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Efficiency of labour use in the Swedish banking industry: a stochastic frontier approach*

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Abstract. The purpose of this paper is to analyse the impact of the deregulation of the Swedish banking industry in the mid-1980s, and the consequent banking crisis, on productive efficiency and productivity growth in the industry. An unbalanced panel of Swedish banks is studied over the period, 1984 to 1995. A total of 1275 observations are analysed for 156 banks that were observed for between two and twelve years. We adopt a translog stochastic frontier model to estimate the labour-use requirements in terms of the variables, loans, deposits, guarantees, number of branches and total inventories, together with the year of observation. The inefficiency effects in the labour-use frontier are modelled in terms of the number of branches, total inventories, the type of bank and year of observation. The technical inefficiencies of labour use of Swedish banks were found to be significant, with mean inefficiencies per year estimated to be between about 8 and 15 per cent over the years of study. However, the confidence interval predictions for these inefficiencies were found to be quite wide.

Key words: Labour demand, labour-use, technical efficiency, banking industry

JEL Classification: C23, D24, G21

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1. Introduction

As in many other countries, the banking industry in Sweden was deregulated in the mid-1980s. Prior to 1985, the Swedish Central Bank (Riksbanken) imposed limitations on the amount by which banks could expand their loan portfolios each year and the interest rates for bank loans were strictly regulated. The competitive pressure was weak. The abolition of the official guidelines for Swedish banks led to a dramatic increase in lending by the banks, many of which embarked on a strategy of rapid growth without effective risk management. The Swedish tax rules, in combination with relatively high inflation and rising property values, created an excess demand for loans that was then to a large extent satisfied. Therefore, this strategy made the banks vulnerable to market volatility and policy shifts. The combination of radical tax reform in 1990, which limited the tax deductibility of interest payments, and the high interest rates since early 1990, contributed significantly to a collapse (about 50% decrease) in real estate values. The crisis was at its apex in the fall of 1992, when the government, as an emergency measure, introduced guarantees for the entire liability side of the balance sheets of Swedish banks (see Macey (1994) for a review of the Swedish banking industry).

Cost cutting, mergers and acquisitions followed the financial disruptions that occurred after 1992. The financial situation of the banks gradually improved. At the same time, the banking industry was internationalised, with a slowly growing international competition domestically and establishment of offices abroad. However, the competitive pressure was quite weak, and most "crisis banks" were able to recover financially. The rapid return of Swedish banks to profitability suggests that the crisis was attributable to liquidity problems rather than insolvency, in a balance sheet sense.

Berger and Humphrey (1997) reported that of the 122 efficiency analyses of depository financial institutions, covering 21 nations, rather few studies have evaluated the performance of the banking industry during a period of deregulation. The purpose of this paper is to analyse the impact of the deregulation and the consequent banking crisis on productive efficiency and productivity growth in Swedish banking using a stochastic frontier analysis (SFA). We adopt a translog stochastic frontier input-requirement function to estimate labour use to benchmark the relative performance of Swedish banks. The input-requirement frontier is expressed in terms of the five variables, total loans to the public, deposits, guarantees, the number of branches and the total inventories, together with the year of observation. The inefficiency effects in the input-requirement frontier are also modelled in terms of the number of branches, inventories, the type of bank and the year of observation. Only about 20 per cent of the studies cited by Berger and Humphrey (1997) used a stochastic frontier approach, but none of these sought to explain the variations of the inefficiency effects in terms of other variables, in a single-stage approach, as in this paper. One weakness of our approach is that, if the functional form is misspecified, the measured efficiency may be confounded with the specification errors.

The very popular non-parametric method, data envelopment analysis (DEA), is a major competing approach to stochastic frontier analysis. This approach imposes less structure on the frontier but it does not allow for random errors. It is not possible to determine which of the two major approaches dominates the other because the true level of efficiency is unknown. In DEA, all deviations from the frontier are interpreted as inefficiency, and so the SFA approach normally yields lower inefficiency levels.

2. Data on Swedish banks

The data used in our analysis were obtained from the annual reports of the banks in Sweden. Thus the data are not from a sample, but effectively consist of the population of Swedish banks. The data involved are for the years, 1984 to 1995. Over this time, some banks ceased to exist and others were established. Some of the changes in the banks have been due to amalgamations of banks or takeovers.

The variables obtained from the annual reports were not as detailed or disaggregated as desirable for a more complete analysis. The data were obtained at the bank level, rather than at the individual branch level. Hence, the large national banks that have a large number of branches report the data for the bank at the aggregative level. Other small regional banks may involve only one branch, and so the data are for those banks that are identical to branches.

The variables, whose values are used in our analysis, include total labour used (in hours per year), deposits, public loans, guarantees, inventories, number of branches and type of bank. Data on "Other Loans" and "Other Costs" were considered in preliminary analyses, but these variables were subsequently deleted because it was evident that there were problems with these data, perhaps due to different accounting procedures being used over the years involved. Data on variables, originally expressed in current money values, were deflated using the Consumer Price Index (CPI) so that they are expressed in terms of values for 1980 (the base year of the CPI).

Data for several small banks were deleted from our analysis because the values of one or more of the variables were missing or were clear outliers. This was particularly the case with some banks with only one or two part-time employees. A total of 1275 observations for 156 banks are used in the analyses reported below.

In the first year of our study, 1984, the number of banks in the data set was 140. The maximum number of the 156 different banks observed in any particular year was 146 in 1985, after which the total number of banks declined steadily to 115 in 1990. In 1991, there was a somewhat dramatic decline in the number of banks to 85, after which the number declined steadily to 65 in 1995. The numbers of banks observed in the data set, in the 12 individual years, are depicted in Figure 1.

The number of observations obtained for any given bank varied between two and twelve years. A total of 59 (about 38 per cent) of the banks were observed in all 12 years. The median number of times banks were observed in the data set was seven years. Observations are available on the banks for a consecutive number of years, except for two banks, which had missing data during years when they were operating.

The analysis of the changes in ownership, the decline in the number of banks, etc., would be interesting studies in their own right. However, we estimate the efficiency of labour use of Swedish banks, using the data from the annual reports, without associating continuing banks with those that were amalgamated.

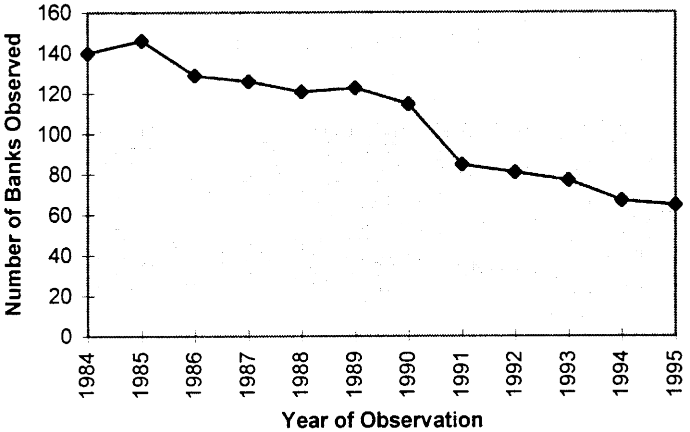

Fig. 1. Number of the 156 Banks Observed in the Years, 1984–1995

Labour use is a key variable in the efficiency of the Swedish banking industry, because it is a significant component in the cost structure of the banks. The focus of this study is the efficiency of the use of labour in producing the levels of public loans, guarantees and deposits, given the values of the quasi-fixed inputs, number of branches and total inventories.

In some studies of the efficiency of banks, deposits are considered as an input, along with labour and capital (eg., Altunbas, 1997). These studies follow the financial intermediation approach, proposed by Sealey and Lindley (1977). However, we use an input-requirement frontier model, in which the amount of labour used is a function of the variables, public loans, guarantees and deposits, which we refer to as outputs, and the quasi-fixed inputs, number of branches and total inventories. The issue of whether deposits are inputs or outputs only influences our analysis in the estimation of the returns to scale of the input-requirement function.

A basic summary of the values of the variables in our data set is in Table 1. The amount of labour used varied from about 800 to over 20 million employee hours per year. This reflects the fact that there are some very small regional banks, together with some very large national ones. The values of public loans, guarantees and deposits also indicate the considerable variation in the size of the banks in the data set. The average number of years for which the banks were observed was about 10 years.

3. Stochastic frontier labour-use model

We assume that the following translog stochastic frontier model defines the labour use for the 156 banks in our data set[1]

[1] Frequently, cost functions are estimated under the assumption that the translog form, involving costs of inputs and quantities of outputs, applies [eg., Beattie and Taylor (1985, pp. 247–9) and Coelli, Rao and Battese (1998, pp. 53–6)]. The input-requirement functions are then obtained from the cost function using Shephard's Lemma. In the absence of data on input prices, we consider a translog input-requirement function that is a function of only outputs and quasi-fixed inputs.

Table 1. Summary statistics for variables on Swedish banks, 1984–95

Variable*	Mean	Stand. Dev'n	Minimum	Maximum
Labour	646,827	2,157,815	827	20,534,000
Public Loans	2,616,276	10,251,004	3,686	106,140,351
Guarantees	565,075	2,612,723	0**	27,855,010
Deposits	2,739,946	9,822,914	6,507	73,550,101
Branches	29.4	81.9	1	700
Inventories	10,354	34,667	1.6	356,514
Year of Obs.	5.6	3.3	1	12
Obs./Bank	9.8	2.9	2	12

* The monetary variables are measured in thousands of Swedish kronor (SEK), expressed in 1980 values. Labour is in hours. The other variables are in units. All variables are given per bank.
** Four per cent of the observations were reported to have zero guarantees.

$$\ell n Y_{it} = \beta_0 + \beta_0^* D_{it} + \sum_{j=1}^{6} \beta_j x_{jit} + \sum_{j\leq}^{6} \sum_{k=1}^{6} \beta_{jk} x_{jit} x_{kit} + V_{it} + U_{it}, \tag{1}$$

where the subscripts, i and t, represent the i-th bank ($i = 1, 2, \ldots, 156$) and the t-th year of observation ($t = 1, 2, \ldots, 12$), respectively;

Y represents the total quantity of labour used (in hours per year);
D is a dummy variable for guarantees, which has value one if guarantees were zero or not observed, and zero, otherwise;[2]
x_1 is the logarithm of the total amount of public loans (in SEK1,000);
x_2 is the logarithm of the *maximum* of the guarantees (in SEK1,000) and D;
x_3 is the logarithm of deposits (in SEK1,000);
x_4 is the logarithm of the number of branches;
x_5 is the logarithm of the value of inventories (in SEK1,000);
x_6 is year of observation, where $x_6 = 1, 2, \ldots, 12$ for the 12 years involved;

the $V_{it}s$ are random variables, associated with measurement errors in the labour variable or the effects of unspecified explanatory variables in the model, which are assumed to be independent and identically distributed with $N(0, \sigma_v^2)$-distribution, independent of the $U_{it}s$;
the $U_{it}s$ are non-negative random variables, associated with the inefficiency of the use of labour in the banks, given the levels of the outputs and the quasi-fixed inputs, and U_{it} is obtained by the truncation (at zero) of the $N(\mu_{it}, \sigma^2)$-distribution;

$$\mu_{it} = \delta_0 + \sum_{j=1}^{4} \delta_{0j} D_{jit} + \sum_{j=1}^{4} \delta_j z_{jit} \tag{2}$$

where the $D_j s$ are dummy variables having value one, if the observation in-

[2] Some small banks had zero guarantees, as indicated in Table 1. The variable, D, permits the intercepts to be different for banks with positive and zero guarantees, see Battese (1997).

volved is on a bank of types 1, 2, 3 and 4, respectively, and zero, otherwise;[3] and

z_1 is the logarithm of the number of branches (i.e., $z_1 = x_4$);
z_2 is the logarithm of the total inventories (i.e., $z_2 = x_5$);
z_3 is the year of observation involved (i.e., $z_3 = x_6$); and
z_4 is the square of the year of observation (i.e., $z_4 = z_3^2$).

This is a *frontier* model because the non-negative random variable, U_{it}, in equation (1), implies that the observed labour hours, associated with the given level of outputs and quasi-fixed inputs, are not as small as would be possible if the banks were fully efficient in their use of labour. The flexible functional form of the translog function is specified in equation (1) so that more general technologies can be accounted for than is possible with the Cobb-Douglas model.[4] The model incorporates non-neutral technical change in the use of labour in the production of the outputs, given the quasi-fixed inputs used in the banking operations.

The model for the inefficiency effects in equation (2) specifies that the inefficiency effects are different for different types of banks and that they depend on the number of branches in the banks, total inventories and the year of observation. The inefficiency effects are assumed to change in a quadratic fashion over time. This parametric model permits the estimation of productivity growth by obtaining the derivative of the logarithm of the mean labour use with respect to time. The rate of productivity growth can be decomposed into technical change and inefficiency changes over time, provided the inefficiency effects are stochastic and have the assumed distribution.

The labour-use frontier, defined above, is a development of the stochastic frontier model, originally proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), to account for random errors, in addition to the non-negative technical inefficiency effects. Most applications of frontier models have involved production functions, in which the inefficiency effect is subtracted, because observed outputs are no larger than their corresponding stochastic frontier outputs, because of technical inefficiency of production. The model of equations (1) and (2) is an input-requirement counterpart of the stochastic frontier production function model, proposed by Battese and Coelli (1995).

The parameters of the stochastic frontier model, defined by equations (1) and (2), are simultaneously estimated by the method of maximum likelihood using the computer program, FRONTIER 4.1, written by Coelli (1996).[5] The variance parameters in the frontier model are estimated in terms of the vari-

[3] Bank types 1, 2, 3 and 4 were Föreningsbanken, Handelsbanken, Sparbanken and SE-banken, respectively. SE-banken and Handelsbanken are the largest commercial banks in Sweden with many branches. Föreningsbanken, a co-operative bank, and Sparbanken, the savings banks, merged in 1997. The reference type of bank was "Other Banks", being all other commercial banks.

[4] Recently, the Fourier flexible functional form has been used in several studies of bank efficiency, eg., Altunbas (1997), Berger and Humphrey (1997) and Mitchell and Onvural (1996).

[5] FRONTIER 4.1 can be downloaded from the Internet by accessing the address for the Centre for Efficiency and Productivity Analysis at the University of New England, Armidale, NSW, Australia: http://www.une.edu.au/econometrics/cepa.htm

ance parameters

$$\sigma_s^2 = \sigma_v^2 + \sigma^2 \quad \text{and} \quad \gamma = \sigma^2/\sigma_s^2 \tag{3}$$

where γ is a parameter that has possible values between zero and one. Tests of hypotheses, involving the parameters of the stochastic frontier model, can be obtained using the generalised likelihood-ratio statistic.

The technical efficiency of labour use for the i-th bank in the t-th year of observation, given the values of the outputs and quasi-fixed inputs, is defined by the ratio of the stochastic frontier labour use to the observed labour use. The *stochastic frontier labour use* is defined by the value of labour use if the technical inefficiency effect, U_{it}, was zero (i.e., the bank was fully efficient in the use of labour). Given the specifications of the translog stochastic frontier labour-use function in equation (1), the technical efficiency of labour use is defined by

$$TE_{it} = \exp(-U_{it}) \tag{4}$$

which indicates that the technical efficiency is no greater than one. The reciprocal of this quantity, $\exp(U_{it})$, is no less than one, and can be interpreted as a measure of the *technical inefficiency* of labour use.[6] This is the quantity actually computed in FRONTIER 4.1.

4. Empirical results

4.1. Estimates and tests

The maximum-likelihood estimates for the 40 parameters in the translog stochastic frontier labour-use function, defined by equations (1) and (2), obtained using the "cost function" option in FRONTIER 4.1,[7] are presented in Table A.1 of the Appendix. The coefficients of the first-order terms in the translog function are not elasticities of labour use with respect to the outputs and the quasi-fixed inputs. Elasticity parameters are estimated after considering some tests of hypotheses below.

Because the labour-use frontier model involves a large number of parameters, tests of several null hypotheses, concerning the nature of the frontier model, are first considered to decide if a simpler model would be an adequate representation of the data, given the specifications of the translog stochastic frontier labour-use model. The null hypotheses involved, the corresponding test statistics, and the conclusions obtained, are given in Table 2.

The first null hypothesis in Table 2 specifies that the second-order coefficients in the translog function are equal to zero, and hence the Cobb-Douglas function applies. The value of the generalised likelihood-ratio statistic, 465.3, is much larger than 32.67, the upper five per cent point for the

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[6] More precisely, the amount by which $\exp(U_{it})$ *exceeds one* is a measure of technical inefficiency of labour use, because it gives the proportion by which the actual labour use exceeds the corresponding stochastic frontier labour value, given the level of the outputs and quasi-fixed inputs.

[7] This option in FRONTIER 4.1 assumes that the frontier function has the non-negative inefficiency effect *added*, which is the case if a cost frontier was being estimated.

Table 2. Generalised likelihood-ratio tests of null hypotheses for parameters of the translog stochastic frontier model for labour use in Swedish banks

Null Hypothesis, H_0	Test Statistic, λ	Critical Value
H_0: $\beta_{ij} = 0,\ i \le j = 1, 2, \ldots, 6$	465.3	32.67
H_0: $\beta_{i6} = 0,\ i = 1, 2, \ldots, 5$	29.5	11.07
H_0: $\gamma = \delta_0 = \cdots = \delta_4 = 0$	669.1	17.67*
H_0: $\delta_{01} = \cdots = \delta_4 = 0$	113.2	15.51

* This critical value is obtained from Table 1 of Kodde and Palm (1986) because $\gamma = 0$ is on the boundary of the parameter space and the asymptotic distribution of the generalised likelihood-ratio statistic is a mixed Chi-square distribution with degrees of freedom equal to 10, if H_0 is true.

χ^2_{21}-distribution. Thus the Cobb-Douglas function is not an adequate representation of the data on the Swedish banks, given the specifications of the translog stochastic frontier labour-use function.

The second null hypothesis specifies that the interaction terms involving year of observation are zero, and so there is *neutral* technical change in labour use, relative to the outputs and quasi-fixed inputs. This null hypothesis is also rejected by the data.[8]

The third hypothesis considered in Table 2 is that the inefficiency effects in the labour-use function are not present in the model, and so the banks are fully technically efficient in their use of labour. This null hypothesis is strongly rejected by the data.

The last null hypothesis in Table 2 specifies that the coefficients of all the eight explanatory variables in the inefficiency model (2) are simultaneously equal to zero, and so these variables are not useful in describing the inefficiencies of labour use in Swedish banks. This hypothesis is also strongly rejected by the data.

The above results imply that the model for describing the labour use in Swedish banks cannot be adequately specified in terms of a simpler model associated with these null hypotheses, given the specifications of the translog stochastic frontier labour-use model, defined by equations (1) and (2).

Given the model for the inefficiency effects in the labour-use function, defined by equation (2), the δ-estimates are of particular interest. The maximum-likelihood estimates, expressed in equation form, (with estimated standard errors in brackets) are

$$\begin{aligned}\hat{\mu} = {} & \underset{(0.15)}{1.791} - \underset{(0.12)}{1.954}D_1 - \underset{(0.33)}{0.886}D_2 - \underset{(0.089)}{1.701}D_3 + \underset{(0.17)}{1.579}D_4 \\ & + \underset{(0.027)}{0.1971} \times \ln(\text{Branches}) - \underset{(0.020)}{0.4666} \times \ln(\text{Inventories}) \\ & + \underset{(0.029)}{0.2706} \times \text{Year} - \underset{(0.0029)}{0.0161} \times (\text{Year})^2. \end{aligned} \tag{5}$$

The estimated coefficients are large, relative to their standard errors, which is consistent with the rejection of the null hypothesis that the true values are

[8] The null hypothesis of no technical change, H_0: $\beta_6 = \beta_{i6} = 0, i = 1, 2, \ldots, 6$, was also rejected.

zero. These results indicate that the inefficiency effects for labour use by the banks tended to be

- smaller for the banks, Föreningsbanken, Handelsbanken and Sparbanken (bank types 1, 2 and 3, respectively) than for "Other Banks";
- larger for SE-banken (bank type 4) than for "Other Banks";
- larger for banks with larger numbers of branches;
- smaller for banks with larger total inventories; and
- increase until about 1991 and then decrease.[9]

Because the stock of inventories is measured by book values, it also reflects the modernity of these and especially computer equipment with short depreciation periods. Thus, the inefficiency-reducing effect of inventories should reflect the productivity-enhancing effect of more modern computer equipment.

The estimate for the γ-parameter of 0.8791, with estimated standard error of 0.0090, implies that the variance of the inefficiency effects is a significant component of the total of the variances of the error terms.[10]

4.2. Technical inefficiency of labour use

The predicted technical inefficiencies of labour use were obtained, but are not presented in this paper. These individual technical inefficiencies ranged from 0.0% to 165.6%. Thus, one bank was estimated to be fully technically efficient in labour use in at least one year, but another bank was estimated to use about 166% *more labour* than for a fully efficient bank with the same level of outputs and quasi-fixed inputs. The arithmetic average of the 1,275 technical inefficiencies for the 156 banks was 11.7%, with a standard deviation of 13.0%.[11] Confidence predictions for the technical inefficiencies were obtained using a similar approach to that of Horrace and Schmidt (1996), as outlined in the Appendix.

The *mean* technical inefficiencies of labour use for the 156 banks ranged from 0.0% for a bank, that was fully efficient for the first two years of the study, to 69.2% for a bank, that was observed for the first six years of the study period. Out of thirteen banks with technical inefficiency of labour use greater than 20% in the last year they were observed, ten disappeared from the data set before 1995. Of the three surviving banks, two were savings banks and the other was a recently started international bank with a non-typical output structure.

As indicated in Figure 2, the mean technical inefficiencies of labour use for the Swedish banks tended to increase from 1984 to 1991, the period of rapid

[9] The mean function, μ_{it}, is estimated to have a maximum value with respect to year of observation when the (coded) year is equal to $\{0.2706/(2 \times 0.0161)\} = 8.4$. This implies the maximum is between the years, 1991 and 1992.

[10] It is noted that γ is not correctly interpreted as the ratio of the variance of the inefficiency effect, U_{it}, to the sum of the variances of U_{it} and V_{it}, because σ^2 is the variance of the normal distributions *before truncation* (at zero) to obtain the distributions of the U_{it}s.

[11] A weighted average of the technical inefficiencies would be a better measure for the whole banking industry, given that the weights were proportional to a measure of the size of the banks involved.

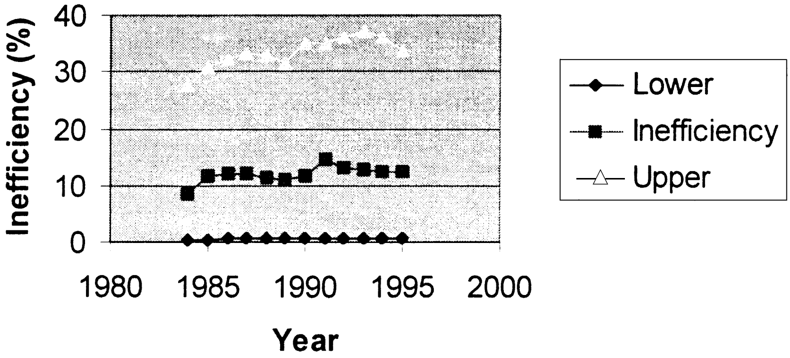

Fig. 2. Mean Technical Inefficiency of Labour Use in Swedish Banks

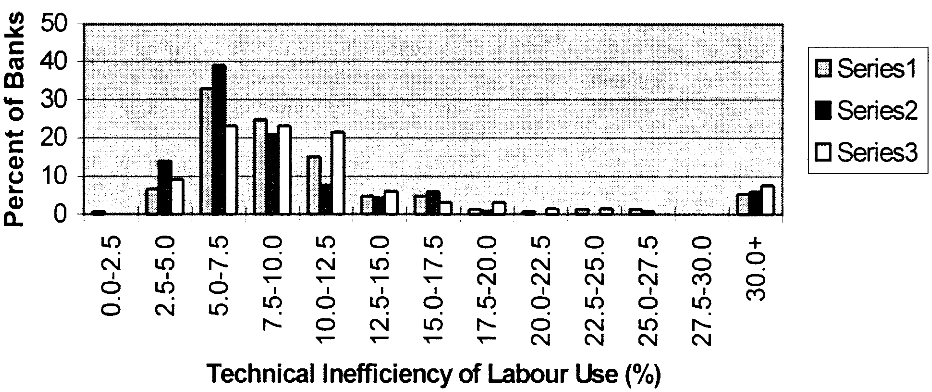

Fig. 3. Distributions of Technical Inefficiency of Labour Use of Swedish Banks in 1985, 1990 and 1995

expansion when the banks were in vigorous competition for market shares. After the crisis in 1992, the mean technical inefficiencies decreased slowly. However, there was a slight increase in the level of mean technical inefficiency of labour use over the twelve-year period. Further, it is clear from Figure 2 that the 90% confidence interval predictions for the mean technical inefficiencies are wide intervals. The width of the confidence predictions tended to increase until 1992, when the interval was (0.7%, 36.0%), after which the confidence intervals tended to decrease in width to (0.6%, 33.7%) in 1995. These are probably *conservative* interval predictions, except that they do not account for sampling variability of the estimators for the parameters of the stochastic frontier model.

The frequency distributions of the technical inefficiencies of labour use for the banks are presented in Figure 3 for the years, 1985, 1990 and 1995, to indicate the patterns over the study period. These distributions show that there were some differences in the relative frequency of technical inefficiency of labour use, especially in the lower ranges of inefficiencies. This figure also indicates that there was a somewhat larger proportion of less efficient banks in

Table 3. Mean technical inefficiency of labour use by bank type, 1984–95

Type of Bank	Mean Tech Ineff (%)	Interval Prediction (%)
1: Föreningsbanken (FB)	5.4	(0.3, 20.6)
2: Handelsbanken (HB)	7.3	(0.4, 22.5)
3: Sparbanken (SB)	11.3	(0.6, 32.3)
4: SE-banken (SE)	30.4	(1.7, 81.9)
5: Other Banks (OB)	19.2	(1.0, 47.9)

1995 than in the earlier years. It is evident that there were some banks that had quite large technical inefficiencies of labour use (greater than 30%) in all the three years involved.

The mean technical inefficiencies of the five types of banks, considered in the study, are given in Table 3, together with the 90% confidence interval predictions. The difference between the two largest commercial banks, Handelsbanken and SE-banken, is striking. While Handelsbanken had technical inefficiencies of labour use below 10% for all years, SE-banken exceeded 20% for all years, except 1984. During the banking crisis, Handelsbanken was never perceived as a crisis bank while SE-banken was. One reason for the somewhat lower loan losses at Handelsbanken, compared with SE-banken and certain other Swedish banks, is usually attributed to the fact that Handelsbanken never abandoned its local branch networks as sources of decision-making about credit allocation. Moreover, the strong local authority at Handelsbanken branch offices was combined with their advanced system of profit-sharing for all bank staff.

Among the savings banks, there was substantial variation in technical inefficiency of labour use not reflected in the aggregative figure in Table 3. Most of those banks were local or regional banks operating as not-for-profit organisations. The same holds for the local or regional branches of Föreningsbanken. This bank specialised in credit to agriculture and small-scale firms before it merged with the largest savings bank in 1997.

Reasons for these differences in the efficiencies of labour use by the different types of banks merit further study. However, in comparison with many other industries, one should also expect a lower degree of mean efficiency and a larger dispersion in efficiency scores, i.e., between best practice and worst practice in the banking industry. The main reason for this is the rather low competitive pressure in the banking industry, in combination with different types of ownership and objectives for commercial banks, cooperative banks and not-for-profit savings banks. In a similar study, based on a small sample of savings banks, observed during 1990 to 1994, Heshmati (1997) found that the inefficiencies of labour use varied in the interval 0–12%. On average the savings banks over-used labour by about 5%.

4.3. Elasticities of labour use

For the translog stochastic frontier labour-use model (1)–(2), the elasticities of mean labour use are estimated for the three output variables, public loans, guarantees and deposits. The returns-to-scale parameter for the labour-use function is estimated by the *reciprocal* of the sum of these three output elas-

Table 4. Mean elasticities, returns to scale, technical change and technical inefficiency change by year and bank type

Code	ploan (x_1)	garan (x_2)	depos (x_3)	branch (x_4)	invent (x_5)	tech (TC)	ineff (IC)	rts
Means by year:								
1984	0.416	0.012	0.470	0.068	0.073	−0.015	0.010	1.148
1985	0.398	0.013	0.492	0.061	0.073	−0.012	0.011	1.141
1986	0.409	0.011	0.479	0.071	0.069	−0.009	0.011	1.162
1987	0.407	0.006	0.461	0.086	0.075	−0.008	0.010	1.198
1988	0.397	0.000	0.451	0.099	0.085	−0.008	0.008	1.358
1989	0.377	−0.001	0.459	0.111	0.087	−0.007	0.006	1.326
1990	0.330	0.002	0.519	0.102	0.090	−0.006	0.003	1.295
1991	0.307	0.009	0.552	0.110	0.074	−0.004	0.001	1.234
1992	0.257	0.017	0.602	0.108	0.069	−0.004	−0.002	1.221
1993	0.201	0.029	0.669	0.105	0.055	−0.000	−0.004	1.161
1994	0.181	0.035	0.694	0.102	0.054	−0.000	−0.006	1.146
1995	0.170	0.032	0.682	0.106	0.074	−0.001	−0.008	1.178
Means by bank type:								
FB	0.278	0.019	0.620	−0.022	0.098	−0.008	0.003	1.100
HB	−0.175	0.039	0.790	0.155	0.083	0.014	0.001	1.534
SB	0.378	0.014	0.518	0.082	0.069	−0.008	0.005	1.128
SE	−0.141	0.004	0.571	0.326	0.033	−0.015	0.011	2.378
OB	0.145	−0.026	0.456	0.241	0.121	−0.005	0.009	2.102
Overall Means and Standard Deviations:								
Mean	0.344	0.012	0.523	0.091	0.075	−0.007	0.005	1.217
Std dev	0.232	0.027	0.170	0.124	0.053	0.012	0.011	0.530

ticities.[12] In addition, we estimate the elasticities of mean labour use with respect to the quasi-fixed inputs, number of branches and total inventories. Because these latter two variables are involved in *both* the stochastic frontier labour-use function (1) *and* the model for the inefficiency effects (2), the calculations of the elasticities are similar to those used in Battese and Broca (1997), as outlined in the Appendix. All the above elasticities were estimated for the individual banks at their observed values of the outputs and quasi-fixed inputs. The averages of these quantities over years of observations and for bank types are presented in Table 4.

The elasticities of mean labour use with respect to deposits were greatest and tended to increase over the years, which indicates that as deposits become larger the responsiveness of labour use was greater over time. The elasticities of mean labour use with respect to public loans were relatively large and tended to decrease over the years. The elasticities of mean labour use with respect to guarantees were estimated to be only slightly positive (except for 1989 when a very small negative value was obtained).

The returns to scale were estimated to be greater than one for all years. This indicates that there were increasing returns to scale in labour use with respect to the three outputs, i.e., increasing the outputs by 1% would require a less than 1% increase in the use of labour. The elasticities of mean labour use

[12] In some banking efficiency studies, the number of branches is treated as an output variable. In these cases, the returns to scale would involve the elasticity of number of branches.

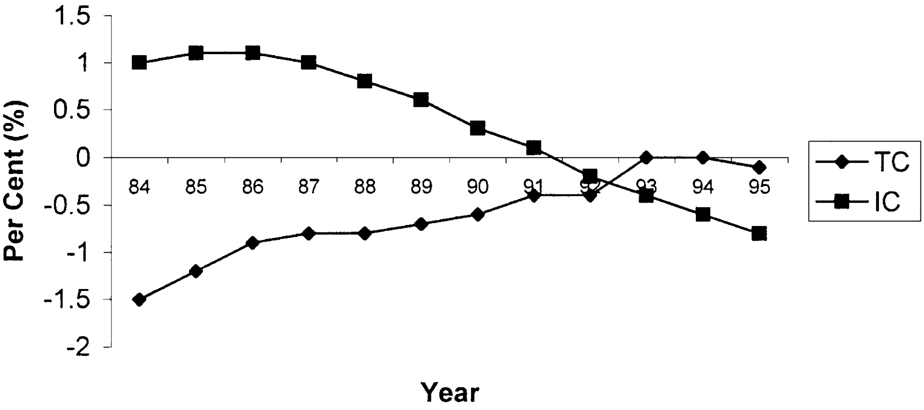

Fig. 4. Technical Change (TC) and Inefficiency Change (IC) in Labour Use by Swedish Banks, 1984–1995

with respect to branches and total inventories were fairly constant over the years.

The elasticities of mean labour use by the different types of banks give quite different results. Föreningsbanken (FB), Sparbanken (SB) and "Other Banks" (OB) had positive elasticities with respect to public loans, but Handelsbanken and SE-banken had negative values. The reasons for these differences merit further study. The returns to scale for SE-banken and "Other Banks" were unusually large.

4.4. Technical change and inefficiency change

Technical change and technical inefficiency change for labour use are separate components of the rate of change of mean labour use with respect to time. The values of technical change and inefficiency change over the 12 years are plotted in Figure 4. The rate of technical change in labour use (TC in Table 4) is estimated to be negative, but small in absolute values, for all years. This indicates that there was modest technical *progress* in the *frontier* labour use during the years of our study. Starting at technical progress of 1.5% in 1984, the industry continued to have technical progress, but at a decreasing rate, until 1992, when the technical progress in labour use was effectively exhausted. Among the bank types, only Handelsbanken experienced technical *regress* in labour use over the entire period.

The change in the inefficiency of labour use over time (IC in Table 4) was positive during 1984 to 1992. This indicates that the inefficiency of labour use increased over those years (cf. Figure 2). Thus the "average" banks did not manage to "catch up" with the labour-use frontier that was showing technical progress. However, when technical progress in labour use was effectively exhausted in 1992, the banks began to "catch up", i.e., the distance between observed labour use and the best-practice labour use decreased somewhat. The dynamic interplay between changes in the frontier (technical change) and changes in inefficiency is discussed in more detail in Hjalmarsson (1973),

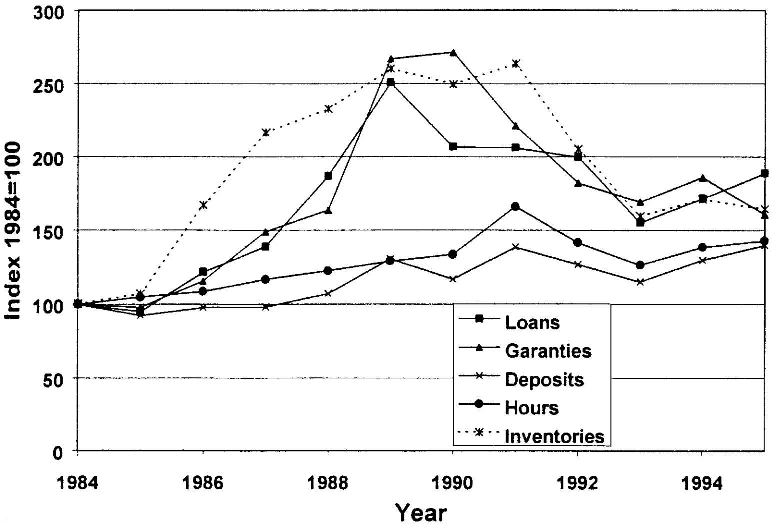

Fig. 5. Development of mean output and mean input.

Førsund and Hjalmarsson (1974) and Førsund, Hjalmarsson and Summa (1996).

One might have expected a much stronger impact of the deregulation and banking crisis on the efficiency of labour use in Swedish banks. An important reason, why this did not occur, might be the rapid return of Swedish banks both to profitability and access to capital markets. Most of the so-called "crisis banks" recovered rather rapidly and some were able to raise money from the capital market as early as 1993. Moreover, the competitive pressure from abroad remained weak.

What is most surprising is the technical change of labour use at the frontier, which ceased in 1992. To a large extent, this result is driven by changes in the outputs. Figure 5 shows the relative movements of outputs, inventories and labour hours over the period of our study. The statistics in Figure 5 are expressed relative to 100 at the branch level. A major reason for the banking crisis in 1992 was the dramatic increase in the real rate of interest causing large changes in household and company portfolios with extensive repayment of old loans and less demand for new loans. Although deposits decreased somewhat in 1992, public loans, guarantees and inventories decreased substantially, and adjustments in the labour use was not at the same rate.

5. Conclusions

The stochastic frontier labour-use model, specified to investigate the labour use in Swedish banks, indicates that there are significant technical inefficiency effects for labour use in the banks. In addition, the different types of banks, number of branches, total inventories and year of observation significantly affect the level of the inefficiencies of labour use. The inefficiency of labour use varied considerably for different banks over the twelve years, but the overall inefficiency was estimated to be about 12 per cent. This implies that the banks, on average, were using about 12 per cent more labour than if they were fully efficient, given the level of the outputs and the quasi-fixed inputs considered. There were a large number of banks that had very high levels of labour inefficiency in some of the years, including some with high inefficiencies in the last year of the study period. However, caution should be exercised in interpreting the technical inefficiencies of labour use, because the reported confidence interval predictions are quite wide. It is desirable to develop more precise interval predictions to enable more definite conclusions on inefficiency.

An unexpected pattern emerged concerning the impact of the deregulation and the banking crisis in 1992. There was a decrease in the use of labour at the frontier (technical change) but an increase in the technical inefficiency of labour use during 1984 to 1992, after which the inefficiencies decreased. While the development of inefficiency seems to be driven by the frontier change, the change in the frontier is to a large extent driven by the trends in the outputs. Dramatic increases in the real rate of interest caused large changes in household and company portfolios with extensive repayment of old loans and less demand for new loans. The banks did not manage to adjust their labour use in proportion to the decline in outputs, resulting in technical progress being exhausted by 1992.

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Appendix

The stochastic frontier model is defined by

$$\log Y_i = x_i\beta + V_i + U_i$$

where the V_is are iid $N(0, \sigma_v^2)$ independent of the U_is, which are independent non-negative random variables, such that U_i is obtained by truncation (at zero) of the normal distribution with mean, μ_i, and variance, σ^2, where $\mu_i = z_i\delta$.

1. Calculation of confidence interval predictions

Given the distributional specifications for U_i, it can be shown that a $(1-\alpha)$ 100% confidence predictor for U_i is defined by $[U_i(\text{lower}), U_i(\text{upper})]$, where $U_i(\text{lower})$ and $U_i(\text{upper})$ are defined by

$$U_i(\text{lower}) = \mu_i + \sigma\Phi^{-1}[1 - (1 - \alpha/2)\Phi(\mu_i/\sigma)]$$

$$U_i(\text{upper}) = \mu_i + \sigma\Phi^{-1}[1 - (\alpha/2)\Phi(\mu_i/\sigma)]$$

where $\Phi(.)$ denotes the standard normal distribution function. Thus a $(1-\alpha)$ 100% confidence predictor for $[\exp(U_i) - 1]$ is defined by

$$\{\exp[U_i(\text{lower})] - 1, \exp[U_i(\text{upper})] - 1\}.$$

Horrace and Schmidt (1996) suggested that the confidence prediction of U_i should be based on the conditional distribution of U_i, given $V_i - U_i$, for the case of a production frontier (see equation (5) and discussion on pp. 261–2). However, the conditional distribution of U_i given $\varepsilon_i \equiv V_i + U_i$, is the truncation (at zero) of the normal distribution with mean, $\mu_i^* = \dfrac{-\varepsilon_i\sigma^2 + \mu_i\sigma_v^2}{\sigma^2 + \sigma_v^2}$, and variance, $\sigma_*^2 = \dfrac{\sigma^2\sigma_v^2}{\sigma^2 + \sigma_v^2}$.

This distribution has a *much smaller variance* than that for U_i. Although the conditional distribution is appropriate for best prediction of U_i, we found

Table A.1. Maximum-likelihood estimates for parameters of the translog stochastic frontier model for labour use in Swedish banks

Variable	Parameter	Estimate	Standard Error
Cost Function			
Intercept	β_0	−12.16	0.98
D-variable	β_0^*	0.026	0.077
Ploans = x_1	β_1	2.37	0.32
Guarantees = x_2	β_2	−0.110	0.094
Deposits = x_3	β_3	0.70	0.33
Branches = x_4	β_4	−1.70	0.20
Inventories = x_5	β_5	0.21	0.19
Year = x_6	β_6	−0.096	0.038
$(\text{Ploans})^2$	β_{11}	−0.012	0.029
$(\text{Guarantees})^2$	β_{22}	−0.0012	0.0022
$(\text{Deposits})^2$	β_{33}	0.081	0.021
$(\text{Branches})^2$	β_{44}	−0.093	0.012
$(\text{Inventories})^2$	β_{55}	−0.0063	0.0075
$(\text{Year})^2$	β_{66}	0.00136	0.00064
Ploans × Guarantees	β_{12}	−0.059	0.017
Ploans × Deposits	β_{13}	−0.176	0.038
Ploans × Branches	β_{14}	0.055	0.030
Ploans × Inventories	β_{15}	0.148	0.029
Ploans × Year	β_{16}	−0.0204	0.0076
Guarantees × Deposits	β_{23}	0.071	0.017
Guarantees × Branches	β_{24}	0.0038	0.0075
Guarantees × Inventories	β_{25}	−0.0069	0.0057
Guarantees × Year	β_{26}	0.0027	0.0013
Deposits × Branches	β_{34}	0.101	0.031
Deposits × Inventories	β_{35}	−0.144	0.026
Deposits × Year	β_{36}	0.0233	0.0083
Branches × Inventories	β_{45}	0.020	0.016
Branches × Year	β_{46}	−0.0044	0.0036
Inventories × Year	β_{56}	0.0014	0.0029
Inefficiency Model			
Intercept	δ_0	1.79	0.15
Bank Type 1	δ_{01}	−1.95	0.12
Bank Type 2	δ_{02}	−0.89	0.33
Bank Type 3	δ_{03}	−1.701	0.089
Bank Type 4	δ_{04}	1.58	0.17
Branches	δ_1	0.197	0.027
Inventories	δ_2	−0.467	0.020
Year	δ_3	0.271	0.029
$(\text{Year})^2$	δ_4	−0.0161	0.0029
Variance Parameters			
	σ_s^2	0.200	0.011
	γ	0.8791	0.0090
Log-likelihood	377.535		

that the predictions, calculated from the conditional distribution of U_i, given $\varepsilon_i \equiv V_i + U_i$, were frequently outside the confidence intervals. The confidence interval predictors, suggested above, are likely to be quite conservative, except that sampling variability of the etimators of the parameters is not accounted for in the analysis.

2. Calculation of elasticities of mean labour use

Given the assumptions about the distributions of V and U, it can be shown that

$$\ln\{E(Y)\} = x\beta + 0.5\sigma_v^2 + \ln\{E(e^U)\}$$

and

$$E(e^U) = e^{\mu+1/2\sigma^2}\left\{\Phi\left(\frac{\mu}{\sigma}+\sigma\right)\Big/\Phi\left(\frac{\mu}{\sigma}\right)\right\}$$

where μ is defined by equation (2).

The elasticity of mean labour use with respect to branches can be shown to be

$$\frac{\partial \ln E(Y)}{\partial z_1} = \frac{\partial x\beta}{\partial z_1} + C\frac{\partial \mu}{\partial z_1}$$

where

$$C = \left\{1 + \frac{1}{\sigma}\left[\frac{\phi\left(\frac{\mu}{\sigma}+\sigma\right)}{\Phi\left(\frac{\mu}{\sigma}+\sigma\right)} - \frac{\phi\left(\frac{\mu}{\sigma}\right)}{\Phi\left(\frac{\mu}{\sigma}\right)}\right]\right\}$$

and $\phi(.)$ and $\Phi(.)$ denote the standard normal density and distribution functions, respectively. A similar expression is obtained for inventories.

The rate of change of the mean labour with respect to time is given by

$$\frac{\partial \ln E(Y)}{\partial t} = \frac{\partial x\beta}{\partial t} + C\frac{\partial \mu}{\partial t}$$

where $\frac{\partial x\beta}{\partial t}$ is technical change and $C\frac{\partial \mu}{\partial t}$ is the inefficiency change.

These derivations are similar to those in Battese and Broca (1997, pp. 403–5).