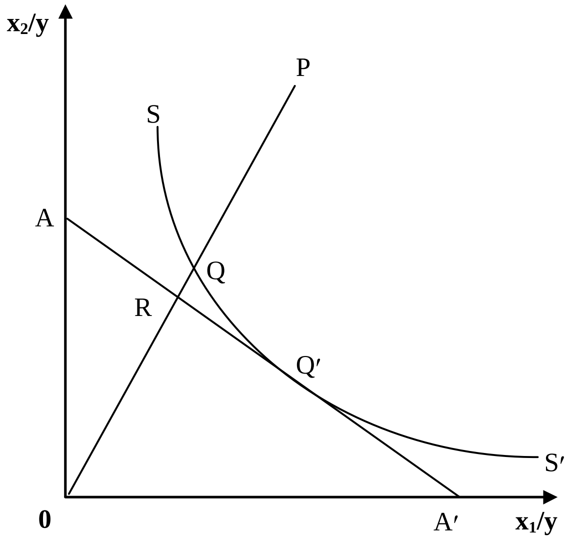
Unfortunately, little empirical evidence exists concerning departures from cost minimisation in Australian credit unions. A thorough examination of cost efficiency will throw light on both possible pressures for consolidation (either regulatory enforced or otherwise) and the ability of credit unions to effectively compete in product markets dominated by the major banks. Likewise, the presence of scale economies in financial services has been sufficiently well established, both in Australia and overseas [see, for instance, Drake and Weyman-Jones (1992), Esho and Sharpe (1994), Fukuyama (1996) and Worthington (1999)] and the concomitant cost advantages larger banks have over smaller competitors quantified. However, for various reasons credit unions may be unable to achieve an optimal scale of operations. For example, regulatory restrictions on membership to a specific associational bond (that is, either industrial, community-based or parish) may restrict credit unions to a sub-optimal size. Furthermore, "cost reduction strategies which seek economies of scale … may have the effect of distancing a credit union from the members it needs to know well" (Brown *et al*., 1999, p. 18). These concerns highlight the need for measures of cost efficiency that are not confounded by the impact of scale economies.

With these considerations in mind, an attempt is made to examine the cost efficiency of Australian credit unions. The purposes of this exercise are twofold. First, we calculate measures of cost efficiency using nonparametric methods. Second, we explain the calculated efficiency scores in terms of the operating characteristics of individual credit unions. This provides insights into the determinants of inefficiencies, and yields useful information about the possible impact of recent deregulation and future pressures for consolidation. The paper itself is divided into five main areas. Section 2 briefly surveys the frontier approach to efficiency measurement in financial services. Section 3 explains the nonparametric technique used in the measurement of credit union cost efficiency. Section 4 deals with the specification of inputs and outputs in this model. The results are dealt with in Section 5. The paper ends with some brief concluding remarks.

2. Frontier approaches to efficiency measurement

The recent history of microeconomic efficiency measurement begins with Farrell (1957) who defined a simple measure of firm efficiency that could account for multiple inputs. In his approach, Farrell (1957) proposed that the efficiency of any given firm consisted of two components: technical efficiency, or the ability of a firm to maximise output from a given set of inputs, and allocative efficiency, or the ability of a firm to use these inputs in optimal proportions, given the respective prices. Combining the two measures provides a measure of cost or productive efficiency. It is Farrell's (1957) suggestion that efficiency could be measured empirically in reference to an idealised frontier isoquant – or equivalently, disturbances in an econometric model – which forms the basis of subsequent analysis.

Fig. 1. Technical, allocative and cost efficiencies



The essence of Farrell's (1957) argument is contained in Figure 1. Here two inputs, x_1 and x_2, are utilised to produce a single output, *y*, under an assumption of constant returns to scale. The isoquant of the fully efficient firm *SS′* (showing the alternative combinations of inputs which can used to produce a given level of output) permits the measurement of technical efficiency. For a given firm using quantities of inputs defined by point *P* to produce a unit of output, the level of technical efficiency may be defined as the ratio *OQ/OP*. This is the proportional reduction in all inputs (ie. by movement onto the efficient isoquant) that could be theoretically achieved without any reduction in output. The technical efficiency ratio for the firm at point *P* will then be less than unity. Point *Q*, on the other hand, is technically efficient since it already lies on the efficient isoquant. The technical efficiency ratio of the firm at *Q* is *OQ*/*OQ* or unity, thereby implying absolute or relative efficiency (depending upon the manner in which the efficient isoquant is constructed). If the input price ratio *AA′* is known (showing the different combinations of inputs that can be purchased with a given cost outlay), then allocative efficiency at point *P* is the ratio *OR/OQ*, where the distance *RQ* is the reduction in production costs which would occur if production occurred at *Q′* – the allocatively and technically efficient point, rather than *Q* – the technically efficient, but allocatively inefficient point. Hence, total economic (cost) efficiency is the ratio *OR/OP*, with the cost reduction achievable being the distance *RP*. Note that the cost efficiency ratio *OR*/*OP* is the product of the technical efficiency ratio *OQ*/*OP* and the allocative efficiency ratio *OR*/*OQ*.

Of course, these efficiency measures assume the production function of the fully efficient firm is known. As this is usually not the case, the efficient isoquant must be estimated using sample data. Farrell (1957) suggested the use of either: (i) a nonparametric piecewise-linear convex isoquant constructed such that no observed point should lie to the left or below it (known as the *mathematical programming* approach to the construction of frontiers); or (ii) a parametric function, such as the Cobb-Douglas form, fitted to the data, again such that no observed point should lie to the left or below it (known as the *econometric* approach). These approaches use different techniques to envelop the observed data, and therefore make different accommodations for random noise and for flexibility in the structure of the production technology.

First, the econometric approach specifies a production function and normally recognises that deviation away from this given technology (as measured by the error term) is composed of two parts, one representing randomness (or statistical noise) and the other inefficiency. The usual assumption with the two-component error structure is that the inefficiencies follow an asymmetric half-normal distribution and the random errors are normally distributed. The random error term is generally thought to encompass all events outside the control of the organisation, including both uncontrollable factors directly concerned with the 'actual' production function (such as differences in operating environments) and econometric errors (such as misspecification of the production function and measurement error). This type of reasoning has primarily led to the development of the 'stochastic frontier approach' (SFA) which seeks to take these external factors into account when estimating the efficiency of real-world organisations, and the 'deterministic frontier approach' (DFA) which assumes that all deviations from the estimated frontier represent inefficiency. A number of previous studies have used this approach to estimate the efficiency of non-bank financial institutions. These include Cebenoyan *et al*. (1993), McKillop and Glass (1994), Drake and Weyman-Jones (1996), Esho and Sharpe (1996) and Worthington (1998a; 1998b).

Second, and in contrast to the econometric approaches which attempt to determine the *absolute* economic efficiency of organisations against some imposed benchmark, the mathematical programming approach seeks to evaluate the efficiency of an organisation *relative* to other organisations in the same industry. The most commonly employed version of this approach is a linear programming tool referred to as 'data envelopment analysis' (DEA). DEA essentially calculates the economic efficiency of a given organisation relative to the performance of other organisations producing the same good or service, rather than against an idealised standard of performance. A less-constrained alternative to DEA sometimes employed in the analysis of efficiency in financial services is known as ‘free-disposal hull’ (FDH). Both DEA and FDH are nonstochastic methods in that they assume all deviations from the frontier are the result of inefficiency. These approaches have been applied to non-bank financial institutions by Fried, Lovell and Vanden Eeckaut (1993), Piesse and Townsend (1995), Drake and Weyman-Jones (1996), Fried, Lovell and Turner (1996), and Worthington (1999). Suitably detailed surveys of both the mathematical programming and econometric approaches to efficiency measurement may be found in Førsund, Lovell and Schmidt (1980), Seiford and Thrall (1990), Greene (1993), Lovell (1993), Ali and Seiford (1993) and Charnes, Cooper, Lewin and Seiford (1993)].

The approach employed in the current paper to empirically construct measures of cost, allocative and technical efficiency is based upon the DEA approach. One obvious problem with DEA is that in contrast to the econometric approaches to efficiency measurement it is both nonparametric and nonstochastic. Thus, no accommodation is made for the types of bias resulting from environmental heterogeneity, external shocks, measurement error, and omitted variables. Consequently, the entire deviation from the frontier is assessed as being the result of inefficiency. This may lead to either an under or over-statement of the level of inefficiency.

However, there a number of benefits implicit in the mathematical programming approach that makes it attractive on a theoretical level. First, given its nonparametric basis it is relatively easy to alter the specification of inputs and outputs and thereby the formulation of the production correspondence relating inputs to outputs. Thus, in cases where the usual axioms of production activity breakdown (ie. profit maximisation) then the programming approach may offer useful insights into the efficiency of these types of industries. This is especially the case with mutual financial institutions. Second, when using either econometric approach considerable structure is imposed upon the data from stringent parametric form and distributional assumptions regarding both inefficiency and, in the case of SFA, statistical noise. These considerations, and the natural emphasis of DEA on the notion of ‘best-practice’ performance, make it an attractive choice from these two separate, though conceptually similar, approaches to the assessment of cost efficiency

3. Empirical Methodology

The computational procedure used to implement the DEA approach to cost efficiency measurement consists of two steps. The first step is to obtain measures of technical efficiency as introduced by Charnes *et al*. (1978). Consider N credit unions each producing M different outputs using K different inputs. The $K\times N$ input matrix, X, and the $M\times N$ output matrix, Y, represent the data of all N credit unions, while for the individual credit union these are represented by the vectors x_i and y_i.

The purpose of DEA is to construct a non-parametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. The relative efficiency of each credit union in ratio form (where for each credit union we obtain a ratio of all outputs over all inputs) is specified as follows:

$$\begin{aligned} &\max_{u,v}(u' y_i / v' x_i) \\ &\text{s.t. } u' y_j / v' x_j \leq 1 \\ &\qquad u, v \geq 0 \end{aligned} \qquad (1)$$

where y_i is the vector of outputs produced by the ith credit union, x_i is the vector of inputs used by the ith credit union, u is a $M\times 1$ vector of output weights and v is a $K\times 1$ vector of input weights (the prime denotes a transposed vector), i runs from 1 to N, and j equals 1, 2, ..., N. The first inequality ensures that the efficiency ratios for all credit unions cannot exceed one, whilst the second ensures that the weights are non-negative. The weights are determined such that each credit union maximises its own efficiency ratio. A problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this the constraint $v' x_i = 1$ is imposed. This fractional linear program (1) can then be transformed into the following equivalent linear programming problem:

$$\begin{aligned} &\max_{\mu,\nu}(\mu' y_i) \\ &\text{s.t. } \nu' x_i = 1 \\ &\mu' y_j - \nu' x_j \leq 0 \\ &\qquad \mu, \nu \geq 0 \end{aligned} \qquad (2)$$

where the notation change from u and v to μ and ν reflects the transformation. Using the duality of linear programming, this multiplier form can then be used to derive an equivalent envelopment form of the problem:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ \text{s.t.}\ &-y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \tag{3}$$

where θ is a scalar and λ is a $N\times1$ vector of constants. The value of θ will be the technical efficiency score for a particular credit union. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier, and hence a technically efficient credit union. The value of $\theta \leq 1$ identifies the amount of any inefficiencies that may be present.

The model specified in (3) has an assumption of constant returns-to-scale (CRS) and is only appropriate where all credit unions are operating at an optimal scale. Where this assumption does not hold, scale effects will confound the measures of technical efficiency. Generally, regulatory, geographical and institutional constraints imply that most credit unions are not operating at an optimal scale. Following Banker *et al.* (1984) the linear programming problem can be modified to account for variable returns-to-scale (VRS) (that is, measures of technical efficiency without scale efficiency effects) by adding the convexity constraint $N1'\lambda = 1$ to (3).

The second step is to calculate cost efficiency with respect to this DEA dual reference technology by solving the following linear program (including the convexity constraint):

$$\begin{aligned} &\min_{\lambda,x_i^*} w_i' x_i^* \\ \text{s.t.}\ &-y_i + Y\lambda \geq 0 \\ &x_i^* - X\lambda \geq 0 \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \tag{4}$$

where w_i is a vector of input prices for the *i*th credit union and x_i^* is the cost-minimising vector of input quantities for the *i*th credit union given the input price vector w_i and the output vector y_i. The ratio $(w_i' x_i^* / w_i' x_i)$ measures the cost (or economic or productive) efficiency (*CE*) of the *i*th credit union, and $[(w_i' x_i^* / w_i' x_i)^{-1} - 1]$ measures the amount by which cost is increased due to both kinds of inefficiency (both technical and allocative): that is, the ratio of minimum to observed cost. Following the earlier discussion, allocative efficiency (*AE*) can then be calculated residually by dividing cost efficiency (*CE*) by technical efficiency (*TE*).

The primary technique used for explaining variation in the various efficiency measures is a regression-based approach. In this model, the calculated measures of technical efficiency (*TE*), allocative efficiency (*AE*) and cost efficiency (*CE*) for all credit unions (both efficient and inefficient) are specified as the dependent variable in three separate regressions. Given that in each case the calculated measure of efficiency is a limited dependent variable, tobit estimation is appropriate. The explanatory variables posited to explain the presence of inefficiency are a set of institutional characteristics and financial measures that characterise each credit union's operations. Aly, Grabowski, Pasurka and Rangan (1990), Drake and Weyman-Jones (1992), Fried, Lovell and Vanden Eeckaut (1993) and Worthington (1999), amongst others, have also used nonparametric techniques to measure efficiency in financial institutions, followed by parametric techniques to explain variation in efficiency.

4. Specification of variables

Summary statistics of the inputs, input prices and outputs used in the calculation of the nonparametric efficiency measures are detailed in Table 1. All data corresponds to the financial year ending 30 June 1997 and is obtained from the Australian Financial Institutions Commission (AFIC). The variables apply to a sample of the two hundred largest credit unions (by book value of assets).

The actual specification of these variables is contingent upon one's *a priori* conceptualisation of financial institution behaviour, for which two primary approaches exist. The first of these, the production approach, conceptualises financial institutions, such as credit unions, as producers of loan and deposit accounts. In this instance, outputs are defined as the number of such accounts, or their associated transactions, while capital and labour expenses and total operating costs define the firm's inputs and total costs respectively.

The second approach to financial institution behaviour is termed the intermediation approach. Here financial institutions are viewed as "...intermediators of financial services rather than producers of loan and deposit account services, and the values of loans and investments are used as output measures; labour and capital are inputs to this process, hence operating costs plus interest costs are the relevant cost measure. Deposits may be either inputs or outputs" (Colwell and Davis, 1992, p. 113). In most instances, the intermediation approach is the preferred conceptualisation (Colwell and Davis, 1992, p. 113). Furthermore, the intermediation approach is consistent with both existing commercial bank studies, and specific thrift analyses such as Fried *et al.* (1993). Brief reviews of these conceptualisations, along with several others, may be found in Colwell and Davis

(1992) and Favero and Papi (1995). Empirical studies concerned with the effects of alternative specifications of inputs and outputs in financial institutions include Piesse and Townsend (1995) and Worthington (1998c).

The inputs and input prices used in the calculation of the efficiency measures are presented in Table 1. The three inputs selected are (i) labour (*LAB*) (measured in full-time equivalent units), (ii) physical capital (*CAP*) (book value of premises and fixed assets), and (iii) loanable funds (time and savings deposits plus other borrowed funds) (*FND*). The price of labour (*WGE*) is derived by dividing total expenditures on employees (salaries, wages and on-costs) by the number of full-time equivalent units of labour. Of course, there are obvious problems associated with measuring labour inputs and labour input prices in this way. A preferred approach would be to use total hours worked, disaggregated across different types of labour to capture differences in the quality of labour, say, between administrative and operational staff. Unfortunately, information of this type is not readily available.

The price of capital (*RTE*) is proxied by dividing physical capital expenses (office and equipment expenses plus depreciation) by the book value of net office premises and equipment (including office buildings and land, leasehold improvements, furniture and fixtures, capitalised leases). This measure is generally regarded as current payment for the use of physical capital, primarily office buildings, vehicles and office equipment. Specification of the cost of physical capital in this manner is common in the financial services efficiency literature [see, for instance, Aly *et al*. (1990), Grabowski *et al*. (1993), Elyasiani *et al.* (1994), Drake and Weyman-Jones (1996) and Worthington (1998a; 1998b]. Finally, the price of loanable funds (*INT*) is the sum of interest expenses divided by total loanable funds and recognises the direct costs associated with deposits as a source of funds. This measure follows the work of Mester (1987; 1993), Aly, Grabowski, Pasurka and Rangan (1990), McKillop and Glass (1994) and Fried, Lovell and Turner (1996).

Notwithstanding the widespread use of these proxies for the price of labour, physical capital and loanable funds, there is the suggestion that such measures do not reflect the fact that credit unions purchase their inputs in competitive markets and face no such cost differences. For example, in a study of Australian building societies, Esho and Sharpe (1994, p. 264) use weekly earnings in the finance industry to proxy the price of labour on the basis that "Australia's centralised industrial relations system effectively ensures very little wage variation across firms employing the same type of labour". Furthermore, some variation in input prices may merely represent a difference in the combination of inputs employed by different credit unions. For instance, by using office and equipment expenses to calculate the price of capital, different methods of delivering services (such as branch networks versus phone banking) may manifest themselves as mismeasured differences in the price of capital across firms. This problem is also likely to extend to the pricing of loanable funds. For example, by using interest expense to calculate the cost of funds, at least some variation is likely to represent differences in depositor services as bundled into a package of interest income plus services, rather than any real difference in the cost of funds across credit unions.

Table 1
Variables and selected descriptive statistics

Variable	Description	Mean	Standard deviation
Outputs			
PER	Book value of personal loans and consumer credit facilities ($000s)	28307.00	39466.00
RES	Book value of property and real estate loans ($000s)	35212.00	60107.00
COM	Book value of commercial loans ($000s)	2009.20	4287.60
DEP	Deposits with other deposit-taking institutions ($000s)	1208.90	2789.90
SEC	Book value of financial securities ($000s)	13994.00	19873.00
Inputs			
LAB	Labour (number of full-time equivalent staff)	39.65	51.26
CAP	Physical capital (book value of premises and fixed assets) ($000s)	1730.20	3325.80
FND	Loanable funds (time and savings deposits) ($000s)	73862.00	104010.00
Input prices			
WGE	Price of labour (salary expenses per employee) ($000s)	39.01	10.17
RTE	Price of physical capital (ratio of physical capital expenses to book value of office premises and equipment)	0.0393	0.0652
INT	Price of loanable funds (ratio of total interest expenses to loanable funds)	0.0449	0.0118
Explanatory variables			
CAP/TA	Ratio of member capital to total assets	0.1005	0.0356
TA/TL	Ratio of total assets to total liabilities	1.1136	0.0478
NI/TR	Proportion of non-interest income in total revenue	0.0799	0.0551
NPAT/TA	Ratio of net profit after-tax to total assets	0.0066	0.0055
INF/TE	Information technology expense to total expense ratio	0.0479	0.0246
MKT/TE	Marketing expense to total expense ratio	0.0208	0.0120
RES/LOAN	Proportion of real estate and property loans in loan portfolio	0.4832	0.1771
COM/LOAN	Proportion of commercial loans in loan portfolio	0.0348	0.0436
BAD/LOAN	Ratio of bad and doubtful debts expenses to total loans	0.0026	0.0031
MEM	Number of members	16784	21357
BRA	Number of branches (excluding head office)	4.56	6.58

In order to address these questions, the model and empirical work is repeated under the assumption that all credit unions have the same input prices for labour, physical capital and the cost of funds. The average gross weekly earnings of all persons employed in the finance and insurance industry (Australian Bureau of Statistics, Catalogue No. 6302.0) specifies the wage rate (Esho and Sharpe, 1994). The user cost of physical capital is estimated as the long-term interest rate (measured by the yield on ten-year Treasury bonds), plus the annual depreciation rate in private business, less the expected annual rate of capital gain on physical assets (measured using the price indices for business investment). This data is obtained from the Treasury Model of the Australian Economy (Australian Bureau of Statistics, Catalogue No. 1364.0). Hardwick (1997) has used an identical measure of the user cost of capital in a study of non-bank financial institutions. Finally, the Reserve Bank of Australia Bulletin provides the average retail deposit rate on transaction and investment accounts as a measure of the cost of loanable funds. The input prices obtained in this part of the analysis are $38,200 for labour, 7.10 percent for physical capital and 1.05 percent for loanable funds. For the purposes of comparison, average input prices as derived from each credit union's financial statements are detailed in Table 1.

The five outputs used in the present study follow the thrift analyses of Hardwick (1990), Cebenoyan *et al.* (1993), Drake and Weyman-Jones (1992; 1996), Piesse and Townsend (1995) and Worthington (1998a; 1998b; 1999). They are: personal loans and consumer credit facilities (*PER*); property loans and real estate loans (*RES*); commercial loans (*COM*); deposits with other thrift institutions and banks (*DEP*); and finally, other securities (*SEC*) (including bank bills, negotiable certificates of deposit, Commonwealth/State/Local and semi-Government securities). Thus, given the nonparametric model outlined earlier, credit unions are characterised as producing five categories of output, using three inputs with associated factor prices.

The second part of the two-stage procedure used to measure and explain technical, allocative and cost efficiency in Australian credit unions involves the specification of a vector of explanatory variables presumed to account for inefficiency. These are intended to evaluate several associated hypotheses on the relationships between financial institution inefficiency and firm-specific variables. The index measures of efficiency specified as the dependent variables have a lower bound of zero and an upper bound of unity. A credit union with an efficiency score less than one is relatively 'inefficient' to various degrees. For example, a credit union with a cost efficiency score of 0.50 is half as cost efficient as the 'efficient' credit unions that define the best-practice frontier, while one with an efficiency score of 0.90 is only ten percent less cost efficient. A positive estimated coefficient in the regression model is thereby associated with an improvement in efficiency, while a negative coefficient is linked with a reduction in efficiency. Summary statistics for these variables are detailed in Table 1.

The first group of explanatory variables relates to firm-specific operational characteristics. The first explanatory variable is the credit union's member capital to asset ratio (*CAP/TA*). All other things being equal, "moral hazard theory suggests [the capital asset ratio] should be inversely related to inefficiency" (Mester, 1993, p. 282). The next three variables relate to additional aspects of credit union financial management. These are: (i) the ratio of total assets to total liabilities (*TA/TL*), (ii) the proportion of non-interest income to total revenue (*NI/TR*) and (iii) the ratio of net profit after-tax to total assets (*NPAT/TA*). The measure of non-interest income as a proportion of interest plus non-interest income is considered especially important given that one focus of deregulation was that "...the pricing of banking services ... reflect more closely the user pays principle, thus creating incentives for allocative efficiency improvements" (Financial System Inquiry, 1997, p. 610). However, given the fact that their underlying commitments may not be related to specific balance sheet magnitudes, it is somewhat difficult to postulate the relationship between non-interest revenue sources and firm efficiency. Regardless, in all three cases, a positive coefficient is hypothesised.

The next group of variables is intended to measure whether efforts by credit unions to improve the level of competitiveness and dynamic efficiency post-deregulation are reflected in relatively higher levels of technical, allocative and overall cost efficiency. These are the proportions of total expenses derived from expenditures on information technology (*INF/TE*) and total expenses associated with expenditures on marketing and promotion (*MKT/TE*). All other things being equal, it is hypothesised that credit unions that have invested heavily in information technology and product development should be relatively more efficient in the production of the dollar outputs of loans and other financial assets: positive coefficients are hypothesised on both counts.

The next three variables used to explain credit union efficiency relate to the composition and performance of the loan portfolio: (i) the proportion of residential and property loans in the total portfolio (*RES/LOANS*); (ii) the proportion of commercial and business loans in the total loan portfolio (*COM/LOANS*) and (iii) the percentage of total current expenses expensed on bad and doubtful debts (*BAD/LOANS*). One argument here is that a clear 'market-orientation' in regards to commercial and residential loans may be associated with a relatively more efficient credit union (Mester, 1993). In addition, we could also expect that credit unions which are exposed to the strong post-deregulation competitive forces in residential and commercial loan markets are obliged to undertake programs aimed at enhancing efficiency; at the same time as minimising the side-effects of delinquent loans. The *ex ante* signs on the coefficients for commercial and residential loans are thought to be positive, while that for bad and doubtful debts should be negative.

The final group of variables relates to additional non-financial characteristics of Australian credit unions. The first variable is intended to account for the effect of the number of credit union members (*MEM*) on efficiency. All other things being equal, a large credit union in terms of number of members will have a more diversified membership than one with a smaller membership.

Generally, this would imply that the prospects for attaining efficiency are higher (Fried *et al.*, 1993). Similarly, credit unions with a large number of members are more likely to actively engage in the technological innovation associated with deregulation. Both hypotheses suggest a positive coefficient for credit union membership when used as an explanatory variable for technical, allocative and cost efficiency.

The second variable relates to the branching behaviour of credit unions, generating three somewhat conflicting hypotheses (Fried *et al.*, 1993). The first is that under the intermediation approach, the number of branches and agencies (*BRA*) are recognised as "...central to the intermediation process for most [non-bank financial institutions], it may also be the case that differences in the intensity of branching may be an important factor" (Drake and Weyman-Jones, 1992, p. 5). Accordingly, the number of branches are closely related to the level of financial intermediation provided; a negative coefficient is inferred. The second hypothesis is that the number of branches and agencies are a critical, and possibly negative factor, in the ability of head offices to promote cost efficient behaviour. In this case, we would expect *ceteris paribus* a positive coefficient. The third hypothesis is that branch services are an output offered jointly with deposit services; a positive coefficient is also thus postulated.

5. Results

Table 2 provides summary statistics for the DEA measures of Australian credit union technical, allocative and cost efficiency. The inputs used are the number of full-time equivalent staff, physical capital and loanable funds, whilst the outputs are the dollar value of personal loans and consumer credit facilities, property loans and real estate loans, commercial loans, deposits with other thrift institutions and banks, and other financial securities. The factor prices used are the implied prices of labour, physical capital and the interest rate paid on loanable funds. The measure of overall cost inefficiency provided therefore incorporates both allocative inefficiencies which result from failing to react optimally to relative prices of inputs and technical inefficiencies from employing too much of the inputs to produce the outputs.

The first set of descriptive statistics in Table 2 are those obtained when input prices are allowed to vary across the sample. As indicated, of the 200 credit unions examined, 67 credit unions (or 33 percent) are judged technically efficient (that is, with an efficiency index equal to one), while 29 credit unions (some 15 percent) are allocatively efficient. The results for technical efficiency indicate that, on average, inputs could be reduced to 94.92 percent of the current level based upon observable best-practice, whilst the results for allocative efficiency suggest that efficiency losses due to allocative effects account for 27.14 percent of inputs (that is, 1.0000 – 0.7286). In general, more credit unions are either technically efficient or nearly so, with 75 percent of institutions having an efficiency score greater than 90.9090 percent. On the other hand, 50 percent of credit unions are less than 68.890 percent allocatively efficient when compared to best-practice.

The results generally indicate that the larger portion of cost efficiency is the result of allocative, rather than technical, effects. Examination of the cost-minimising input quantities suggests that if the average credit union reduced inputs to the extent of moving onto the efficient frontier, labour inputs would be reduced by 7.42 full-time equivalent staff (a cost saving of $289,400) while physical capital inputs could achieve a cost saving of $108,460. In terms of international comparisons, Fukuyama (1996) measured technical efficiencies of 83 percent in Japanese credit associations, Lang and Welzel (1996) estimated cost efficiencies up to 87 percent in a sample of German cooperative banks, and Fried *et al*. (1993) calculated technical efficiencies of 91 percent in US credit unions.

The distribution of technical, allocative and cost efficiency across credit unions using a number of nonparametric tests is also examined. It should be emphasised that the sample of 200 councils used in this analysis comprises the largest (by total assets) 72 percent of all Australian credit unions, and therefore excludes many smaller institutions. Using the Kruskal-Wallis (one way analysis of variance) test, an additional effort was made to determine whether the technical, allocative and cost efficiencies differed statistically across credit unions. All credit unions were divided into quartiles defined on the basis of three variables. The variables by which the credit unions were categorised were net profit after-tax, loan portfolio size, and the book value of total assets. For example, the first group of credit unions grouped on the basis of the book value of total assets consisted of the largest twenty-five percent of credit unions by asset size, the second group were the next largest twenty-five percent, and so on.

This exercise was repeated for all three grouping variables. The test for technical efficiency differences using the Kruskal-Wallis test statistic [KW = 12.333, 15.905 and 25.022 ~ $\chi^2(3)$ respectively] rejects the null hypothesis of equal means across all three variables at the .01 level. Put differently, when credit unions are divided into quartiles using the level of net profit after-tax, the size of the loan portfolio and total asset size, there are statistically significant differences in technical efficiency. Similar results are obtained for Kruskal-Wallis tests with the null hypothesises of equal means for allocative efficiency at the .10 level (grouped by total assets) [KW = 6.813 ~ $\chi^2(3)$] and cost efficiency grouped by net profit after-tax and total assets at the .10 and .01 level respectively [KW = 6.492 and 11.685 ~ $\chi^2(3)$]. This would suggest there are statistically significant differences in the efficiency of credit unions when ranked on the basis of size (by both the size of the loan portfolio and the book value of total assets) and profitability.

In order to further investigate this possibility, these same groups of credit unions are compared on the basis of Mann-Whitney and Kolmogorov-Smirnov nonparametric test statistics. The null hypothesis in the first instance is that the indices are equivalent in location, while in the second the null hypothesis is that the groups are equivalent in the shape and location of the efficiency distribution. On this basis, it was found that the upper quartile of credit unions based on net profit after-tax have a significantly different distribution of technical, allocative and cost efficiency compared to the lowest, next to lowest and next to highest quartiles.

Identical tests of credit unions grouped by the size of the loan portfolio and total assets suggest that differences in the distribution of efficiency are more pronounced between the upper 25 percent and the lowest 50 percent of credit unions, than between the highest and the next to highest quartiles. In addition, most of these differences are on the basis of technical efficiency, rather than either allocative or cost efficiency. The main finding is that most of the differences in overall cost efficiency across groups of credit unions arise from differences in the distribution of technical efficiency rather than allocative efficiency.

Table 2
Credit union efficiency indices

	Technical efficiency		Allocative efficiency		Cost efficiency	
	All credit unions	Inefficient credit unions	All credit unions	Inefficient credit unions	All credit unions	Inefficient credit unions
With different input prices						
Number	200	133	200	171	200	171
Mean	0.9492	0.9236	0.7286	0.6825	0.6966	0.6451
Standard deviation	0.0532	0.0480	0.1662	0.1328	0.1839	0.1456
First quartile	0.9090	0.8940	0.5935	0.5775	0.5565	0.5380
Second quartile	0.9600	0.9310	0.6890	0.6650	0.6535	0.6200
Third quartile	1.0000	0.9600	0.8570	0.7755	0.8435	0.7445
Fourth quartile	1.0000	0.9980	1.0000	0.9870	1.0000	0.9870
With identical input prices						
Number	200	133	200	182	200	182
Mean	0.9492	0.9236	0.6643	0.6311	0.6354	0.5994
Standard deviation	0.0532	0.0480	0.1781	0.1502	0.1917	0.1608
First quartile	0.9090	0.8940	0.5280	0.5245	0.4925	0.4848
Second quartile	0.9600	0.9310	0.6325	0.6155	0.5905	0.5765
Third quartile	1.0000	0.9600	0.7658	0.7323	0.7598	0.7183
Fourth quartile	1.0000	0.9980	1.0000	0.9800	1.0000	0.9800

The second set of descriptive statistics detailed in Table 2 are those where the sample of credit unions are assumed to face identical input prices. As the change in specification of the labour, physical capital and loanable funds input prices has no influence on the specification of inputs and outputs, the descriptive statistics for technical efficiency are unchanged from those discussed above. However, there are some differences between the allocative efficiency indices assuming identical input prices and those where input prices are allowed to vary, and accordingly between the measures of overall cost efficiency in each case. For example, the mean level of allocative efficiency assuming identical prices is 0.6643 and 182 credit unions are calculated to be inefficient, whereas the mean level of allocative efficiency assuming different input prices was 72.86 percent and 171 credit unions were inefficient. Similarly, the mean level of cost efficiency is 63.54 percent assuming identical input prices, and 69.66 percent when input prices are allowed to vary. The suggestion is that the mean level of allocative efficiency (and hence, cost efficiency) is generally lower when identical input prices are imposed. However, because of the differences in prices the cost-minimising input quantities for the average credit union differ from those found earlier. Moving onto the efficient frontier when identical input prices are assumed in this instance would entail a reduction of labour inputs by 5.89 full-time equivalent staff (a cost saving of $224,900) while physical capital inputs could achieve a cost saving of $67,180.

In order to further investigate how these differences in assumptions may influence efficiency indices, a number of nonparametric tests are calculated. First, the Spearman's (rank) correlations between both sets of indices (with and without the assumption of identical prices) are calculated. The correlation coefficient for allocative efficiency is 0.847 and that for cost efficiency is 0.873. Both correlation coefficients are significant at the .01 level, thereby rejecting the null hypothesis of no positive rank correlation. A Wilcoxon signed-ranks test is then calculated for both sets of allocative and cost efficiency indices. Test statistics of -8.731 for allocative efficiency and –8.708 (both significant at the .01 level) confirm that median level of efficiency is lower when identical input prices are assumed. Overall, the results indicate that while there are high positive rank correlations between allocative and cost efficiency indices under the competing assumptions of identical and different input prices, the median level of efficiency is generally lower (at least in the current sample) when identical input prices are used.

The second stage of the estimation procedure involves regressing the calculated efficiency indexes (technical, allocative and cost) on a vector of explanatory variables. Results for the tobit regressions are summarised in Table 3. The dependent variables for the first three regressions in Table 3 are the DEA measures of technical, allocative and cost efficiency indices assuming different input prices. The second set of regressions (allocative and cost efficiency only) is where identical input prices are imposed in the DEA model. The first three columns are the normalised coefficients, standard errors and elasticities (at the means) of the regression of technical efficiency scores on the vector of financial and institutional characteristics presumed to account for efficiency differences. The tobit regression shows that technical efficiency varies significantly with a large number of included explanatory variables. A test of the null hypothesis that all slope coefficients are zero is rejected at the 0.01 percent level using the likelihood ratio procedure.

Table 3
Tobit regression results

	Technical efficiency			Allocative efficiency			Cost efficiency		
	Normalised coefficient	Standard error	Elasticity	Normalised coefficient	Standard error	Elasticity	Normalised coefficient	Standard error	Elasticity
With different input prices									
CONS.	-56.7620	58.5880		-3.1872	17.9220		6.2051	17.9400	
CAP/TA	-71.6750	73.9200	-0.2851	-12.2320	24.7680	-0.2182	4.8696	24.7760	0.0996
TA/TL	73.8820	59.3060	3.2561	10.1610	18.3490	2.0076	-0.5951	18.3570	-0.1349
NI/TR	***6.0505	1.6707	0.0191	***10.1180	1.6643	0.1435	***9.9554	1.6614	0.1620
NPAT/TA	***45.2600	17.2240	0.0118	**31.6270	15.3160	0.0371	**34.2920	15.3420	0.0461
INF/TE	4.6969	3.3793	0.0089	***15.1570	3.3362	0.1287	***13.8320	3.3201	0.1348
MKT/TE	***24.4090	7.5068	0.0201	***31.7080	6.9032	0.1170	***32.6550	6.9170	0.1382
RES/LOAN	0.4723	0.4941	0.0090	-0.0066	0.4537	-0.0006	0.1028	0.4532	0.0101
COM/LOAN	***6.2754	2.0693	0.0086	***8.9929	1.9611	0.0555	***9.2221	1.9620	0.0653
BAD/LOAN	26.5330	27.2850	0.0027	-5.1755	25.2810	-0.0024	-0.4558	25.2660	-0.0002
MEM	***2.16E-05	6.10E-06	0.0144	***1.35E-05	5.15E-06	0.0401	***1.57E-05	5.18E-06	0.0538
BRA	-0.0117	0.0176	-0.0021	0.0121	0.0157	0.0098	0.0099	0.0157	0.0091
With identical input prices									
CONS.				14.6970	17.6710		20.7800	17.6850	
CAP/TA				14.1780	24.4480	0.3227	25.4380	24.4670	0.6354
TA/TL				-9.5387	18.0820	-2.4052	-16.4400	18.0930	-4.5495
NI/TR				***7.7412	1.6236	0.1401	***7.9720	1.6265	0.1584
NPAT/TA				*26.3030	15.0640	0.0394	**30.7150	15.0880	0.0504
INF/TE				***9.1991	3.2574	0.0997	***8.9590	3.2556	0.1066
MKT/TE				***27.8400	6.7848	0.1311	***29.3510	6.8017	0.1516
RES/LOAN				-0.0808	0.4475	-0.0088	0.0128	0.4473	0.0015
COM/LOAN				***6.3867	1.8186	0.0503	***6.8510	1.8259	0.0592
BAD/LOAN				-13.2670	25.0860	-0.0079	-8.1304	25.0780	-0.0053
MEM				***1.77E-05	5.09E-06	0.0671	***1.95E-05	5.11E-06	0.0812
BRA				*-0.0290	0.0152	-0.0299	*-0.0289	0.0152	-0.0327

Notes: Asterisks indicate the level of significance at the * – .10, ** – .05 and *** – .01 level; elasticities calculated at the means; log-likelihoods are 157.241, 71.993, 55.971, 62.406 and 53.821 respectively

Of the variables selected to proxy operational characteristics, the proportion of non-interest revenue (*NI/TR*) net profit after-tax (*NPAT/TA*), marketing and promotion expense (*MKT/TE*), and commercial loans orientation (*COM/LOAN*) are significant and conform to the hypothesised sign. The sign on the number of members (*MEM*) is positive and significant at the .01 level, suggesting that credit unions with larger memberships tend to be more technically efficient. A Wald Chi-square statistic [W = 74.492 $\sim \chi^2(4)$] confirms the joint significance of *CAP*/*TA*, *TA*/*TL*, *NI*/*TR* and *NPAT*/*TA* on technical efficiency at the one percent level. An identical test for the characteristics of the loan portfolio (that is, *RES*/*LOAN*, *COM*/*LOAN* and *BAD*/*LOAN*) also rejects the null hypothesis of joint insignificance, though at the .05 level [W = 11.008 $\sim \chi^2(3)$]. These results provide mixed results when compared to Fried's *et al*. (1993, p. 262) conclusions concerning U.S. credit unions: "efficiency is generally higher for credit unions with a large number of members with large assets, with a high delinquency ratio, a high ratio of investments to loans, a low ratio of real estate loans to total loans, and no branches".

An examination of the elasticities of the coefficients suggests that marketing expenditure (*MKT*/*TE*) and the number of members (*MEM*) are relatively more significant at the margin in determining technical efficiency. In terms of organisational structure, the number of branches (*BRA*) does not appear to significantly influence credit union technical efficiency. These results contrast to those found by Fried *et al.* (1993) in a study of US credit unions, and Drake and Weyman-Jones (1992) of UK building societies, where excessive branching behaviour implied a lower level of technical efficiency. Overall, 71.4 percent of the credit unions can be predicted as being technically inefficient (that is, with efficiency scores less than one) on the basis of the set of explanatory variables.

Very similar results are obtained for the regression where allocative efficiency is regressed upon the set of financial institution characteristics. Tests of the null hypothesis that all the slope coefficients are jointly zero is rejected at the .01 level using a Wald chi-square statistic. The main difference between the results from the regression using technical efficiency is that the coefficient for the share of expenditures made on information technology (*INF/TE*) is positive and significant at the .01 level. This would suggest that relatively larger expenditures on information technology are associated with relatively higher levels of allocative efficiency. Allocative efficiency in the utilisation of resources given their respective factor prices is also higher for credit unions with a high level of non-interest income (*NI*/*TR*) and commercial loans (*COM*/*LOAN*). The marginal effect of these variables on allocative efficiency is highest for non-interest income, followed by information technology, and finally marketing expenses. The predictive power of the regression including allocative efficiency is also higher with 97 percent of credit unions able to be predicted as inefficient on the basis of the set of explanatory variables.

Finally, the estimated coefficients of the tobit regression where cost (or productive) efficiency is specified as the dependent variable are also detailed in Table 3. The non-interest income (NI/TR) variable yields a positive coefficient, consistent with the interpretation that the adoption of a userpay basis to accounts improves overall cost efficiency, and the level of information technology (*INF*/*TE*) and marketing expenditures (*MKT*/*TE*) are also associated with efficiency gains. A test of the null hypothesis of the joint insignificance of the explanatory variables is rejected at the .01 level, and we may conclude that the same explanatory variables exert a significant influence on the level of cost efficiency.

The final two regressions in Table 3 also specify DEA measures of allocative and cost efficiency as the dependent variable. The difference in these regressions is that the underlying DEA model assumes that credit unions face identical input prices. However, despite this change in the dependent variable, the results are generally consistent with the previous regressions where different input prices were assumed. Levels of significance do vary, though not to the extent of changing the list of significant and insignificant coefficients, as does the level of explanatory power in the regressions. This would suggest, at least in this case, that the competing assumptions of credit unions purchasing inputs in competitive markets (and therefore facing identical prices) and credit unions paying different prices (as derived from financial statement information) has no significant influence on measures of allocative (and hence, cost) efficiency.

6. Summary and conclusions

A number of points emerge from the present study. The first part of the paper used a nonparametric methodology to measure the cost efficiency of Australian credit unions. The cost frontier measures indicate that in 1997 a typical Australian credit union’s costs were thirty percent above what could be considered necessary based on observable best-practice. The main source of this cost inefficiency would appear to be allocative inefficiency, rather than technical inefficiency; that is, the inability of the firm to use inputs in optimal proportions, given the respective prices, rather than the inability of the firm to minimise inputs for a given level of output.

In addition, the efficiency measures are generally invariant to two alternative specifications of input prices. In the first specification, input prices are calculated using credit union-specific financial statement information and therefore differ across the sample. In the second specification, input prices are drawn from an external source of data and assumed to be identical for the entire sample. These results counter a criticism that studies of this type may provide biased measures of efficiency since they frequently ignore the competitive realities of input markets in labour, physical capital and loanable funds. The second part of this paper relates these inefficiency measures to several correlates. All other things being equal, a profitable credit union with a high proportion of revenues derived from non-interest income, relatively high expenditures on information technology and marketing, a small branch network, and a large number of members will be more cost efficient.

There are at least three ways in which this research may be extended. First, the approach used in this study could be expanded to include additional influences on credit union efficiency. These may include variables related to regulatory and administrative frameworks, the degree of competition amongst credit unions and other deposit-taking institutions, and additional detail relating to the quantity and quality of services offered. Second, in order to more fully examine the changing patterns of efficiency improvements, technological change and productivity gain since deregulation it may be useful to obtain estimators of credit union efficiency using pooled time-series, cross-sectional data. This would not only provide consistent estimators of efficiency over time, but would also indicate improvements in efficiency due to deregulation and so on. One approach could be the Malmquist index approach used by Berg, Førsund and Jansen (1992) to analyse the effects of deregulation in Norwegian financial services, and Fukuyama (1995) in Japanese commercial banking. Finally, similar techniques to the present study could be extended to examine the question of merger in Australian credit unions. Given that mergers largely account for the twenty-three percent decline in the number of credit unions over the period 1992 to 1997, a natural question arises as to the role of cost inefficiency in promoting merger activity and the cost efficiency consequences of these same mergers.

References

Ali, A.I. and L.M. Seiford, 1993, The mathematical programming approach to efficiency analysis, in: H.O. Fried, C.A.K. Lovell and S.S. Schmidt, eds., The measurement of productive efficiency: Techniques and applications (Oxford University Press, New York) 120–159.

Aly, H.Y., R. Grabowski, C. Pasurka and N. Rangan, 1990, Technical, scale and allocative efficiencies in U.S. banking: An empirical investigation, The Review of Economics and Statistics, 211–218.

Banker, R.D., A. Charnes and W.W. Cooper, 1984, Some models for estimating technical and scale inefficiencies in data envelopment analysis, Management Science, 30, 1078–1092.

Berg, S.A., F.R. Førsund and E.S. Jansen, 1992, Malmquist indices of productivity growth during the deregulation of Norwegian banking, 1980–89, Scandinavian Journal of Economics, 94, 211–228.

Brown, R., R. Brown and I. O'Connor, 1999, Efficiency, bond of association and exit patterns in credit unions: Australian evidence, Annals of Public and Cooperative Economics (forthcoming).

Cebenoyan, A.S., E.S. Cooperman, C.A. Register and S.C. Hudgins, 1993, The relative efficiency of stock versus mutual S&Ls: A stochastic frontier approach, Journal of Financial Services Research, 7, 154–170.

Charnes, A., W.W. Cooper and E. Rhodes, 1978, Measuring the efficiency of decision making units, European Journal of Operational Research, 2, 429–444.

Charnes, A., W.W. Cooper, A.Y. Lewin and L.M. Seiford, 1993, Data envelopment analysis: Theory, methodology and applications (Kluwer, Boston).

Colwell, R.J. and E.P. Davis, 1992, Output and productivity in banking, Scandinavian Journal of Economics, 94, 111–129.

Drake, L. and T.G. Weyman-Jones, 1992, Technical and scale efficiency in UK building societies, Applied Financial Economics, 2, 1–9.

Drake, L. and T.G. Weyman-Jones, 1996, Productive and allocative inefficiencies in UK building societies: A comparison of non-parametric and stochastic frontier techniques, The Manchester School, 64, 22–37.

Elyasiani, E., S. Mehdian and R. Rezvanian, 1994, An empirical test of association between production and financial performance: The case of the commercial banking industry, Applied Financial Economics, 4, 55–59.

Esho, N. and I.G. Sharpe, 1994, Scale and scope economies of Australian permanent building societies in a dynamic framework, Asia Pacific Journal of Management, 11, 255–273.

Farrell, M.J., 1957, The measurement of productive efficiency, Journal of the Royal Statistical Society, 120, 253–289.

Favero, C.A. and L. Papi, 1995, Technical efficiency and scale efficiency in the Italian banking sector: A non-parametric approach, Applied Economics, 27, 385–395.

Financial System Inquiry, 1997, Financial system inquiry: Final report (AGPS, Canberra).

Førsund, F.R., C.A.K. Lovell and P. Schmidt, 1980, A survey of frontier production functions and of their relationship to efficiency measurement, Journal of Econometrics, 13, 5–25.

Fried, H.O., C.A.K. Lovell and J.A. Turner, 1996, An analysis of the performance of university-affiliated credit unions, Computers and Operations Research, 23, 375–384.

Fried, H.O., C.A.K. Lovell, and P. Vanden Eekaut, 1993, Evaluating the performance of US credit unions, Journal of Banking and Finance, 17, 251–265.

Fukuyama, H., 1995, Measuring efficiency and productivity growth in Japanese banking: A nonparametric frontier approach, Applied Financial Economics, 5, 95–107.

Fukuyama, H., 1996, Returns to scale and efficiency of credit associations in Japan: A nonparametric frontier approach, Japan and the World Economy, 8, 259–277.

Grabowski, R., N. Rangan and R. Rezvanian, 1993, Organisational forms in banking: An empirical investigation of cost efficiency, Journal of Banking and Finance, 17, 531–538.

Greene, W.H., 1993, The econometric approach to efficiency analysis, in: H.O. Fried, C.A.K. Lovell and S.S. Schmidt, eds., The measurement of productive efficiency: Techniques and applications (Oxford University Press, New York) 68–119.

Hardwick, P., 1990, Multi-product cost attributes: A study of U.K. building societies, Oxford Economic Papers, 42, 446–461.

Hardwick, P., 1997, Measuring cost inefficiency in the UK life insurance industry, Applied Financial Economics, 7, 37–44

Lang, G. and P. Welzel, 1996, Efficiency and technical progress in banking: Empirical results for a panel of German cooperative banks, Journal of Banking and Finance, 20, 1003–1023.

Lovell, C.A. (1993) Production frontiers and productive efficiency, in: H.O. Fried, C.A.K. Lovell and S.S. Schmidt, eds., The measurement of productive efficiency: Techniques and applications (Oxford University Press, New York) 3–67.

McKillop, D.G. and C.J. Glass, 1994, A cost model of building societies as producers of mortgages and other financial products, Journal of Business Finance and Accounting, 21, 1031–1046.

Mester, L.J., 1987, A multiproduct cost study of savings and loans, The Journal of Finance, 42, 423–445.

Mester, L.J., 1993, Efficiency in the savings and loan industry, Journal of Banking and Finance, 17, 267–286.

Piesse, J., and R. Townsend, 1995, The measurement of productive efficiency in UK building societies, Applied Financial Economics, 5, 397–407.

Seiford, L.M. and R.M. Thrall, 1990, Recent developments in DEA: The mathematical programming approach to frontier analysis, Journal of Econometrics, 46, 7–38.

Thompson, S., 1997, Take-over activity among financial mutuals: An analysis of target characteristics, Journal of Banking and Finance, 21, 37–53.

Worthington, A.C., 1998a, The determinants of non-bank financial institution efficiency: A stochastic cost frontier approach, Applied Financial Economics, 8, 279–289.

Worthington, A.C., 1998b, Efficiency in Australian building societies: An econometric cost function approach using panel data, Applied Financial Economics, 8, 459–467.

Worthington, A.C., 1998c, Testing the association between production and financial performance: Evidence from a not-for-profit, cooperative setting, Annals of Public and Cooperative Economics 69, 67–83.

Worthington, A.C., 1999, Measuring technical efficiency in Australian credit unions, The Manchester School, 67, 231–248.