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Nonparametric Frontier Models for Assessing the Market and Cost Efficiency of Large-scale Bank Branch Networks

In this paper we propose models for assessing the efficiency in large networks of bank branches. We distinguish bank branch efficiency into *market* and *cost* components suitably modified to capture different tiers of bank management. The paper proposes a methodology which includes the use of multivariate analysis in order to ensure the homogeneity of the branches assessed and then data envelopment analysis for assessing efficiency. The methodology is applied on a sample of 580 branches of a commercial bank in the United Kingdom. The results obtained reinforced previous claims regarding the presence of high technical inefficiencies and economies/diseconomies of scale at the branch level from a production and cost point of view. Furthermore, the decision to pre-cluster the network of branches into homogenous groups has had profound implications on the magnitude of the assessed efficiencies.

THE PERFORMANCE OF FINANCIAL INSTITUTIONS is a topic that draws considerable attention within the business environment of many countries. This interest primarily concerns the corporate performance of individual banks (see Berger, Hunter, and Timme 1993). Less attention can be found in the literature of branch-specific efficiency studies which is the principal channel of the production work in banking. Berger, Leusner, and Mingo (1997) discuss in detail the consequences of ignoring the bank branch efficiency on issues of technical efficiency, economies of scale, and product mix.

The assessment of branch efficiency has variable significance to financial institutions that operate under different regulatory regimes. For example, in markets with no restrictions on the size of the branch network of individual banks (for example, Greece, Japan, and the United Kingdom) the corporate performance of a bank does not convey any information about the performance of its possibly three thousand branches. In the United Kingdom the focus on bank branch performance has had recent stimuli from (i) the limited ability of the main clearing banks to realize investment profits from foreign markets and (ii) the intensified competition at the national level by the entrance of the mortgage lending institutions (building societies) with expanded retail banking capabilities. This changing environment brought up issues re-

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lated to the operational efficiency and the quality of services at the bank branch level. The recognition of the importance of these issues invited considerable theoretical and applied work over the last ten years (see Sherman and Ladino 1995).

Previous studies about bank branch efficiency have concentrated on their ability to control costs. In the parametric frontier literature Pavlopoulos and Kouzelis (1989) employed a translog cost function on 362 branches of the National Bank of Greece. They reported economies of scale and scope at the branch level while monopolistic phenomena were detected in the rural areas of Greece. Doukas and Switzer (1991) also used a translog cost function on 563 bank branches in Canada and reported the presence of economies of scale at the branch level. Another translog cost function was most recently employed by Zardkoohi and Kolari (1994) on 615 branches of 43 Finnish banks also reporting economies of scale at the branch level. Berger, Leusner, and Mingo (1997) analyzed 760 branches of a U.S. bank over a three-year period using a Fourrier-Flexible (instead of the translog) form. The latter study reports results regarding the presence of technical and scale inefficiencies at the branch level that explain partly the bank inefficiencies at the corporate level.

The other methodology used to assess bank branch efficiency is based on nonparametric deterministic frontier estimations whose applications have been on small sample sizes. Sherman and Gold (1985) focused on fourteen branches of a savings bank; Parkan (1987) assessed thirty-five branches of a chartered bank in Canada; Oral and Yolalan (1990) assessed twenty branches of a bank in Turkey; Vassiloglou and Giokas (1990) and Giokas (1991) studied the efficiency of twenty branches of the Commercial Bank of Greece. Finally, Al-Faraj, Alidi, and Bu-Bshait (1993) assessed the performance of fifteen bank branches in Saudi Arabia employing, however, a production technology with eight inputs and seven outputs which showed all but three branches as relatively efficient.

Berger, Leusner, and Mingo (1997) noticed that most empirical results from the nonparametric studies do not give a very representative picture of the "true" level of technical efficiency at the bank branch level. The limited number of observations used in these studies do not allow discrimination between efficient and inefficient branches. More recent nonparametric studies assess the efficiency of larger networks of bank branches. Drake and Howcroft (1994) report 92 percent average cost efficiency of 190 bank branches in the United Kingdom under the constant-returns-to-scale assumption. Tulkens and Vanden Eeckaut (1991) and Tulkens (1993) assessed the cost efficiency of 773 branches of a public and 911 branches of a private bank in Belgium. They report an average efficiency of 69 percent and 76 percent for the public bank branches and 62 percent and 71 percent for the private bank branches under constant and variable returns-to-scale assumptions respectively.

Evidence from the literature shows that the bank branch efficiency studies focus on the cost efficiency of individual branches while ignoring their marketing activities to penetrate their market. The two aspects constitute *intrinsic* and *extrinsic* dimensions of the performance of bank branches. In this paper we propose a nonparametric frontier estimation framework for assessing bank branch efficiency that is based on two complementary efficiency dimensions.

The paper is organized in five sections as follows. In the next section we decompose the bank branch efficiency into market and cost components. Section 2 proposes a methodology for assessing market and cost efficiency in large banking networks. Results from the application of the methodology on 580 bank branches are also discussed in this section. Section 3 gives further insights into the market and cost efficiency analysis with particular emphasis on the effects of economies of scale and the assessment of the competitive advantage of clusters of bank branches with different operating profile. Section 4 concludes the paper.

1. PERFORMANCE ISSUES IN A RETAIL BANKING ENVIRONMENT

The corporate performance of financial institutions is examined in the literature by adopting behavioral objectives such as *intermediation* and *production.* Under the *intermediation* approach performance is assessed using as inputs the total operating and interest costs while outputs are considered to be the amount of money intermediated. The *production* approach, on the other hand, emphasizes the services provided by the bank, and thus, operating costs are considered as inputs while the number of transactions with customers are taken as outputs. A *utility function* approach has also been proposed by Fried, Lovell, and Vanden Eeckaut (1993) to encapsulate the behavioral assumptions that describe the operations of credit unions as banking institutions.

The current bank efficiency studies recognize the difference between the cost and market penetration efficiency orientation. Two branches that service the same number of deposit accounts and customer transactions while incurring similar costs are considered equally successful in terms of cost efficiency. No information is provided as to the extent to which either of the branches underutilized its potential to generate more deposit accounts. This performance dimension is encapsulated by the concept of market efficiency as defined by Athanassopoulos (1995a, 1995b). The primary objective of a bank branch is to penetrate its market by selling financial products to new customers while delivering services to existing customers. Market efficiency has an output maximization orientation and can be defined as *the extent to which individual bank branches, given their capacity and resources available, utilize their market potential by maximizing sales.* The assessment of market efficiency will also draw upon the multilevel structure of retail organizations, that is, to evaluate the market efficiency of individual branches, managed by local agents, in a way that controls for location and size decisions made by central principals.

The second component of the performance of individual branches is their cost efficiency which has an input minimization orientation concentrating on *the extent to which individual bank branches minimize their expenditure, given the services they provide, without reducing the levels of service quality.* Cost efficiency can be assessed adopting either the production or the intermediation approaches. The assessment of cost efficiency is pursued using internal inputs and outputs which are under the control of each bank.

2. METHODOLOGY FOR ASSESSING EFFICIENCY OF BANK BRANCH NETWORKS

The assessment of the performance of a large-scale network of bank branches brings up problems not encountered in small-scale applications. These problems concern the lack of homogeneity among individual branches due to their diverse operating profiles, the development of causal input-output models for assessing market and cost efficiency, and the comparative viability of groups of branches with different operating profiles.

A methodological framework is proposed for assessing performance in large-scale bank branch networks. The discussion of the methodology is facilitated by the results obtained from an application on a set of 580 bank branches in the United Kingdom. The bank of our study has taken many initiatives to monitor the efficiency of its network and thus its management was keen to evaluate and ultimately adopt the proposed methodology. The assessment of efficiency was pursued in three interrelated phrases:

1. In the first phase the bank branches are split into homogenous clusters in order to increase the validity of the comparisons between efficient and inefficient branches.[1] Factors reflecting the differences between the environment and/or the operations of bank branches are used as criteria that form the clusters.
2. In the second phase input and output models are specified to capture efficiency from the intrinsic (cost) and extrinsic (market) perspectives.
3. The linear programming models are specified in the third phase seeking to assess branch efficiency according to the behavioral assumption made in the previous phase.

2.1 Homogeneity of the Sample Set

Despite the similarities in the operations of bank branches, it is a customary practice to distinguish branches based on their location and other idiosyncratic features. *Factor analysis* was used for the identification of differentiating factors and *cluster analysis* for the definition of homogeneous clusters of bank branches.[2]

The method of principal component analysis was used to identify factors that would be used in the cluster analysis step (for the variables used in this phase and their factor loadings see the Appendix). Four factors were selected which have accounted

1. The adoption of the cluster analysis approach was motivated by the management of the bank. Previous attempts to assess the efficiency of the network found the resistance of regional managers since inefficient branches were compared to efficient branches with fundamentally different characteristics (for example, location, size, concentration of competition, market segments).

2. The homogeneity of the efficiency comparisons can be pursued by either clustering the assessed branches prior to the efficiency assessment or by introducing control variables and assess the whole sample together. In the present study we have adopted the first approach which was also the methodology preferred by the management of the organization. The pre-efficiency clustering has the advantage that we can incorporate a variety of qualitative factors that cannot be quantified in the production possibility sense. Use of DEA models with categorical factors (see Banker and Morey 1986b) will run into inconsistencies when the number of categorical variables is more than one. Pre-efficiency clustering is increasingly used in the econometric literature where separate equations are estimated for subsamples with different-sized firms (see Berger, Hanweck, and Humphrey 1987 and Cummins and Weiss 1993).

for 88 percent of the cumulative proportion of the variance explained. Using the factor loadings of these factors, after a quadrimax rotation, the predominate features of each cluster can be summarized as follows:

Factor 1: Level of competition faced by individual bank branches tested on alternative radius specifications. (*Proportion of variance explained* 43.8%)

Factor 2: Size characteristics of the branch including the space of the branch, and the number of counter transactions. (*Proportion of variance explained* 23.7%)

Factor 3: Variables reflecting the potential market of individual bank branches regarding various financial products. (*Proportion of variance explained* 11.9%)

Factor 4: Measure of the types and average size of accounts held in the branches and also the affluence of the surrounding area. (*Proportion of variance explained* 8.6%)

The 580 bank branches were next classified into six clusters applying the Ward's clustering method on the four factors' variables. The figure of six clusters was selected using the pseudo-F statistic and the cubic clustering criterion. The number of branches within each cluster was as follows: cluster 1 = 90, cluster 2 = 175, cluster 3 = 150, cluster 4 = 115, cluster 5 = 30, and cluster 6 = 20. The characteristics of the branches within each cluster are next summarized: above-average market potential and below-average branch size for the branches in cluster 1; relatively weak market potential and below-average size of accounts in cluster 2; higher average account balances in cluster 3; large branch sizes in cluster 4; high market potential enjoyed by branches in cluster 5; high competition levels and below-average market potential in cluster 6.

2.2 Setting Up Input-Output Sets

The selection of input-output sets for assessing cost efficiency of branches focusses on the intermediation and production operations of banks (Berger, Leusner, and Mingo 1997). The assessment of market efficiency, however, requires the use of surrogate measures of the market conditions of individual bank branches. Figure 1 lists the input and output variables (see Appendix) used for assessing the market and cost efficiency of bank branches.

On the output side, the sales of new products have been summarized into four broad categories concerning various types of new accounts (liability sales), loans and mortgages, financial products concerning insurances and securities, and the number of credit cards sold. On the input side, the *number of transactions* are used as a surrogate of the passing trade of individual branches, considered an indication of their customer base. It is noteworthy that the number of transactions are normally considered as outputs of individual bank branches; however, since the market efficiency focusses on the maximization of the central management objectives, the variable is given an input character. Information on the *potential market size* was provided by market research

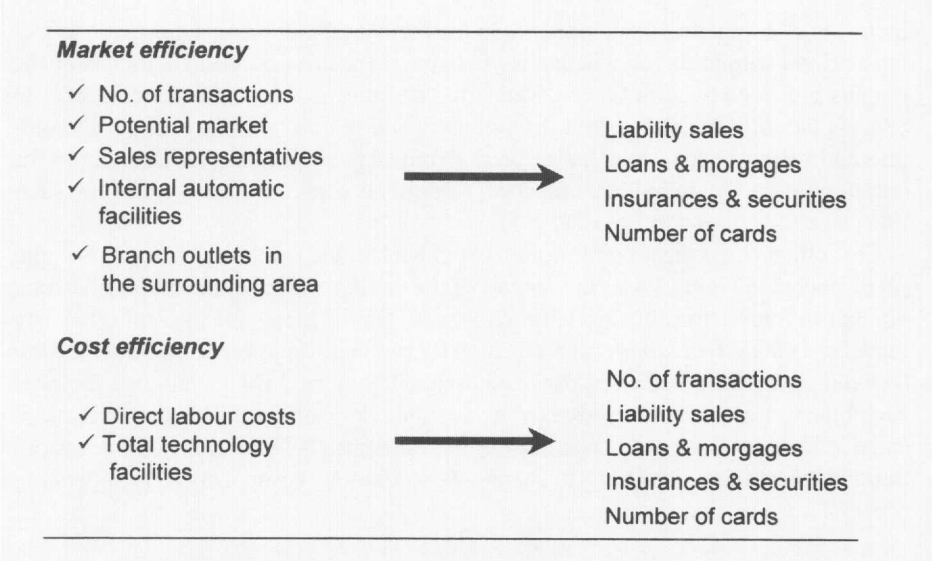

FIG. 1. Input-Output Set for Assessing Market Efficiency

and geographical information systems; the *sales representatives* are bank employees trained to sell financial products to customers, and the number of *internal automatic facilities* is a surrogate variable regarding the branch size[3] and the state of technology of the branch concerned. Technology is considered here as an investment which is deemed to enhance the branches; delivery of services in terms of speed and accuracy.

The variable concerning the number of bank branches in the surrounding area of each assessed bank branch is considered as a special case. The key issue is how competition will be represented in a DEA context and also whether competition should be assumed to have a positive or negative effect on the assessed market efficiency. In previous research Mahajan (1991), Athanassopoulos and Thanassoulis (1995), and Athanassopoulos (1995a, 1995) have discussed the issue of competition extensively. This research has concluded that the effect of the number of competitors on an individual branch is context dependent. That is, for some outputs competition has a negative effect while for some others it has a positive effect.

Correlation analysis showed that the number of competitors has a positive effect on the sales of loans and mortgages (0.65) and negative effect on the number of liability sales (−0.59) of the assessed bank branches, respectively. The geographical concentration of bank branches in similar areas creates small financial markets which attract customers. Financial products and services provided by the branches of all banks are based on competitiveness. On the other hand, for differentiated products (for example, mortgages) individual branches can benefit from other branches' customers. The

3. The physical size of individual branches was highly correlated with the number of automatic facilities and thus it was dropped from the input list.

inclusion of competing bank branches in the market efficiency model is made avoiding a priori assumptions on whether it would have a positive or negative impact on the outputs produced by each branch. The term "attribute" is introduced here in order to express the differential between discretionary and nondiscretionary inputs and outputs and attributes that do not have a predetermined positive or negative impact on the output produced by individual branches. Arguments supporting this type of formulation can also be found in Lovell (1995).

Cost efficiency is the second component of bank branch viability. The input-output set displayed in Figure 1 uses the outputs of the market efficiency model plus the total number of transactions incurred at each branch. On the input side the cost efficiency model uses the *direct labor costs*[4] adjusted for regional wage variations and the *total technology facilities* at the disposal of individual branches. The technology factor of each branch is, however, represented as an input element not deemed to be reduced since it includes not easily transferrable investments (ATMs) and also the overall trend in the banking industry is to change the technology component of the operating process.

2.3 Mathematical Models for Evaluating Market and Cost Efficiency

Data envelopment analysis is suggested as the tool for assessing the market and cost efficiency of bank branches. Let us consider a set of $j = \{1, ..., n\}$ bank branches which use input quantities to produce various output quantities. We shall distinguish the input quantities via an index set of discretionary inputs $D = \{1, ..., m_D\}$, a set of nondiscretionary inputs $F = \{1, ..., m_F\}$ and a set of attributes $A = \{1, ..., m_A\}$ that affect the operation of individual branches. x_{ij} denotes the quantity of input i of DMU j and with y_{rj} is denoted the quantity of output r of DMU j. Data envelopment analysis models are proposed for assessing the market and cost efficiency of bank branches under different assumptions on the effect of scale on the assessed efficiency.

Modeling Components of Market Efficiency

The assessment of the market efficiency is the concern of both central management (aggregate) and also local management (site-specific). Central management should be accountable for the selection of branch location, size, product mix, and management. These issues constitute the scale size characteristics of a branch and thus the corresponding efficiency (aggregate) includes scale size effects. Local management, on the other hand, is not responsible for the scale size characteristics of their branches and thus a measure of site-specific market efficiency free of scale size effects must be obtained.

Discretionary inputs ($i \in D$) are considered to be the internal automatic facilities

4. An alternative input in the cost efficiency model could be the number of staff split into different grades in accord with the Drake and Howcroft (1994) study. This type of assessment is not seen to be appropriate for the assessment of technical efficiency since a branch that has chosen to have a minimal level of input for a particular grade of staff will be rated DEA-efficient by default. The appropriateness of input-mix is a very important question closely related to the concept of allocative efficiency which is beyond the scope of the current study.

and the sales representatives within each branch. Nondiscretionary inputs ($i \in F$) are considered to be the number of transactions and the potential market. Finally, the number of other branch outlets in the surrounding area ($i \in A$) are considered as an attribute of the operating process of bank branches.

Assessment of the site-specific market efficiency concentrates on the performance of local management to generate sales given the size of the branch and its market conditions. The market efficiency, free of scale size effects, of branch k can be assessed suing model (1).

Site-specific Market Efficiency

$$\min_{\alpha_r, \beta_i} \sum_{i \in D \cup F \cup A} \beta_i x_{ik} - \omega_K$$

$$\sum_{r \in O} \alpha_r y_{rk} = 100$$

$$\sum_{i \in D \cup F \cup A} \beta_i x_{ij} - \sum_{r \in O} \alpha_r y_{rj} - \omega_K \geq 0 \ \forall j \qquad (1)$$

$$\alpha_r, \beta_i \geq \varepsilon \qquad \forall r \in O, i \in D \cup F$$

$$\omega_K, \beta_i \, i \in A \text{ sign free}$$

where

x_{ij}, y_{rj}	are quantities of input i and output r of branch j,
β_i, α_r	are weight factors of input i and output r obtained by the solution to (1),
ω_k	is a sign-free scale factor concerning the economies of scale effect of the assessed branch k,
ε	is a non-Archimedian small positive number.[5]

This market efficiency model in (1) has been developed by Banker, Charnes, and Cooper (1984) and estimates the efficiency ME_k^{SF} of branch k as $ME_k^{SF} = 100 / \sum_{i \in D} \beta_i x_{ik}$. The formulation of (1) focusses on the efficiency of individual branches by considering their scale size of operation as given. The input-output set of the site-specific market efficiency model is made of the factors listed in Figure 1. The distinction made in (1) between discretionary and nondiscretionary inputs is absorbed with the scale size factor ω while for the attribute inputs there model in (1) allows sign-free weight factors.

The aggregate market efficiency assessment concentrates on the sales ability of individual branches taking into account the scale size of their inputs and outputs. The mathematical formulation of this type of efficiency is given in (2) and it is an extension of models developed by Banker and Morey (1986a), Golany and Roll (1993) and Athanassopoulos (1995a).

5. The inclusion of the ε lower bound for the weights of the DEA formulations is indicative. In fact, most DEA software routines avoid the use of the ε and solve a two-phase optimization problem. To save space we have avoided writing the second phase of the optimization problems used in the paper. For more details about the role of second phase optimization, see Charnes.

Aggregate Market Efficiency

$$\underset{\alpha_r,\beta_i,\gamma_i,\phi_i}{Min} \quad \sum_{i\in D}\beta_i x_{ik} \tag{2.0}$$

$$\sum_{r\in O}\alpha_r y_{rk} = 100 \tag{2.1}$$

$$\sum_{i\in D}\beta_i x_{ij} + \sum_{i\in F}\gamma_i(x_{ij} - x_{ik}) + \sum_{i\in A}\phi_i\,(x_{ij} - x_{ik}) - \sum_{r\in O}\alpha_r y_{rj} \geq 0 \;\forall j, j \neq k \tag{2.2}$$

$$\sum_{i\in D}\beta_i x_{ik} - \sum_{r\in O}\alpha_r y_{rk} \geq 0 \tag{2.3}$$

$$\alpha_r, \beta_i, \gamma_i \geq \varepsilon$$

$$\phi_i\, free$$

where

x_{ij}, y_{rj}	are quantities of input i and output r of branch j,
$\beta_i, \gamma_i, \phi_i, \alpha_r$	are weight factors of the inputs and outputs of branch k,
D	is the set of discretionary outputs,
F	is the subset of nondiscretionary inputs
A	is the subset of attributes affecting the operation of branches.

The objective function (2.0) and the standardization constraint (2.1) include only the subset of discretionary inputs D. Furthermore, the constraints (2.2) that link the weighted sum of inputs to the weighted sum of outputs for each branch j differ from the constraints used in a typical DEA assessment. These differences are next discussed in more detail focussing on the way nondiscretionary inputs and attributes are formulated.

Nondiscretionary Input Levels ($i \in F$). The nondiscretionary input and output levels of each branch are adjusted in (2) by subtracting the observed levels of the assessed branch k (this is why the objective function (2.0) and the standardization constraint (2.1) do not include the corresponding inputs of branch k). This standardization affects the mechanism of the DEA comparisons in the following way. The assessed branch k will be rated relatively inefficient it at least one of the remaining branches ($j \neq k$) has its constraint in (2.2) binding in the optimal solution of k. The adjustments of nondiscretionary inputs of each branch j can affect their likelihood to have their constraints binding in a positive or negative way. Let us consider the case of branch j and nondiscretionary input I, when branch k is assessed:

1. For branch j, if $x_{ij} < x_{ik}$, then the difference is $dx_{ij} = x_{ij} - x_{ik} < 0$ and thus the revised input dx_{ij} of branch j is taken as an output during the assessment of branch k. Thus, branches with smaller than k's nondiscretionary inputs are compensated by the model for the difference between their values and the values of the assessed branch k.

2. If $x_{ij} > x_{ik}$, then the difference $dx_{ij} = x_{ij} - x_{ik} > 0$, and therefore the revised input dx_{ij} of branch *j* is taken as an input in the assessment of branch *k*. This shows that for branches with higher nondiscretionary inputs to those of the assessed branch *k* their difference operates as an input.

This analysis shows that despite the modeling enhancements of nondiscretionary inputs-outputs the model entails an isotonicity property that implies that *positive* differences of nondiscretionary factors would be treated as inputs and *negative* differences as outputs.

Attributes within the Production Set $i \in A$. The way competition affects the performance of individual branches underlies the definition of a subset of *attributes* within the production set of bank branches. The crucial issue in the formulation of these attributes in (2) is that no assumptions are made on whether they are inputs or outputs. The latter has been confirmed empirically as it was found that competition had positive effect on some outputs and negative on some others. In the formulation of the market efficiency model in (2) the attributes are assigned a sign free weight factor ϕ_i, $i \in A$ as there is no a priori assumption regarding their effect on the generated output.

Modeling Components of Cost Efficiency

The assessment of cost efficiency is based on the distinction between the labor costs that are deemed to be reduced and the ATM facilities that are treated as a control factor of the state of transaction-facilitating technology of each branch. In mathematical terms the distinction between the two input factors lead to the use of the Banker and Morey (1986a and b) model about discretionary (direct labor costs ($i \in D$)) and nondiscretionary (automatic teller machine ($i \in F$)) inputs. The number of transactions encountered within a bank branch and all the outputs used in the market efficiency models were the outputs ($r \in O$) used to assess cost efficiency. Aggregate cost efficiency of branch k can be assessed suing the model in (3).

$$\underset{\alpha_r,\beta_i,\gamma_i}{Max}\left(\sum_{r\in O}\alpha_r y_{rk} - \sum_{i\in F}\gamma_i x_{ik}\right) \left| \begin{array}{l} s.t. \sum_{i\in D}\beta_i x_{ij} = 100; \sum_{r\in O}\alpha_r y_{rj} - \sum_{i\in D}\beta_i x_{ij} - \sum_{i\in F}\gamma_i x_{ij} \le 0 \\ \forall j; \alpha_r, \beta_i, \gamma_i \ge \varepsilon \end{array} \right. \qquad (3)$$

The cost efficiency $CE_k^{SA} = 100/\Sigma_{r\in O}\alpha_r y_{rk} - \Sigma_{i\in F}\gamma_i x_{ik}$ is assessed under the assumption of constant returns to scale and thus it aims at the long-run cost control of bank branches. It can be seen that the nondiscretionary input is represented in the efficiency formulae of each assessed branch. The site-specific cost efficiency $CE_k^{SF} = 100/\Sigma_{r\in O}\alpha_r y_{rk} - \Sigma_{i\in F}\gamma_i x_{ik} + \omega_k^*$ is assessed under the assumption of variable returns to scale [it is assessed by adding the scale factor variable ω_k^* in (3)] and thus it has a short-run cost control orientation.

2.4 Results on the Market and Cost Efficiency of Bank Branches

The cluster-based assessment of efficiency yielded an increased number of efficient branches compared to what would have been found otherwise. For example, the aver-

TABLE 1

MARKET EFFICIENCY (%) OF CLUSTERS OF BRANCHES

	Average	Median	Min	Lower Quart.	Upper Quart.
AGGREGATE					
Cluster 1 (Obs. 90) *Small branch size*	86.74	88.78	49.52	78.3	93.2
Cluster 2 (Obs. 175) *Small account sizes*	84.25	87.65	39.10	77.6	94.0
Cluster 3 (Obs. 150) *Large account sizes*	84.30	84.21	50.30	78.1	92.8
Cluster 4 (Obs. 115) *Large branch sizes*	86.31	87.00	45.98	78.0	93.4
Cluster 5 (Obs. 30) *Large potential market*	93.72	96.00	78.19	90.2	100
Cluster 6 (Obs. 20) *High competition*	94.12	98.00	82.00	92.1	100
SITE-SPECIFIC					
Cluster 1 (Obs. 90) *Small branch size*	89.29	91.72	68.45	80.34	100
Cluster 2 (Obs. 175) *Small account sizes*	87.82	91.00	54.32	78.87	100
Cluster 3 (Obs. 150) *Large account sizes*	88.12	89.11	69.78	79.34	100
Cluster 4 (Obs. 115) *Large branch sizes*	90.10	91.90	63.22	80.00	100
Cluster 5 (Obs. 30) *Large potential market*	96.50	100.0	83.23	95.55	100
Cluster 6 (Obs. 20) *High competition*	97.60	100.0	86.66	96.00	100

age site-specific market efficiency was dropped from 90 percent to 82 percent when the assessment was done without separating the bank branches into homogenous clusters. In absolute terms sixty branches were found relatively efficient when the assessment was carried out without clustering the network, while this number was increased to 221 when the branches were assessed separately within their clusters. Similarly, the average site-specific cost efficiency was dropped from 88 percent and seventy-five efficient branches to 81 percent and thirty-eight efficient branches when it was obtained from the overall sample set and not separately for each cluster. These results show the importance of homogeneity in the operation of branches when their efficiency is assessed. Summary results regarding the market efficiency of each cluster are given in Table 1.

The minimum aggregate market efficiency (ME^{SA}) was found to be 39 percent while the average market efficiency was 85 percent across the whole network. The average site-specific market efficiency (ME^{SF}), on the other hand, was found to be 90 percent without noticeable extreme changes across clusters. The noteworthy result concerns the very similar pattern of assessed market efficiencies across the six clusters. Clusters five (high potential market) and six (high competition) have shown the highest average efficiencies. Cluster two has the lowest mean and cluster three (high average account size) the lowest median market efficiencies. The performance differences between the six clusters is investigated in section 3.2 focussing on the market efficiency of the cluster profiles (and not individual branches).

TABLE 2

COST EFFICIENCY (%) OF CLUSTERS OF BRANCHES

	Average	Median	Minimum	Lower Quart.	Upper Quart.
AGGREGATE					
Cluster 1 (Obs. 90) *Small branch size*	80.81	79.12	49.72	70.18	88.23
Cluster 2 (Obs. 175) *Small account sizes*	78.91	78.88	44.08	67.12	89.34
Cluster 3 (Obs. 150) *Large account sizes*	81.08	79.92	42.70	69.34	87.56
Cluster 4 (Obs. 115) *Large branch sizes*	86.13	85.85	64.81	72.32	87.77
Cluster 5 (Obs. 30) *Large potential market*	89.85	90.46	67.09	79.89	100.0
Cluster 6 (Obs. 20) *High competition*	85.27	84.64	66.20	82.33	95.66
SITE-SPECIFIC					
Cluster 1 (Obs. 90) *Small branch size*	85.08	84.70	47.82	79.78	96.78
Cluster 2 (Obs. 175) *Small account sizes*	83.59	84.12	45.13	74.56	96.65
Cluster 3 (Obs. 150) *Large account sizes*	89.09	88.17	48.80	81.10	96.71
Cluster 4 (Obs. 115) *Large branch sizes*	88.89	87.99	67.78	81.88	97.04
Cluster 5 (Obs. 30) *Large potential market*	93.86	94.06	71.92	83.34	100
Cluster 6 (Obs. 20) *High competition*	92.00	94.06	73.73	82.89	100

The next step concerns the assessment of the cost efficiency of the bank branches. Table 2 shows summary statistics regarding the long and short-run cost efficiency of each cluster.

The cost efficiency results gauge lower scores from the corresponding market efficiency scores. The minimum aggregate cost efficiency has reached a value of 42.7 percent whilst the corresponding site-specific cost efficiency a minimum value of 45.13 percent. The average aggregate and site-specific cost efficiencies across the whole network were found to be 82 percent and 88 percent respectively.

Cluster one (small branch size) has had the lowest median and cluster three (large account sizes) the lowest average cost efficiencies respectively. Clusters five and six have shown a consistent pattern of high cost and high market efficiencies indicating the similarity in the operations of the branches within these clusters. There are no previous studies to compare our market efficiency results and thus we only compare the cost efficiency ratings. Our cost efficiency results are close[6] to those of Berger, Leusner, and Mingo (1997) and Tulkens (1993) that indicate an average level of cost efficiency below 80 percent showing some scope for cutting costs within the branch networks. These magnitudes of technical inefficiency are considerably lower from

6. If the clustering of the branches is avoided, we get average cost efficiency results of 78 percent and 72 percent under variable and constant returns-to-scale assumptions which are close to the Tulkens (1993) and Berger, Leusner, and Mingo (1997) results.

those reported by Drake and Howcroft[7] (1994) and also previous DEA studies that were based on small data sets.

The association between market and cost efficiency scores were finally examined using rank correlation coefficients. At the aggregate level the rank correlations within each cluster gave positive association between the market and cost efficiencies (cluster 1 = 0.40, cluster 2 = 0.23, cluster 3 = 0.35, cluster 4 = 0.62, cluster 5 = 0.60, cluster 6 = 0.28). The rank correlations for the site-specific efficiencies within each cluster were as follows (cluster 1 = 0.40, cluster 2 = 0.40, cluster 3 = 0.39, cluster 4 = 0.58, cluster 5 = 0.67, cluster 6 = 0.32). These results indicate the relatively high concordance between the ranks obtained in clusters 4 and 5 for both efficiencies while for the remaining clusters the ranks have not been very similar. The diversity between market and cost efficiency results indicate the importance of studying branch efficiency from different perspectives since it yields information regarding extrinsic and extrinsic strengths and weaknesses of each branch.

3. FURTHER INSIGHTS FROM THE MARKET AND COST EFFICIENCY ASSESSMENT

3.1 Investigating Returns-to-Scale Effects

The presence of economies of scale is a puzzling question for banking institutions that require information on how close they are to producing at the scale that minimizes their cost per unit of output (see, for example, Doukas and Switzer 1991, Berger, Leusner, and Mingo 1997). Clearly, there is no one-to-one correspondence between the economies of scale at the corporate and branch level of banks. Investigation of economies of scale at the corporate level may mask the presence of economies of scale at the individual branch level.[8] Nonparametric tools like DEA yield characterizations with respect to the presence of local economies of scale of individual branches.[9] The technical details of these assessments have been subject to intense research by Banker, Charnes, and Cooper (1984), Fare, Grosskopf, and Lovell (1985), Banker and Thrall (1992), Fare and Grosskopf (1994), and most recently by Zhu and Shen (1995).

Based on Zhu and Shen (1995) we adopt the dual coefficient ($\Sigma_{j=1}^{n}\lambda_j^{k*}$) of the scale factor ω_k^{ME*} from the formulation of the market efficiency models, where λ_j^{k*} are intensity variables showing the factor contribution of the branch j on the targets of branch k when branch k is assessed. The economies of scale investigation is based on the solution of the aggregate market and cost efficiency models. An inefficient branch k is operating under local Increasing Returns to Scale (IRS) if $\Sigma_{j=1}^{n}\lambda_j^{k*} \leq 1$ for all opti-

7. It must be argued, however, that the Drake and Howcroft study (1994) is based on an extended set of input variables where labor costs are split across different grades of staff.

8. Athanassopoulos and Toivannen (1995) provide a theoretical framework for investigating economies of scale versus economies of density within multiproduct firms that operate networks of branches.

9. Characterizations of returns to scale from DEA-based assessments characterize the segments of the efficient frontier upon which technically inefficient branches are projected. Any characterization of increasing or decreasing returns to scale can only be made after the corresponding branch is projected on the technical efficiency frontier.

TABLE 3

RETURNS TO SCALE FOR CLUSTERS OF BRANCHES

	Increasing		Constant		Decreasing	
	Market	Cost	Market	Cost	Market	Cost
Cluster 1 (Obs. 90) *Small branch size*	46	28	39	9	5	52
Cluster 2 (Obs. 175) *Small account sizes*	85	45	60	25	30	105
Cluster 3 (Obs. 150) *Large account sizes*	105	51	38	21	7	78
Cluster 4 (Obs. 115) *Large branch sizes*	61	59	47	12	7	44
Cluster 5 (Obs. 30) *Large potential market*	6	13	23	9	1	8
Cluster 6 (Obs. 20) *High competition*	5	4	14	5	1	11
Total (No. 580)	288	200	221	75	51	305

mal solutions and under local Decreasing Returns to Scale (DRS) if $\Sigma_{j=1}^{n}\lambda_j^{k*} \geq 1$ for all optimal solutions. Similar analysis can be carried out to obtain cost-efficiency-based returns-to-scale effects using the cost efficiency scale factor ω_k^{CE*}. A breakdown on the returns to scale results per cluster of bank branches is provided in Table 3.

Table 3 shows that the main difference between the returns-to-scale estimation lies on the 102 branches that were found operating under IRS by the market efficiency and then under DRS by the cost efficiency models. There is also the case of another 120 bank branches that were found scale market efficient but operating under DRS on cost efficiency.

Increasing the size of bank branches that operate under IRS would augment the sales of their products at a rate higher than the rate of input increase. The mathematical formulation of the market efficiency model in (3) makes provision such that the nondiscretionary inputs do not affect the assessment of returns to scale. On the DRS case a proportionate increase of the activities of bank branches would lead into more than proportionate cost increases. The decision makers of the bank would like to know whether their branches have deployed the appropriate scale size (given its input mix) to penetrate their market.

Returns to scale that correspond to cost efficiency have an *intrinsic* orientation seeking to investigate how economic is the scale size of the operation of individual branches, that is, whether the benefits from increasing the branch outputs by expanding their physical size would offset the corresponding cost increases. It is worth clarifying, however, that the output expansion under the market efficiency scenario concerns new sales of financial products while the cost efficiency scenario considers as an additional output the transactions occurring at the branch level. When conflicting results arise between the two characterizations we get the signal that possible expansion of the scale of operation of a branch will add proportionately or disproportionately to the costs of the branch. Statistical analysis has shown that there are statistically significant[10] differences between the returns to scale of each cluster on both market and cost efficiency assessments which reinforces the proposed methodology for clustering the network of branches.

In cluster 1 the trade-offs between cost and market efficiency are concentrated between market efficient branches and branches with DRS on cost efficiency. For about 40 percent of the branches there is scope for increasing their scale of operation on both the market and cost side. For the fifty-two branches that exhibit DRS on cost efficiency any increase of their activities would cost disproportionately higher to the bank. Branches of cluster 1 have relatively smaller size accompanied by a disproportionately high number of transactions given their customer base and sales. Thus the DRS characterization is a result of the indirect services that they provide to the network of the bank and not a result of the relation between their realized sales and their size. Upon further investigation it was found that the branches of this cluster are predominantly located at city centers giving them many interbank transactions for bank accounts that belong to different branches.

Cluster 2 (small account sizes) has revealed considerable IRS on the market efficiency assessment that shows scope for increasing the scale of operation of a number of branches. This picture is reversed, however, in cost efficiency since 60 percent of the branches operate under DRS in a manner similar to cluster 1. The importance of product mix and targeted clientele is highlighted by these contradicting results as these branches should expand their scale of operation targeting new segments of clientele away from the small-depositor accounts which prove to be uneconomical in cost terms.

About 70 percent of the branches in cluster 3 operate under IRS on the market efficiency assessment that emphasizes scale expansion. Branches with accounts of large size, on the other hand, seem to have dispersed cost efficiency as only 13 out of 150 were found to be cost efficient. This phenomenon was further supported by the DRS rating that prevailed in the cost efficiency of 50 percent of the branches. This cluster contains branches with accounts of very large sizes that at the same time have a relatively low number of transactions. Furthermore, the branches are located in affluent areas that do not have passing trade or working population. These characteristics indicate that the low cost efficiency of these branches can be attributed to the cost of quality that are expected to encounter in order to meet the service quality expectations of their large-size depositors.

In the remaining clusters 4, 5, and 6 there is a more compatible correspondence between the market and cost efficiency returns to scale effects. For branches of large size (cluster 4) the DRS on cost efficiency are associated with the large size of the branches that cannot be compensated by the market conditions of individual branches (the same branches were found to be market efficient).

Our nonparametric ratings of economies of scale cannot be contrasted to any previ-

10. ANOVA and Kruskal-Wallis tests were employed to test the hypothesis of significant differences between the average and median scale indicators ($\Sigma_{j=1}^{n} \lambda_j^{k*}$) *within each cluster.*

ous studies in banking other than the very small scale study by Giokas (1991). Some cautionary parallelism only can be made using the results reported by the econometric studies of Doukas and Switzer (1991) and Berger, Leusner, and Mingo (1997) concentrating on the cost efficiency of bank branches. There is an agreement between both methodologies that there are widespread scale inefficiencies at the branch level within banking networks. The disagreement exists, however, between the direction of the scale inefficiencies that was diagnosed. We next discuss some plausible causes of the different scale efficiency assessments. The first is methodological as the econometric studies yield economies-of-scale characterizations based on the aggregate data set while DEA yields local economies-of-scale results based on segments of the efficient frontier of the production possibility set. Banker, Conrad, and Strauss (1986) were the first to report this type of discrepancies between the DEA and econometric methods. The second reason emanates from the setup of our cost efficiency model which contrasts only the operating costs and technology of the bank branches against their volume of services and sales. That is, the scale economies contrast costs against volume of services without direct reference being made to other determinants of branch size.

Finally, reference must be made to the relevance of our results to the proposition of Berger, Hanweck, and Humphrey (1987) and Berger, Leusner, and Mingo (1997) regarding the tendency of bank headquarters to adopt "overbranching" strategies[11] in order to achieve higher market shares. That is, economies of scale at the branch level could lead to diseconomies of scale at the firm level. Our findings support the claim that at the market efficiency level the bank needs to exploit the increasing returns to scale of its branches before new branches are opened. For those branches with DRS at the cost efficiency level, the main cause was that their load of transactions does not indicate the necessity for more branches. This might signal the bank headquarters to exploit methods for reducing the transaction pressures for those branches by investing in new technologies and furthermore to assist branches to utilize their transactions and generate new sales.[12]

3.2 Assessing the Performance of Different Types of Clusters

The decision to group individual branches into homogenous clusters prior to their assessment was made in an attempt to increase the validity of the comparisons between efficient and inefficient branches.[13] The subsequent analysis that focussed on economies of scale and viability assessment has shown statistically significant differences between the profile of those clusters. This comparison, however, has been

11. Decisions regarding the size of branch networks have been studied by Athanassopoulos and Toivannen (1995) and it was shown that diseconomies of scale at the branch level lead to the opening of more branches whilst economies of scale at the branch level are sought to be exploited and thus are disincentives for opening new branches.

12. A limitation of our study is that we could not separate the number of branch transactions that are made with customers of other branches. Had that been possible we could have investigated the extent to which the DRS on cost efficiencies are reinforced by the market inefficiency of these branches.

13. There was vivid evidence from the management of the bank that the efficiency ratings with the pre-DEA clustering were based on more realistic comparisons between efficient and inefficient branches.

TABLE 4

BETWEEN CLUSTERS MARKET AND COST EFFICIENCY (%)

Clusters	Average	Median	Minimum	Lower Quart.	Upper Quart.
MARKET EFFICIENCY					
Cluster 1 (Obs. 90) *Small branch size*	92.34	91.51	72.13	88.55	95.46
Cluster 2 (Obs. 175) *Small account sizes*	93.45	94.23	69.22	88.67	96.78
Cluster 3 (Obs. 150) *Large account sizes*	91.23	91.23	49.45	87.67	92.33
Cluster 4 (Obs. 115) *Large branch sizes*	97.45	98.23	86.26	97.35	100
Cluster 5 (Obs. 30) *Large potential market*	93.45	94.23	78.45	89.67	100
Cluster 6 (Obs. 20) *High competition*	87.45	93.22	68.34	73.88	100
COST EFFICIENCY					
Cluster 1 (Obs. 90) *Small branch size*	88.49	87.77	70.78	85.88	89.88
Cluster 2 (Obs. 175) *Small account sizes*	94.96	96.98	81.08	94.89	100
Cluster 3 (Obs. 150) *Large account sizes*	93.72	91.88	68.77	89.95	96.88
Cluster 4 (Obs. 115) *Large branch sizes*	95.64	97.89	79.86	94.86	100
Cluster 5 (Obs. 30) *Large market potential*	95.88	93.88	79.67	92.88	96.63
Cluster 6 (Obs. 20) *High competition*	88.78	89.98	74.89	86.87	88.98

descriptive using as a basis the efficiency scores of individual branches. One step forward can be made by assessing the competitive advantage of individual clusters using as a basis their efficient frontier and not the efficiency of individual bank branches.

On the methodological side this assessment has similarities with the Charnes, Cooper, and Rhodes (1981) concept of program efficiency and also the Berg et al. (1993) concept of generalized Malmquist indices. Application of the same principles can also be found in Athanassopoulos and Thanassoulis (1995) and Athanassopoulos (1995b). The methodology can be applied to investigate the extent to which specific characteristics such as time, location, service mix, or operating profile give efficiency advantage to branches with these characteristics. In our study, the investigation sought to assess the potential superiority of one cluster of bank branches over the other and it was pursued in two stages as follows: In the first stage the bank branches were assessed for their market and cost efficiency (scale free in both cases) and then their inputs-outputs were adjusted according to their estimated efficient target levels. In the second stage the bank branches were brought within a single cluster, using as inputs/outputs their adjusted levels, and their market and cost efficiency were reassessed. Summary results obtained for the six clusters of the bank branches are listed in Table 4.

The results shown in Table 4 contrast the competitive advantage of individual operating profiles. In the market efficiency assessment cluster 4 (branches with large size characteristics) dominates the remaining five clusters. The worst affected cluster seems to be cluster 6 (high level of competition) which has an average cluster efficiency value below 90 percent. Overall, however, the average market efficiency of individual clusters retained high scores. This result validates further our decision for pre-DEA clustering as the differences between the environmental profile of individual branches prevent widespread cross-cluster comparisons.

Cluster 4 is also the dominant cluster in the cost efficiency assessment. The average efficiency of the remaining clusters took much lower values as compared with the equivalent market efficiency scores. Cluster 1 (small branch size) and cluster 6 are the most cost inefficient clusters, a result that shows that larger bank branches tend to outperform the smaller ones on the cost efficiency side. The problem of the smaller branches is that they do not generate sufficient volume of services in order to explain their level of fixed costs in terms of labor. This observation draws upon the strategy of financial institutions to retain relatively uneconomical branches due to their market share contribution (Berger, Leusner, and Mingo 1997).

4. CONCLUSIONS

This paper sought to investigate issues related to the assessment of performance of bank branches. Market efficiency is put forward as a new dimension of bank branch efficiency which has been systematically neglected by the efficiency assessment literature in banking. A framework where market and cost efficiency are recognized as two complementary components of efficiency was proposed. Nonparametric deterministic frontier analysis models were suggested for assessing site-specific and aggregate market and cost efficiency of bank branches. The application of this framework on a large scale was made by grouping the bank branches into clusters of homogeneous operating profiles.

The results obtained have shown a site-specific and aggregate average market efficiency of 90 percent and 85 percent respectively which shows scope for improving the sales performance throughout the bank branch network. Considerable inefficiencies were also found on the site-specific (88 percent) and aggregate (82 percent) cost behavior of branches. The assessment has also concentrated on the presence of economies of scale while the cluster profiles of bank branches were compared for their market and cost efficiency. This indicated diverse competitive advantage prospects across the different clusters.

The definition of market efficiency as a key component of bank branch operations alongside with the traditional definition of cost efficiency offers an improved framework for assessing performance of banking institutions. Future research should touch upon the effects of product mix and economies of scope on the assessment of market and cost efficiency of bank branches. Another direction could also be the incorporation and assessment of service quality as a further performance indicator in the operations of bank branches.

APPENDIX

A. Factor Analysis Results

Original variable	Factor 1	Factor 2	Factor 3	Factor 4
	Factor loadings after quadrimax rotation			
Average size of mortgage sales (in £)	0.444	0.254	−0.364	0.628
Average size of investment sales (in £)	−0.070	−0.149	−0.042	0.938
Size of customer base	0.012	0.908	0.233	−0.120
Branch size in square feet	0.164	0.607	0.258	0.077
Market potential: savings accounts (£)	0.014	0.266	0.859	−0.165
Market potential: mortgage accounts (£)	0.242	0.282	0.837	−0.037
Number of counter transactions	0.005	0.943	0.065	−0.023
Number of own branches within 0.5 km	0.724	−0.047	0.204	0.045
Number of own branches within 1.0 km	0.952	−0.011	−0.058	0.010
Number of own branches within 1.5 km	0.927	0.017	−0.221	−0.036
Number of competitors within 0.5 km	0.529	0.165	0.680	0.067
Number of competitors within 1.0 km	0.911	0.106	0.321	0.008
Number of competitors within 1.5 km	0.942	0.079	0.097	−0.035
Proportion of variation explained	*43.8%*	*23.7%*	*11.9%*	8.6%

B. Inputs-Outputs for DEA Models

Number of transactions	Counter transactions with customers.
Potential market	This variable is based upon the location of account holders at each branch combined with information about the total sales of mortgages and saving accounts segmented into post code areas.
Sales representatives	This variable accounts only for the staff authorized to negotiate and sell financial products of the bank.
Internal automatic facilities	It accounts the number of on-line terminals and also the number of PC terminals installed in the branch concerned.
Total technology facilities	Internal automatic facilities plus the number of ATMs
Number of branches	This variable accounts all bank branches (of the same or competing banks) in the surrounding area of individual branches.
Direct labor costs	The cost of labour per branch with the values of the branches in the London area being adjusted for the regional variation of wages.
Liability sales, loans and mortgages, insurances and securities, and number of cards	Account for the sales of new products sold which are taken as number of contracts and not with their economic value.

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