

FRONTIER EFFICIENCY MEASUREMENT IN DEPOSIT-TAKING FINANCIAL MUTUALS: A REVIEW OF TECHNIQUES, APPLICATIONS, AND FUTURE RESEARCH DIRECTIONS

by

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ABSTRACT: *Despite the global importance of mutuals in financial services, and the universal need to measure and improve organizational efficiency in all deposit-taking institutions, it is only relatively recently that the most advanced econometric and mathematical programming frontier techniques have been applied. This paper provides a synoptic survey of the comparatively few empirical analyses of frontier efficiency measurement in deposit-taking financial mutuals, comprising savings and loans, building societies and credit unions in Australia, the United Kingdom, and the United States. Both estimation and measurement techniques and the determinants of efficiency are examined. Particular focus is placed on how the results of these studies may help inform regulatory policy and managerial behaviour.*

1 Introduction

During the last two decades, sweeping global changes have affected deposit-taking institutions worldwide, including financial market deregulation and the intensification of competition, the widespread adoption of information technology, and the ongoing process of innovation in financial products and services. Consequently, much empirical attention has naturally focused on the efficiency and productivity of financial institutions as a way of better understanding their ability to survive in ever-more competitive environments and deliver valuable services to their stakeholders.

In the main, the substantive part of this research has focused on medium-to-large deposit-taking institutions structured as public companies (corporations). This effectively ignores the feature that in many economies at least some financial services (especially housing finance and retail deposits) are provided by mutuals, which along with

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proprietorships, partnerships and nonprofits, provide alternative ways of organizing productive activity. Importantly, the need to understand issues of efficiency and productivity is no less pronounced in financial mutuals with the important role this information can provide in assessing the impact of regulation and yielding insights into the process of organisational and structural change characteristic of recent decades.

Economists have developed three main measures of efficiency to meet the needs of researchers, managers, and policy makers in financial mutuals in this regard. Firstly, *technical efficiency* refers to the use of productive resources in the most technologically efficient manner. Put differently, technical efficiency implies the maximum possible output from a given set of inputs. Within the context of financial services, technical efficiency may then refer to the physical relationship between the resources used (say, capital, labor and equipment) and some service outcome, including profits, revenue, loans, and financial investments.

Secondly, *allocative efficiency* reflects the ability of an organisation to use these inputs in optimal proportions, given their respective prices and the available production technology. In other words, allocative efficiency is concerned with choosing between the different technically efficient combinations of inputs used to produce the maximum possible outputs. Consider, for example, a policy of changing from branch services to internet banking. Internet banking may need fewer labour inputs but does require the use of another resource – electronic technology. Since different combinations of inputs are being used, and notwithstanding differences in the quantity and quality of outputs, the choice of service delivery is then based on the relative costs of these different inputs,.

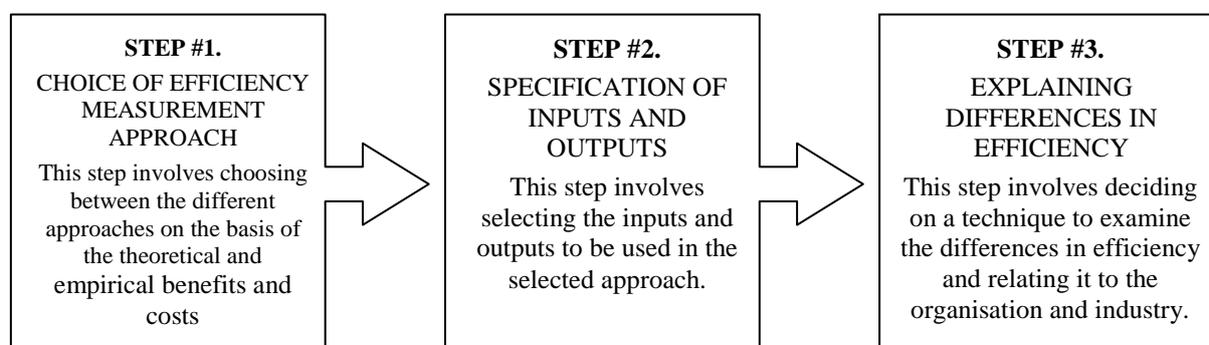
Finally, when taken together allocative efficiency and technical efficiency determine the degree of *productive efficiency* (also known as total economic efficiency). Thus, if a financial mutual uses its resources completely allocatively and technically efficiently, then it can be said to have achieved total economic efficiency. Alternatively, to the extent that either allocative or technical inefficiency is present, then the organisation will be operating at less than total economic efficiency.

The empirical measurement of economic efficiency centres on determining the extent of either allocative efficiency or technical efficiency or both in a given organisation or industry. Most recently, economists have employed frontier efficiency measurement techniques to measure the productive performance of financial services. Frontier efficiency measurement techniques use a production possibility frontier to map a locus of potentially

technically efficient output combinations an organisation is capable of producing at a point in time. To the extent an organisation fails to achieve an output combination on its production possibility frontier, and falls beneath this frontier, it can be said to be technically inefficient. Similarly, to the extent to which it uses some combination of inputs to place it on its production frontier, but which do not coincide with the relative prices of these inputs, it can be said to be allocatively inefficient. Equivalently, cost functions transform the quantitative physical information in production frontiers into monetary values such that cost efficiency entails producing technically efficient combinations of outputs and inputs at least cost. A useful introduction to frontier efficiency measurement techniques may be found in Coelli *et al.* (2005).

Accordingly, if we can determine production frontiers that represent total economic efficiency using the best currently known production techniques, then we can use this idealized yardstick to evaluate the economic performance of actual organisations and industries. By comparing the actual behavior of organisations against the idealized benchmark of economic efficiency we can determine the degree of efficiency exhibited by some real-world agency. This survey concentrates on selected efficiency studies of deposit-taking financial mutuals using frontier efficiency measurement techniques published since 1990. *EconLit*, the Journal of Economic Literature electronic database, was searched to identify articles that were representative of the contexts and techniques associated with frontier efficiency measurement in financial services provided by mutuals. References were also used from these studies to identify other relevant articles.

Figure 1. Empirical Steps in Measuring and Analysing Deposit-taking
Financial Mutual Efficiency



Of the twenty-seven studies presented in Table 1, 44 percent are based on deposit-taking financial mutuals in Australia, 30 percent in the United States (US) and 26 percent in

the United Kingdom (UK); 56 percent are in credit unions, 30 percent in building societies, and the remainder are savings and loans (S&L); while 67 percent employ nonparametric techniques. Without exception, these are inter-firm studies relying on cross-sectional or panel (pooled time-series, cross-sectional) data. However, despite their dissimilar contexts and techniques, these studies share a common step-by-step empirical procedure that determines first the choice of frontier efficiency measurement approach, second the specification of inputs and outputs to be used in the selected approach, and finally, the method used to explain efficiency differences and the factors thought to be associated with these differences. This common process, depicted in Figure 1, forms a convenient framework for the survey.

2. New contribution and survey limitations

At least two studies, Berger *et al.* (1993) and Berger and Humphrey (1997), have surveyed efficiency measurement techniques as they apply to financial services. However, both Berger *et al.* (1993) and Berger and Humphrey (1997) include both parametric and non-parametric methods and applications and focus on the efficiency measures obtained, not the steps used to obtain these measures. Moreover, attention is placed very broadly on an excessively wide range of financial institutions—including banks, S&Ls, credit unions, life and general (non-life) insurance—and comparatively little direct attention given to mutuals.

The current article is the first attempt to examine each of the main frontier efficiency measurement approaches as it applies to the services provided by financial mutuals. Moreover, apart from discussing the strengths and weaknesses of the different approaches, this article also examines the steps faced by researchers as they move from a selected approach, to the specification of inputs and outputs, to the means of explaining efficiency differences. This highlights the empirical problems that have received attention in the literature, and the efforts by researchers to overcome these problems. It therefore provides guidance to those conducting empirical research in efficiency and productivity and also an aid for policymakers, managers and practitioners interpreting the outcomes of frontier efficiency studies.

The present survey does, however, suffer from three major limitations. First, outside deposit-taking institutions mutuals are also found in life and general insurance and these have likewise been the subject of frontier efficiency assessments. However, the conceptualisation of productive behaviour in insurance differs dramatically from deposit-taking intuitions and their inclusion would make the survey rather more complex and lengthy. For the interested

reader, recent studies measuring efficiency in the insurance industry using frontier approaches include Fukuyama and Weber (2001), Worthington and Hurley (2001), Greene and Segal (2004), Fenn *et al.* (2007) and Cummins and Xie (2008). Second, no attempt is made to compare frontier efficiency techniques with non-frontier approaches, such as simple production and cost functions and index numbers that generally place emphasise on comparisons with average performance. For the most part, these older techniques are confined to the period before 1990 and are now increasingly superseded by the more recent frontier approaches. Finally, this survey is necessarily general in that there are many differences in the objectives and behaviour of financial mutuals across countries. In varying degrees, this relates to their essential mutuality, but also to regulation and competitive differences in their respective markets. Llewellyn and Holmes (1991), Kay (1991) and Baker and Thompson (2000) provide useful insights into these aspect of financial mutuals.

3. Choice of frontier efficiency measurement approach

All efficiency measures assume the production frontier of the fully efficient organisation is known. As this is usually not the case, the production frontier must be estimated using sample data. Two approaches are possible. These are: (i) a nonparametric piecewise-linear convex frontier constructed such that no observed point should lie outside it (known as the *mathematical programming* approach to the construction of frontiers); or (ii) a parametric function fitted to the data, again such that no observed point should lie outside 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 recognizes 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 data measurement errors). 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 [with pioneering work by Aigner *et al.* (1977), Battese and Corra (1977) and Meeusen and van den Broeck (1977)] and the earlier (though unapplied to financial mutuals) ‘deterministic frontier approach’ (DFA) which assumes that all deviations from the estimated frontier represent inefficiency. A number of studies have used these approaches to estimate the efficiency of financial mutuals. These include Cebenoyan *et al.* (1993), McKillop and Glass (1994), Worthington (1998b), Esho (2001) and Glass and McKillop (2006).

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 [with seminal work by Charnes *et al.* (1978) and Banker *et al.* (1984)]. A less-constrained alternative to DEA sometimes employed in the analysis of efficiency 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. Draek and Weyman-Jones (1992), Fried *et al.* (1993), Piesse and Townsend (1995), Worthington (1998c), Garden and Ralston (1999), Brown *et al.* (1999), Worthington (2000) and McKillop *et al.* (2002) have applied these approaches to mutuals.

Applications that use Malmquist productivity indexes (MI) (as derived from DEA-like linear programs) to measure changes in efficiency over time are also found in the literature. In this approach, a production frontier representing the efficient level of output that can be produced from a given level of input is constructed, and the assumption made that this frontier can shift over time. Different frontiers are thus obtained for different time periods and these correspond to differences in the available technology. When inefficiency is assumed to exist, the relative movement of any given financial mutual over time will therefore depend on both its position relative to the current frontier (technical efficiency) and the position of the frontier (technical change). If inefficiency is ignored, then productivity growth over time will be unable to distinguish between improvements that derive from an institution ‘catching up’ to its own frontier, or those that result from the frontier itself shifting up over time for all

institutions included (or the industry). Studies of financial mutuals using this technique include Worthington (1999) and Glass and McKillop (2000).

The discussion thus far addresses three separate, though conceptually similar, theoretical approaches to the assessment of efficiency. These are the econometric frontier approach (including DFA and SFA), and the mathematical programming approach (including DEA, FDH and MI). Details of the approach taken by selected studies are detailed in Table 1. Whilst the selection of any particular approach is likely to be subject to both theoretical and empirical considerations, it may be useful to summarize the strengths and weaknesses of each. The emphasis here is not on selecting a superior theoretical approach, as it should be emphasized that the mathematical programming and econometric approaches address different questions, serve different purposes and have different informational requirements. A subtle terminological distinction made at this point is the mathematical programming approach involves ‘measurement’ or ‘calculation’, while the econometric approach comprises ‘estimation’.

The first approach is the construct of the deterministic statistical frontier. While this has not been applied to financial mutuals during the survey period, it is in evidence in the broader bank efficiency literature and serves as a useful benchmark for the more complex techniques. Using statistical techniques a deterministic frontier is derived, such that all deviations from this frontier are assumed to be the result of inefficiency. That is, no allowance is made for noise or measurement error. In the primal (production) form the ability to incorporate multiple outputs is difficult, whilst using the dual cost frontier such extensions are possible. However, if the cost frontier approach is employed, it is not possible to decompose inefficiency into allocative or technical components, and therefore all deviations are attributed to overall cost inefficiency.

In terms of computational procedure, the deterministic frontier approach necessitates a large sample size for statistical reasons. In addition, it is generally regarded as a disadvantage that the distribution of the technical inefficiency has to be specified, i.e. half-normal, normal, exponential, log-normal, etc. Ideally this would be based on knowledge of the economic forces that generate such inefficiency, though in practice this may not be feasible. If there are no strong a priori arguments for a particular distribution, a choice is normally made on the basis of analytical tractability. Similarly, the choice of a particular technology is imposed on the sample, and once again this may be a matter of empirical convenience (i.e. Cobb-Douglas, translog, etc). Moreover, the choice of a particular production function may place severe

restrictions on the types of analysis possible, and therefore the content of managerial and policy prescriptions, using this particular approach.

The second approach discussed, namely the stochastic frontier, removes some of the limitations of the deterministic frontier [see, for example, Cebenoyan *et al.* (1993), Mester (1993), Drake and Weyman-Jones (1996), Esho and Sharpe (1996), Worthington (1998b) and Esho (2001)]. Its biggest advantage lies in that it introduces a disturbance term representing noise, measurement error, and exogenous shocks beyond the control of the production unit. This permits the decomposition of deviations from the efficient frontier into two components, inefficiency and noise. However, in common with the deterministic approach, an assumption regarding the distribution (usually normal) of this noise must be made along with those required for the inefficiency term and the production technology. The main effect here is that under both approaches, especially the stochastic frontier, considerable structure is imposed upon the data from stringent parametric form and distributional assumptions. In addition, stochastic frontier estimation usually uses information on prices and costs, in addition to quantities, which may introduce additional measurement errors.

The programming approach differs from both statistical frontier approaches in that is fundamentally nonparametric, and from the stochastic frontier approach in that is nonstochastic [see, for example, Garbacio *et al.* (1994), Fried *et al.* (1999), Worthington (2000), Ralston *et al.* (2001), and McKillop *et al.* (2002)]. Thus, no (direct) 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, and as a nonstochastic technique there is no possible way in which probability statements of the shape and placement of this frontier can be made. In view of erroneous or misleading data, some critics of DEA have questioned the validity and stability of these measures of efficiency.

However, there a number of benefits implicit in the mathematical programming approach that makes it attractive on a theoretical level. Given its nonparametric basis, substantial freedom is given on the specification of inputs and outputs, the formulation of the production correspondence relating inputs to outputs, and so on. Thus, in cases where the usual axioms of production activity breakdown (i.e. profit maximization) then the programming approach may offer useful insights into the efficiency of these types of organizations and industries [some assumptions regarding the production technology are still

made regardless, such as that relating to convexity]. Similarly, it is entirely possible that the types of data necessary for the statistical approaches are neither available nor desirable, and therefore the imposition of as few as possible restrictions on the data is likely to be most attractive. Simulation studies have also indicated that the piecewise linear production frontier formulated by DEA is generally more flexible in approximating the true production frontier than even the most flexible parametric functional form.

These theoretical and empirical considerations explain part of the dominance of DEA in mutual efficiency measurement studies, comprising some 67 percent of the studies included in this survey. The obvious desirability of quantifying multiple inputs and outputs in different units of measurement is one consideration. For example, many mutual studies define inputs as dollar values of financial and physical capital, operating expenses, at-call and term deposits along with the number of employees and branches. Alternatively, outputs are often defined as the dollar values of loans, profit after-tax and interest income along with the number of different deposit and loan services and the number of deposit accounts. Finally, and once again in a mutual context where the usual axioms of production activity are (contentiously) argued by some to breakdown [i.e. the replacement of strict profit maximisation with a not-for-profit or a maximisation of member services motivation], there is the ability to define inputs and outputs depending on the conceptualization of financial institution performance thought most appropriate.

4. Specification of inputs and outputs

Within the broad scope of mutual financial services, frontier efficiency measurement techniques have been applied to a number of different types of institutions. As shown in Table 1, these include building societies (Field 1990; McKillop and Glass (1984), Esho and Sharpe 1996; Worthington 1998a) credit unions (Fried *et al.* 1993; Worthington 1998b; Fried *et al.* 1999; Esho 2001; McKillop *et al.* 2002) and S&Ls (Cebenoyan *et al.* 1993; Mester 1993; Garbacia *et al.* 1994). Interestingly, unlike the mainstream banking literature which has an overwhelming US focus, the extant financial mutual efficiency studies are dominated by work in the UK and Australia. The reason is not hard to find with building societies confined to Australia and the UK; while credit unions are found in all three contexts, S&Ls in the US are a combination of mutual and stock forms. As discussed, the primary frontier technique employed in assaying the efficiency of mutual financial services has been the DEA approach (Drake and Weyman-Jones 1992; Piesse and Townsend 1995; Garden and Ralston 1999; Worthington 1999; Glass and McKillop 2006).

The measures of efficiency obtained by these studies have varied widely. In Australia, Worthington's (2000) analysis of Australian credit unions found mean cost efficiencies of 70 percent and technical efficiencies of 95 percent, while Brown *et al.* (1999) calculated cost efficiencies of 77 percent in exiting credit unions and 78 percent in acquiring credit unions. In the UK, Field (1990) and Drake and Weman-Jones (1992) calculated respective mean efficiencies of 93 and 98 percent for building societies. More interestingly, Cebenoyan (1993a) and Cebenoyan *et al.* (1993b) used almost identical data on US S&Ls to calculate mean efficiencies of between 77 and 83 percent in the first instance and between 86 and 87 percent in the second. There is also wide variability across institutional settings. For example, respective analyses of Australian credit unions and UK building societies by Worthington (1999a) and Glass and McKillop (2000) both employed the MI approach to efficiency measurement. Over the period 1993-1997 Worthington (1999a) measured an average annual efficiency increase of less than one percent and technological regression of 2 percent, while Glass and McKillop (2000) over the period 1989-1993 calculated an annual efficiency increase of nearly 2 percent and technical change of nearly 50 percent.

This divergence in results has, of course, awakened interest in the consistency of frontier-based measures of efficiency. Unfortunately, only limited comparison has been made between the alternative frontier efficiency measurement techniques, though there is some work that has compared the consistency between productive and financial performance (Worthington 1998b). The only study of the former known is Drake and Weyman-Jones's (1996) comparison of DEA and SFA efficiency measures and estimates for 46 UK building societies. Satisfyingly, a strong correspondence was found between the rankings of both approaches.

Certainly, and in common with all econometric and mathematical techniques, it is important to establish *a priori* the existence of associations between inputs and outputs, the need to minimise redundancies in these variables, and the requirement for the careful specification and measurement of data. Accordingly, three aspects of variable specification require attention. These are: (i) the appropriate specification of the input-output relationship for financial intermediaries; (ii) the applicability of these same assumptions to financial mutuals, such as credit unions, building societies and S&Ls; and (iii) problems encountered in the use of financial statement and other information for this purpose.

At least three conceptualisations have been used in defining the input-output relationship in financial institution behaviour: These are: (i) the production approach (Field *et*

al. 1990; Fried *et al.* 1993; Piesse and Townsend 1995; Fried *et al.* 1999; Ralston *et al.* 2001), (ii) the intermediation approach (Mester 1993; Esho and Sharper 1996; Worthington 1998a; Worthington 1999), and (iii) the asset approach (Draek and Weyman-Jones 1992; Glass and McKillop 2000; McKillop *et al.* 2002) [yet other possibilities found in the broader literature are the user-cost approach, where the net contribution to revenue determines the nature of inputs and outputs, and the value-added approach, where the inputs and outputs are identified by their share of value added]. First, the production approach views deposit-taking institutions as producers of deposit accounts and loans; defining output as the number and type of accounts and their associated transactions. Inputs in this case are calculated as the number of employees (labour), and capital expenditures on fixed assets and other material. The underlying assumption is that mutuals produce services for account holders.

Second, the intermediation approach conceptualises deposit-taking institutions as intermediators, converting and transferring financial assets from surplus units to deficit units. In this case, the institutional inputs are labour and capital costs, and the interest payable and the value of deposits and other borrowed funds, with the outputs denominated in loans and financial investments. Finally, the asset approach conceptualises a deposit-taking institutions primary function as the creation of loans: this closely related to the intermediation approach except that outputs are strictly defined by loan assets.

Whilst there is no simple solution to the problem of output and input specification, a number of points may be made. Firstly, the intermediation approach has tended to dominate empirical research. In part, this has been the result of fundamental limitations found in the production approach – especially the omission of major aspects of bank services, such as interest costs – but perhaps more prosaically due to the difficulties encountered in collating accurate (information sensitive) data. This is unfortunate in the production approach is potentially better for evaluating the efficiency of branches of mutuals. Second, even though the intermediation approach fails to account for inflationary bias (a matter of somewhat less concern for cross-sectional studies) and effectively mixes flow and stock concepts (contrary to conventional production theory), it has proved itself a remarkably resilient tool for the analysis of deposit-taking institutions. Much of this resilience apparently flows from adaptability: categories of deposits, loans, financial investments and financial borrowings may be arbitrarily assigned to either inputs or outputs, or excluded, on the basis of *a priori* reasoning alone.

The appropriateness of an intermediary model originally designed for banks is also the subject of some debate when it comes to measuring efficiency in mutuals. For example, some providers of financial services may have behavioural assumptions that differ markedly from neo-classical profit maximisation. These are generally argued to include mutual service providers, such as building societies and credit unions. Fried *et al.* (1993: 253) argues *inter alia* "...since credit unions are owned and operated by members, the objectives of credit unions can be thought of as maximising services provided to members. This immediately suggests that profit maximisation is not an appropriate objective". However, Fried *et al.* (1993: 253) also recognise that while "it is not appropriate, for example, to treat credit unions like commercial banks [neither is it] appropriate to ignore the services offered by other financial intermediaries...since they compete in many of the same markets". Fried *et al.* (1993) go some way towards resolving this issue by incorporating price and service variety components into the measured output of the firm.

While it is not the purpose of this survey to enter the theoretical debate on the fundamental differences between mutuals and other organizational forms, a few basic points following Jensen (2000) are noted. To start with, the primary distinction among the various organizational forms (corporations, proprietorships, partnerships, mutuals, not-for-profits) is the nature of their residual claims on the organization's net cash flows. The important distinction is that in mutuals these claims are redeemable (by depositors) and this effectively amounts to a partial internal takeover and liquidation that deprives management of control over some assets. Accordingly, mutuals assets must be able to be expanded and contracted at low cost to allow the purchase or redemption of residual claims and this favours investment in assets that are easy to price (usually in a secondary market) have low transaction costs and are more efficiently owned than rented. Moreover, redeemability precludes a secondary market for residual claims and this removes the market for corporate control as management discipline. For these and other reasons, where the efficiency of stock and mutual financial institutions is compared in the same study, the typical hypothesis is that mutuals are less efficient because of the departure from strict profit maximisation.

The final issue relates to the use of financial statement information for analysing efficiency in financial services. It is possible to identify a number of concerns, not least the nature of stocks and flows in financial services, the treatment of off-balance sheet activities, and the role of financial capital. The first point relates to the types of information made available through balance sheet (financial position) and profit and loss (financial

performance) statements. Logically, when comparing the efficiency of one institution with another, comparison should be made between institutions producing the same output quality. But there are likely to be unmeasured differences in quality because much of the available data does not fully capture the heterogeneity in output. Moreover, the amount of service *flow* associated with financial products in all of the financial services efficiency studies is, by necessity, assumed to be proportional to the *stock* of assets and liabilities detailed on the balance sheet. For example, for a given loan output can vary in size, repayment schedule, risk, covenants, etc. Only some effort has been made to incorporate these issues into outputs, including Fried *et al.* (1993), Fried *et al.* (1996), Brown *et al.* (1999)

The second point relates to the substantial off-balance sheet activity found in the financial services industry. To some extent, this has been offset by relatively recent changes in accounting standards, but it remains problematic that failing to recognise this activity may understate many aspects of mutual performance. The final aspect of the use of financial statement information relates to the treatment of financial capital. For most financial institutions, the level of insolvency risk depends on its ability to absorb portfolio losses, and its ability to engage in diversification. Yet paradoxically, an institution that holds a larger portion of financial capital, and is, inferentially, safer, would be penalised under most existing approaches to efficiency measurement.

5. Explaining differences in financial mutual efficiency

Alongside the empirical research into the measurement of inefficiency in mutuals, an equal amount of attention has been directed to the factors which influence or result from the efficiency of financial services. Very often these involve the use of descriptive statistics and parametric and non-parametric tests of efficiency differences between different types or attributes of mutuals. The other equally common approach is the specification of the estimated or calculated efficiencies as independent or dependent variables in ordinary least squares, logistic, Tobit, probit and seemingly unrelated regression models.

In practice, the factors that are likely to influence or result from the efficiency of financial mutuals may be grouped into (i) the benefits and costs of the mutual form, (ii) regulation, organisational and legal structures, (iii) the role of branches and membership; and (iv) merger activity. The variables employed and their definitions are provided in Table 1. In terms of the first area, a number of studies have examined the impact whether mutuals are necessarily less efficient than their stock counterparts, thereby supporting the ongoing process

of demutualisation found in many industry sectors [Davis (2005) provides a useful discussion of the benefits and costs of demutualisation in credit unions]. In a US study, Mester (1993) concluded that, contrary to theory and previous results, stock S&Ls were less efficient than mutual S&Ls. Mester (1993) argued that this perverse finding may result from a firm selection process with less-efficient mutuals converting to a potentially more efficient stock form with yet unrealised efficiency gains. By comparison, Cebenoyan *et al.* (1993) found no statistical difference between the efficiency of mutual and stock S&Ls. Unfortunately, this type of analysis is empirically problematic in that some shared behavioural standard must be first agreed upon, regardless of whether parametric or non-parametric techniques are employed.

A second area of analysis relates to an institution's organisational and regulatory structure and its impact upon efficient outcomes. Within this broad area, there are a number of reasons why attempts have been made to proxy the regulatory and institutional framework within which mutuals operate. On the one hand, studies have been undertaken where the overriding regulatory structure has varied significantly across the sample in question. Efforts are usually made to account for differences and the impact of regulation (McKillop *et al.* 2005; Glass *et al.* 2009), especially in the US where both state and federal charters for mutuals coexist: see, for example, Cebenoyan *et al.* (1993), Fried *et al.* (1993) and Fried *et al.* (1996). Another vein has attempted to take account of the associational bond in credit unions that is argued to restrict behaviour to varying degrees. Studies that have included variables to variously identify geographic, industrial, and religious bonds of association in mutuals include Ceneboyan *et al.* (1998b), Fried *et al.* (1993), Fried *et al.* (1996), Worthington (1998b; 1999b), Fried *et al.* (1999), Esho (2001) and McKillop and Glass (2002). These and other imposed variables, like the number of members, geographic location, and the presence of sponsor subsidies, are often used to explain differences in efficiency that may not necessarily result from managerial discretion. Indeed, Glass *et al.* (2009) argue that organisational and structural variables are a more important influence on credit union performance than any operational factors.

The presence of sponsor subsidies is a particular complication in efficiency studies of credit unions. This is because some credit unions benefit in that a percentage of their inputs may be donated (from a sponsoring organisation or members) and are therefore not fully reflected in their financial statement information (notably labour in the form of volunteers and capital in the form of donated premises). This necessarily means that the calculated efficiency

scores may have an inbuilt bias as the information employed to derive the factor inputs (and their prices) may understate the actual level and costs of these factors. For instance, a credit union not owning or leasing its donated branch premises has apparently lower capital inputs, and therefore appears to be more technically efficient than it really is. Alternatively, if office and equipment expenses are used to calculate the (average) price of capital, the lower price of the subsidised capital inputs may make it appear that the firm is under employing capital relative to its non-capital inputs and is therefore more allocatively inefficient than it should be. The challenge is to correctly incorporate all factor inputs into the efficiency analysis in the first instance, or alternately, to ensure that comparisons are only made between equivalently subsidised organisations.

A third group of explanatory variables relate to the branching behaviour of financial institutions, generating three somewhat conflicting hypotheses (Fried *et al.* 1993). Firstly, under the intermediation approach, branches and agencies are recognised as “...central to the intermediation process for most [non-bank financial institutions], [and] it may also be the case that differences in the intensity of branching may be an important factor” (Drake and Weyman-Jones, 1992: 5). Accordingly, the number of branches is closely related to the level of financial intermediation provided, and a positive effect on efficiency 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. The third hypothesis is that branch services are an output offered jointly with deposit services; a positive impact on efficiency is thus postulated. Of course, the impact of low cost, low productivity agencies and electronic telephone and internet is expected to contrast markedly with a full-service branch network.

The final area that has received a substantial amount of empirical attention is the role of efficiency in the merger process. The interest of policymakers, regulators and other concerned parties in this process is efficiency as a motivator for merger in the first instance, and then the capture of the prospective efficiency benefits used as a justification for merger. For the most part, the results have been mixed. Garden and Ralston (1999) and later Ralston *et al.* (2001), for example, found that credit union mergers did not increase the technical or allocative efficiency of Australian credit unions relative to their unmerged counterparts. Brown *et al.* (1999) likewise concluded that was no role for efficiency in either exiting or acquired Australian credit unions. However, Worthington (2001) loan portfolio diversification, efficiency in the form of management ability, earnings and asset size had a

role to play in credit union mergers, with technical and scale efficiency improving across the industry. In the US, Fried *et al.* (1999) concluded a variety of other factors indicated the success of mergers, and that member service provision generally improved in acquired credit unions.

As elsewhere, a primary motivation for the merger of financial mutuals has been the presence of purported increasing returns to scale (economies of scale) in production (cost) terms. Wheelock and Wilson (2008), for example, found evidence of increasing returns to scale across the range of sizes observed among US credit unions, suggesting that an easing of regulations on credit union membership or their activities would lead to further increases in size. In contrast, McKillop *et al.* (2005) used a stochastic frontier analysis to evaluate the relative performance of UK credit unions for the period 1991 to 2001. While the study suggested considerable scope for efficiency gains, it also found that credit unions suffered from a considerable degree of scale inefficiency with more than 50 percent of the scale inefficient credit unions subject to decreasing returns to scale. This finding was problematic for the UK government in that it wished to promote credit unions through encouraging existing institutions to embrace a much wider membership base.

6. Concluding remarks and directions for future research

A small but slowly increasing amount of work using frontier efficiency techniques has been directed towards deposit-taking mutuals, primarily credit unions, building societies and S&Ls in Australia, the UK and the US. The body of work surveyed in this article has provided at least some useful insights into this globally important group of organisations and how they operate in increasingly competitive environments. However, there are at least several ways in which this research could be extended.

First, no existing study of efficiency in deposit-taking mutuals includes comparable institutions from different sub-sectors (say, small banks with building societies and credit unions) or institutions from different national contexts (like UK and Australian building societies) in a single study. One difficulty with such an exercise is that the mixing of mutuals and/or non-mutuals from different contexts would entail some problems in specifying a set of common behavioural objectives. However, once addressed, the results may offer useful insights into the impact of regulation, especially as there are so few cross-country comparative studies to draw upon. Second, a more fundamental step would be to consult with industry and regulators on the nature of the behavioural objectives in deposit-taking financial mutuals and

the extent to which they differ from other organisational forms. This would better inform all future studies of efficiency in deposit-taking mutuals.

Third, many techniques previously applied in the banking industry have not been applied to deposit-taking mutuals. These include not only the deterministic frontier approach discussed in this survey, but also the distribution-free and thick frontier approaches. The later approach in particular may be useful as it distinguishes between marginal departures from the frontier associated with random error and substantive departures associated with inefficiency without strong distributional assumptions. Similarly, an area that has received no attention in deposit-taking mutuals and only some in financial institutions more broadly is the estimation of profit and revenue efficiency. While the techniques are essentially the same, the data requirements are very different. For its part, revenue efficiency focuses on errors in the choice of output mix, having too little output and so on, while profit efficiency effectively combines the merits of cost efficiency with revenue efficiency. This is because cost (revenue) efficiency presumes that the observed level of output (input) is already profit-maximising. Of course, this may not always be the case.

Finally, the lack of suitable data has meant that application of frontier efficiency techniques at the branch or sub-firm level has been restricted in all financial institutions, not least deposit-taking financial mutuals. In principle, any efficiency study can be used by managers as a tool to improve performance, but the availability of detailed proprietary data would allow this to more specifically improve internal policy and procedures. This would be particularly beneficial where regional and seasonal influences, differences in market location or operating environments, office size, etc. are reckoned to confound relatively simple partial performance measures.

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Table 1. *Selected applications in deposit-taking financial mutuals*

Author(s)	Methodology ^a	Sample ^b	Inputs, outputs, explanatory variables ^c	Analytical technique	Main findings
Field (1990)	DEA	71 U.K. building societies, 1981.	Full-time equivalent labour, value of equipment, number of offices and agencies. Value of deposits and newly and previously advanced mortgages.	Descriptive analysis.	Significant negative relationship between overall technical efficiency and size of societies.
Drake and Weyman-Jones (1992)	DEA	76 U.K. building societies, 1988.	Full-time and part-time labour, capital (book value of fixed assets including leased equipment), value of retail funds and deposits, wholesale funds and deposits, number of branches. Mortgage loans, loans on other commercial assets, liquid asset holdings in excess of prudential minimum. Total assets, number of branches.	Descriptive analysis and second-stage regression.	Significant inverse relationship between size and both scale and technical inefficiency, decreasing returns-to-scale found in larger institution.
Cebenoyan, Cooperman, Register and Hudgins (1993)	SFA	559 U.S. savings and loans, 1988.	Total costs (operating and interest expenses), price of physical capital (office, furniture and equipment expenses divided by book value), price of deposits (interest expense divided by dollar value), price of labour (total employee expenditure divided by full-time equivalent employees). Construction and permanent mortgage loans, mortgage-backed pass-through securities, other loans (including commercial, consumer loans and lease financing), other securities (including governmental securities). Asset size, industry concentration ratio, market share for individual firms, qualitative variables for federal vs. state charter and mutual vs. stock firm.	Descriptive analysis and second-stage regression.	Wide range of inefficiency scores amongst S&Ls, operating inefficiency not significantly related to ownership structure, mutual and stock S&Ls have a similar cost structure.
Cebenoyan, Cooperman and Register (1993)	SFA	335 U.S. savings and loans, 1988.	Total costs (operating and interest expenses), price of physical capital (office, furniture and equipment expenses divided by book value), price of deposits (interest expense divided by dollar value), price of labour (total employee expenditure divided by full-time equivalent employees). Mortgage and nonmortgage loans, other investments and other securities. Dummy variables for regulatory closure, fraud convictions, and geographic location, assets, per capital income in area,	Descriptive analysis and second-stage regression.	Significant positive relationship for mutual and stock S&Ls between inefficiency and economically depressed regions and regulatory closure.
Fried, Lovell and Vanden Eeckaut (1993)	FDH	8,947 U.S. credit unions, 1990.	Number of full-time equivalent employees, total operating expense (less employee compensation and benefits and provision for loan losses). Loan quantity, price and variety indexes, savings quantity, price and variety indexes. Dummy variables for associational, occupational or residential bond, number of members, state vs. federal charter, geographic location, asset, loan and savings sizes, ratios of investments and real estate loans to total loans,	Descriptive analysis and second-stage regression.	Large number of best-practice DMUs for inefficient units to emulate. Several influences can be traced to locational and institutional characteristics.

Author(s)	Methodology ^a	Sample ^b	Inputs, outputs, explanatory variables ^c	Analytical technique	Main findings
Mester (1993)	SFA	1,015 U.S. savings and loans, 1991.	Total costs (interest and non-interest expenses), wage rate (labour expenses divided by full-time equivalent employees), price of physical capital (office occupancy and equipment expense divided by office assets), price of deposits (interest expense divided by value of deposits). Mortgage loans, commercial and consumer loans, securities and other investments. Capital to asset ratio, ROA (return on assets), ratios of non-performing assets, commercial loans, consumer loans, and mortgage pool assets to total assets, ratios of brokered deposits and uninsured deposits to total deposits.	Descriptive analysis and second-stage regression.	Stock S&Ls are less efficient than mutual forms. Higher capital-asset ratios are correlated with greater efficiency, other explanatory variables are correlated with efficiency in mutual S&Ls or in stock S&Ls but not both.
Garbacio, Hermalin, and Wallace (1994)	DEA	1,360 U.S. savings and loans, 1987.	Unit price of labour (average wage rate per employee), physical capital (net depreciation and office expenses divided by the number of branches), deposits (interest paid divided by total deposits), and equity (six-month T-bill rate). Total assets (mortgages, consumer and commercial loans, mortgage sales, and mortgage servicing), operating come.	Descriptive analysis and second-stage regression.	DEA and Varian-style efficiency measures provide similar classifications of efficient and inefficient institutions, and provide a strong criteria to predict poorly performing S&Ls.
McKillop and Glass (1994)	SFA	89 U.K. building societies, 1991.	Total costs (including labour, capital and interest expenses), labour input price (average wage per employee), capital input price (expenditure on premises and equipment divided by value of mean assets), price of borrowed funds (interest paid divided by total value of borrowed funds). Outstanding mortgages, other commercial assets.	Descriptive analysis.	Efficiency in the production of mortgage and non-mortgage products vary over national, regional and local building societies.
Piesse and Townsend (1995)	DEA	57 U.K. building societies, 1992.	Management expenses, tangible fixed assets, number of branches, full-time equivalent labour, interest paid on retail funds, interest paid on non-retail funds. Profit, interest earned from mortgages, interest earned from liquid assets, number of borrowers, number of depositors.	Descriptive analysis.	Number of DMUs that are efficient is low for restrictive behavioural specifications. Diseconomies of scale found in a large number of institutions.
Drake and Weyman-Jones (1996)	DEA and SFA	46 U.K. building societies, 1988.	Labour, capital, retail funds and deposits, and non-retail funds and deposits, price of labour (average salary) price of capital (office and administration expenses divided by assets), price of funds (interest payments divided by book value for retail and wholesale funds). Mortgage loans, commercial assets, liquid asset holdings in excess of capital requirements.	Descriptive analysis and second-stage regression.	Overall inefficiency due in the main to allocative rather than technical inefficiency, while technical inefficiency is largely attributable to scale rather than pure technical inefficiency. DEA and stochastic frontier provide consistent rankings.

Author(s)	Methodology ^a	Sample ^b	Inputs, outputs, explanatory variables ^c	Analytical technique	Main findings
Esho and Sharpe (1996)	SFA	20 Australian building societies, 1974–1990.	Total costs (interest and operating expenses), cost of funds, wage index. Average housing loans, average cash, bank deposits, government and other securities, other loans and fixed assets. Total assets, ratios of total revenue, operating expenses, capital and housing loans to total assets, number of branches, ratio of operating income to operating expense.	Descriptive analysis and second-stage regression.	High levels of X-inefficiency in building societies, small cost savings possible via economies of scale, 'efficiency-based' financial ratios produce larger inefficiency estimates than the stochastic frontier approach.
Fried, Lovell and Turner (1996)	FDH	8,954 U.S. credit unions, 1990.	Total operating expense (including employee compensation and benefits and office-related expenses). Indexes of loan quantity and prices, deposit quantity and prices, number of cheque accounts and a measure of variety of services offered. University-sponsored credit unions, geographic location.	Descriptive analysis and second-stage regression.	Feasibility of FDH/SUR combination over DEA/OLS (or DEA/logit or DEA/tobit) two-stage analysis.
Worthington (1998a)	SFA	22 Australian building societies, 1992–1995.	Total cost, price of physical capital (expenditures on office and equipment divided by the book value of office premises and equipment), price of deposits (interest expense divided by total deposits), price of labour (expenditures on employees divided by the number of full-time equivalent employees). Personal, property and commercial loans, deposit securities and other investments. Total assets, total capital, number of branches and agencies, commercial loans, time trend.	Descriptive analysis and single-stage regression.	Building societies operating at a high level of cost efficiency with improvement over the sample period. Branch networks and institutional size have a significant effect on efficient outcomes.
Worthington (1998b)	SFA	150 Australian credit unions, 1995.	Total cost, price of physical capital (expenditures on office and equipment divided by the book value of office premises and equipment), price of deposits (interest expense divided by total deposits), price of labour (expenditures on employees divided by the number of full-time equivalent employees). Personal, property and commercial loans, deposit securities and other investments. Total assets, commercial loans and capital, fee and commission income, number of branches, qualitative variable for community or industrial bond, geographic location by state.	Descriptive analysis and second-stage regression.	A large, well-capitalised credit union with a small branch network will be more efficient. Another important contributor to credit union efficiency is the state-based regulatory framework within which they operate.
Worthington (1998c)	DEA	63 Australian credit unions, 1995.	Operating expenses (marketing, salaries, office occupancy and electronic data processing), total assets (financial assets plus fixed assets), number of branches (includes head office, excludes agency operations), labour (full-time equivalent), interest expense on retail funds, interest expense on non-retail funds. Profit after tax, interest income on retail funds, interest income on non-retail funds, non-interest income (includes proceeds from sale of assets, fees, and all other income), number of borrowers/depositors. Ratio of operating expenses to total assets, ratio of operating income (net interest income plus non-interest income) to operating expense, operating income per unit of labour, operating income per branch.	Descriptive analysis and second-stage regression.	Scale inefficiencies are an important issue. Comparisons between rankings provided by financial ratios and DEA estimates indicate fundamental limitations in the applicability of the former to co-operative financial institutions.

Author(s)	Methodology ^a	Sample ^b	Inputs, outputs, explanatory variables ^c	Analytical technique	Main findings
Garden and Ralston (1999)	DEA	16 Australian credit unions, 1993–1994.	Number of employees, physical capital interest paid on all deposits, cost of labour divided by number of employees, interest on deposits divided by cost of capital, rent and electronic data processing costs divided by physical capital. At call, notice of withdrawal and fixed term deposits, personal, housing and commercial loans.	Descriptive analysis and second-stage regression.	Credit union mergers do not increase technical or allocative efficiency relative to unmerged credit unions.
Fried, Lovell and Yaisawarng (1999)	DEA	5,233 U.S. credit unions, 1988–1995.	Total operating expenses less provision for loan and investment loss and interest paid on borrowings. Average number of shares and deposits outstanding, interest and dividend expenses divided by dollar value of shares and deposits, average number of loans outstanding and loan interest income divided by total value of outstanding loans, average number of share draft accounts, number of deposit and loan services offered. Assets, bad loans, number of branches, capital-to-assets, loans-to-deposits, commercial charter, prior merger accounts-to-members, return on assets, dummy variable for year of merger.	Descriptive analysis and second-stage regression.	Member service provision improves in acquired credit unions and unchanged in acquiring credit unions. Various credit unions characteristics determine probability of merger success.
Worthington (1999b)	DEA	233 Australian credit unions, 1995.	At call, notice of withdrawal, and fixed term deposits, other financial liabilities, full-time equivalent employees, capital (equipment, fixtures and premises, either purchased directly or via capitalised leases), number of full-branch equivalent operations. Personal, housing and commercial loans, revolving credit facilities, other financial investments. Asset and risk management activities (asset size, level of capital, proportion of commercial loans to total loans), associational bond (community or industrial-based), geographic location by state.	Descriptive analysis and second-stage regression.	X-inefficiencies outweigh scale inefficiencies. A large credit union created on the basis of an industrial bond and with a high exposure to commercial loans will be relatively more efficient.
Brown, Brown and O'Connor (1999)	DEA	74–94 Victorian credit unions, 1992–1995.	Operating costs. Quantity of loans, quantity of deposits, loan price indicator (reciprocal of average interest received), deposit price indicator (average interest paid).	Descriptive analysis.	Tighter bond of association reduces operating costs. No evidence of increasing efficiency over period or relationship with exiting and acquiring credit unions during merger period.
Worthington (1999a)	MI	269 Australian credit unions, 1993–1997.	Members funds (share premiums accounts plus reserves), physical capital (book value of land, buildings and plant), inter-bank financial liabilities, number of full-time equivalent employees, number of branches. Call and term deposits, personal, residential and commercial loans, and other financial investments. Total assets, fixed capital, current assets-to-current liabilities, state-based dummy variables.	Descriptive analyse and second-stage regression.	Technological progress following deregulation, with most improvement in technical efficiency rather than scale efficiency. Technical progress more pronounced with more residential and commercial loans.

Author(s)	Methodology ^a	Sample ^b	Inputs, outputs, explanatory variables ^c	Analytical technique	Main findings
Glass and McKillop (2000)	MI	84 U.K. building societies, 1989–1993.	Retails funds and deposits, wholesale funds and deposits, full-time equivalent employees, capital expenditure and premises and equipment plus depreciation, number of branches. Loans secured by residential mortgages, loans secured on other property, unsecured loans, investment in land and investment in subsidiaries, revenue generating liquid assets.	Descriptive analysis.	Substantial productivity growth by shifts in technology, with relatively small improvements in efficiency. Increase in size-efficient number of building societies over sample period.
Worthington (2000)	DEA	200 Australian credit unions, 1997.	Number of full-time equivalent employees, physical capital, time and savings deposits, salary expenses per employee, ratio of physical capital expenses to book value of office premises and equipment, ratio of interest expenses to loanable funds. Personal loans and consumer credit facilities, property and real estate, and commercial loans, deposits with other institutions and book value of financial securities. Ratio of member capital to total assets, total assets-to-total liabilities, proportion of non-interest income in total income, net profit after-tax-to-total assets, information technology expenses-to-total expense, marketing expense-to-total expenses, proportion of real estate, property and commercial loans in portfolio, ratio of bad and doubtful debt expense to total loans.	Descriptive analysis and second-stage regression.	Most cost efficiency associated with allocative efficient. Commercial lending, expenditures on information and marketing, the proportion on non-interest income and association membership exerts an influence on cost efficiency, invariant to whether input prices are calculated for individual credit unions or assumed constant.
Esho (2001)	SFA	80 New South Wales credit unions, 1985–1993.	Total costs and total costs adjusted for subsidies. Total loans less provision for doubtful debts, deposits with other intermediaries, cash governments securities and bills of exchange, deposits, costs of funds, wage rate (subsidy adjusted), cost of capital and cost of capital (subsidy adjusted). Age. total assets, equity-to-asset ratio, deposits-to-total liabilities ratio, depositors-to-number of members, average loans, interest paid on funds less average cost of funds. interest charged on loans less average loan rate. dummy variable for Sydney metropolitan region.	Descriptive analyse and second-stage regression.	Little improvement in average efficiency over sample period. Second-stage estimates indicate that bond type, size, age, average deposit size and interest rate spreads are determinants of relative cost efficiency.
Ralston, Wright and Garden (2001)	DEA	65 Australian credit unions, 1993–1995.	Labour costs, (including subsidies), physical capital, deposit interest paid on all accounts. At call and fixed term deposits, personal, housing, real estate and commercial loans. Dummy variables for merged firms, firm growth, number of outlets, dummy variable for subsidized firm, total assets.	Descriptive analysis and second-stage regression.	Merges are not associated with improvements in efficiency superior to those achieved through internal growth.
Worthington (2001)	DEA	323 Australian credit unions, 1993–1997.	Physical capital, at-call deposits, fixed-term deposits, interest and non-interest expense, personal, commercial and residential loans, investments and interest and non-interest income. Reserves to total assets ratio, doubtful debts expense to total loans, Herfindahl index of loan concentration, net interest income to total loans, total expense to total income, prime liquid assets to total assets, call deposits to total deposits, total assets.	Descriptive analysis and second-stage regression.	Loan portfolio diversification, management ability, earnings and asset size influence acquiring activity, with size being main factor in being acquired. Mergers appear to have improved pure technical and scale efficiency in industry.

Author(s)	Methodology ^a	Sample ^b	Inputs, outputs, explanatory variables ^c	Analytical technique	Main findings
McKillop, Glass and Ferguson (2002)	DEA	104 U.K. credit unions, 1996	Salaries and other management expenses, dividends and non-management expenses. Loans to members, investments and deposits in other institutions. Asset size, loan ratio, liquidity ratio, dummy variable for trade organization membership, bad-debt ratio.	Descriptive analysis and second-stage regression.	Credit unions overspend on dividend payments and underspend on labour costs. Efficiency suffers from a lack of loan portfolio diversification and diseconomies of scale.
Glass and McKillop (2006)	SFA	1,676 U.S. credit unions, 1993–2001.	Variables costs. Investments, unsecured loans, real estate, other and off-balance sheet loans, price of funds, price of labour, costs of capital.	Descriptive analysis and second-stage regression.	Different environments (age of credit unions, bond of association, state/federal regulations, state/federal insurance) and per income and unemployment rate in region account for much of the variation in cost efficiency.

Notes: (a) DEA – Data Envelopment Analysis, SFA – Stochastic Frontier Analysis, MI – Malmquist Indices; (b) Singular dates represent calendar or financial year cross-sections, intervals represent time-series; (c) In order by paragraph, for SFA paragraphs are ordered dependent, independent and explanatory variables; (d) All SFA studies usually discuss the estimated coefficients, significance and elasticities for the production and cost parameters, as well as the measures of efficiency obtained. Analytical technique of descriptive analysis includes analysis of distributions (mean, standard deviations) and/or analysis of efficiency by groups within sample and correlation between efficiency scores obtained by different techniques. Second-stage regression involved regressing efficiency scores from DEA, MI, or SFA on additional explanatory variables in a separate regression (usually Tobit, probit or logit), single-stage regression refers to a stochastic frontier model where efficiency estimates are estimated simultaneously with the coefficients on the explanatory variables.