

Efficiencies and Unobservable Heterogeneity

In Turkish Banking: 1990-2000

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September 2002

Abstract

Studies of bank efficiency tend to draw conclusions from pooled estimates, assuming that all banks in a sample use the same technology, or estimates based on *a priori* classifications of the banks. It is well known that efficiency rankings may be corrupted if banks that use different technologies are pooled together in estimating the technological frontier with respect to which inefficiency is estimated.

In this paper we model unobserved heterogeneity in banking technologies as a mixture model, and investigate the efficiencies of 53 Turkish banks using likelihood-based stochastic frontier analysis for the period 1990-2000. We use the EC (Estimation-Classification) estimator to obtain data-driven identification of bank-technology-classes in our sample, and to estimate the mixture components of banking technologies therein.

We have four dimensions of possible *a priori* heterogeneity in our sample: Large vs. small, state vs. private, foreign vs. domestic, and Islamic vs. conventional banks. In some cases, multiple *a priori* criteria may be confounded, e.g. most foreign banks were also small. Simple tests of homogeneity cannot disentangle those confounded effects. Our likelihood-based analysis finds no evidence of heterogeneity along the state vs. private and Islamic vs. conventional dimensions. The estimated classifications and mixture components have intuitive *ex post* institutional explanations.

Keywords: Turkish banking, stochastic frontier efficiency analysis, classification.

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1. Introduction

While financial innovations have caused traditional banking to decline in developed countries, banks continue to play a dominant financial intermediation role in most countries. For instance, the share of U.S. commercial banks' lending as a percentage of total domestic non-financial sector credit has declined from 35% in 1974 to 25% in 1998. Moreover, U.S. commercial banks' share of total financial intermediary assets declined from 40% in 1980 to below 25% in 1998, c.f. Mishkin and Eakins (2000, p. 481). On the other hand, commercial banks are still the primary financial intermediaries in the financial sector, and U.S. banks' relative share in GDP is increasing, c.f. Allen and Santamero (2001).

Since the main function of banks is moving funds from lenders to borrowers, a bank's loans-to-assets ratio is a good indicator of its fulfillment of this basic function. In this regard, while U.S. banks loans amounted to 60% of their total assets, Turkey's commercial banks averaged a loans-to-assets ratio below 40% for the period 1990-2000. Taking into account that the majority of financial flows go through the banking sector, and that the banking sector accounts for 75% of the assets of the total financial sector in Turkey, c.f. BRSA Report (2001, p.1), it is fair to say that the Turkish banking sector is not fulfilling its potential in generating loans.

Turkish banks have not fared better on the deposits-attraction side of financial intermediation. In this regard, it is estimated that Turkish households are hoarding roughly 15 billion U.S. Dollars'-worth in the form of cash and gold,¹ the latter serving as an inflation-hedge in a highly inflationary environment.² Indeed, this pattern is explained by the fact that real returns for foreign exchange transactions and gold have been positive, while real returns on deposits have been negative. For instance, the real return from USD exchange transaction in 2001 was 27.6%, and the real return from DM exchange transaction was 20.5%, while gold-holdings offered a 30.6% real rate of return. In contrast, the real return on bank deposits was *negative* 5%, c.f. Milliyet (2002).

Mismanagement of a country's banking sector can cause significant damages beyond the low growth caused by financial disintermediation. For instance, banking crises in Mexico, South Korea, Russia and Indonesia are estimated to have cost each of those countries between 21% and 50% of its GDP in the past decade. Similarly, the Banking Regulation Supervision Agency (BRSA) declared at the end of 2001 that recent Turkish banking crises have cost the country more than USD 20 billion (ibid.).

Turkish banking began in 1856, with the establishment of Ottoman Bank. Established by foreign capital, Ottoman Bank was granted the authority of printing money, and mainly served as a vehicle for facilitating internal and external borrowing. Ottoman period banking was dominated by foreign banks, until the declaration of the Turkish Republic in 1923, c.f. B.A.T's 40th Year Book (p. 8).

¹ In 2000, Turkey imported 205 tons of gold, accounting for 6% of total international gold imports, and earning Turkey a ranking of the seventh largest importer of gold in the world.

² Average annual inflation rate is 77 % during 1990-2000.

Akguc (1989) divides the history of Turkish banking after 1923 into five phases: (i) the period of national banks (1923-1932), (ii) the period of state-owned banks (1933-1944), (iii) the period of developing private banking (1945-1959), (iv) the planned period (1960-1980), and (v) the period of liberalization and open economy (After 1980). A detailed review of those five periods is provided in B.A.T's 40th Year Book.

In its early periods of development, the Turkish banking sector's main goal was to regain national control of domestic capital. During the import-substitution era prior to 1980, the national plan called for negative real interest rates to finance the development of domestic industries. This period was also characterized by limited competition and state control of the banking sector. For instance, only seven new banking licenses were issued between 1960 and 1980, two of which for foreign banks. Therefore, the issue of efficiency of the banking system only came to the fore during the period of liberalization and open economy starting in 1980.

The 1980 structural change and reform program called for free market and export-oriented policies, including liberalization of the financial system. New policies included the abolition of directed credit, liberalization of deposit and credit interest rates, liberal exchange rate policies, and the adoption of international best standard banking regulations, c.f. BRSA (2001, p.1).

The liberalization program allowed a number of domestic and foreign banks to enter the market, with a marked increase in competition. On the other hand, the regulatory framework of that period gave banks an opportunity to make “easy profits” through non-core-banking activities. With increased freedom of capital movement and foreign currency transactions, banks borrowed funds from abroad, and invested them in deficit-financing government bonds which paid high interest rates. The high interest payments were, in turn, financed through more public borrowing, and inflationary monetary expansions, leading to very high inflation in the early 1990s.

Starting in the late 1980s, there has been a surge of research on the efficiency of Turkish banking, especially to investigate the effects of the liberalization program. That body of research has mainly focused on the types and degrees of heterogeneity in the Turkish banking industry. In the presence of such heterogeneity in banking technology, measures of “inefficiency” may be corrupted. Using the data-driven Estimation-Classification methods of El-Gamal and Grether (1995), we find significant differences in banking technology between small and large banks, and between foreign (mostly small) and domestic banks. The likelihood functions for our estimation are derived from classical trans-log Stochastic Frontier cost functions, with controls for the quality of loans and risk exposure of banks, following the specification in Mester (1996). In fact, there are a number of *a priori* dimensions along which heterogeneity could have been detected. Interestingly, our data-driven estimation-classification did not select some of the obvious *a priori* classifications.

Apart from methodology, our study also has the advantage of using a panel data set that is superior to those used in previous studies. First, our dataset includes all banks that were in operation throughout the decade. Moreover, the 49 conventional banks in our sample account for more than 93% of the total assets of the conventional banking system. Second, our dataset includes special finance houses (SFHs), which function as "Islamic banks" in Turkey. The four special finance houses in our dataset managed at least 90% of the total assets of all Islamic banks in Turkey during the sample period. While Islamic banking in Turkey started in 1985, there have been virtually no rigorous empirical studies of the Turkish banking sector including the SFHs. As a matter of fact, there has been very little empirical study of "Islamic banking" in general, despite the significant growth of this sector in a number of countries over the past two decades.³

Empirical studies of Islamic banks have mostly relied on descriptive statistics, and theoretical analyses, rather than rigorous statistical estimation methodologies. For instance, Aggarwal and Yousef, (2000) surveyed the financial instruments used by Islamic banks, and found that most of their instruments mimicked conventional banking debt-based financing. That is in contrast to the theory of Islamic banking, which portrayed the focus of the latter to be on equity-based financing and profit-sharing arrangements. In this regard, Al-Deehani, Abdelkarim, and Murinde (1999) proposed a model in which, under certain assumptions, an increase in investment accounts financing would enable Islamic banks to increase both their market values, and their shareholders' rates of return at no extra financial risk to the bank. Their empirical analysis of the annual accounts of 12 Islamic banks supported their theoretical predictions of increased Islamic banks' market values without a change in their cost of capital. More recently, Iqbal (2001) reviewed the performance of various groups of Islamic and conventional banks within various countries, using trend and ratio analyses. His sample consisted of twelve Islamic banks with a "control group" of twelve conventional banks from ten different countries, over the period 1990-98. Similarly, Samad (1999) compared the performance of one Malaysian Islamic bank to seven Malaysian conventional banks over the period 1992-1996 using financial ratios. Bashir (1999) performed a similar risk and profitability examination of two Sudanese banks. Thus, the extant efficiency analyses of Islamic banking have been limited to the examination of simple financial ratios. In this regard, our paper provides the first rigorous efficiency analysis of Islamic banks within a conventional banking industry.

In Section 2, we provide a literature review of the most commonly used econometric methods of efficiency analysis, as well as a review of previous efficiency studies of Turkish conventional banking. In Section 3, we describe our dataset and provide basic ratio analyses. In Section 4, we report the results of our efficiency analysis for the pooled dataset, as well as the results allowing for heterogeneity. Finally, we provide some concluding remarks in Section 5.

³ Recent studies estimate the size of the Islamic finance industry world-wide at \$200 billion, with an estimated annual growth rate of 15%, c.f. Warde (2000, p.1), Lewis and Algaoud (2001, p.7).

2. Literature Review

2.1 Econometric Efficiency Analysis

Econometric efficiency analysis methods may be grouped into three main categories: parametric, nonparametric and semi-parametric. Naturally, parametric techniques impose the strongest functional and distributional assumptions, while nonparametric techniques impose the weakest. Parametric efficiency analysis methods date back to Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), who independently proposed a stochastic frontier approach (SFA). The model was originally specified for cross-sectional data, and included an error term with two components: a normally distributed random effects component, and a half-normally distributed technical inefficiency component. Numerous recent studies use the maximum-likelihood approach for estimating stochastic frontiers allowing for panel data sets, as well as missing data, as developed by Battese and Coelli (1992). Schmidt and Sickles (1984) proposed a semi-parametric approach for estimating stochastic frontiers in panel data models without imposing distributional assumptions on error terms. Cornwell, Schmidt and Sickles (1990) later improved on that "distribution free approach" by allowing for time heterogeneity in slopes and intercepts. Adams, Berger, and Sickles (1997) further approached a fully non-parametric setting by imposing only minimal assumptions on the functional form. The stochastic frontier efficiency analysis approach has been extensively applied to the study of financial institutions' performance. Berger and Humphrey (1997) provided an excellent survey of 130 studies that applied frontier efficiency analysis to financial institutions in 21 countries.

Fully nonparametric techniques, such as Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) are also available (*ibid.*). Those techniques require neither the specification of a functional form, nor the assumption of cost minimization or profit maximization. However, nonparametric techniques have the fundamental drawback of confounding potential random measurement errors with inefficiency measures. Thus, for purposes of efficiency analysis, the SFA approach seems to dominate nonparametric approaches by allowing for measurement error.

In this paper, we utilize a fully parametric stochastic frontier analysis in order to utilize the likelihood-based EC-estimator of El-Gamal and Grether (1995) for modeling unknown heterogeneity. The issue of separating heterogeneity effects from efficiency has been a concern in many studies of U.S. and European banking. For instance, Brown and Glennon (2000) performed tests of homogeneity in U.S. banking technologies and rejected that null hypothesis. They performed their test by grouping the banks using cluster analysis, and then estimating the efficiencies for six different clusters. Altunbas et al. (2001) estimated three separate cost and profit frontiers for German banks, separated according to ownership types, and tested for poolability of the estimates. They found little evidence to suggest that private banks are more efficient than their mutual and public sector counterparts in Germany. Elysiani and Rezvanian (2002) compared the production technologies and the cost characteristics of foreign vs. domestic owned banks

in the U.S., within a cost minimization context, rejecting the null hypothesis of homogeneity of banking technologies across the two groups.

Compared to the above mentioned *a priori* classifications and statistical cluster analyses, EC-estimation has the advantage of parsimoniously selecting classifications based on bank-contributions to the overall likelihood function. For instance, as we shall see in later sections, our null of homogeneity of bank-cost functions is rejected (using a LR test) for small vs. large banks, as well as for foreign vs. domestic banks. However, since most foreign banks are also small, the two effects are confounded. Using the likelihood principle to determine the appropriate classification in this case has a clear epistemological appeal over other statistical or *ad hoc* methods.

2.2 Efficiency studies on Turkish banking

Research on the efficiency of Turkish banks began in late 1980's, focusing mainly on investigating the effect of liberalization policies. Recent studies by Ozkan-Gunay (1996, 1998), Mahmud and Zaim (1998), Yildirim (1999), and Mercan and Yolalan (2000), concluded that liberalization increased efficiency in the banking sector. Many of the Turkish banking studies either pooled all the commercial banks and drew conclusions from the estimated efficiencies, or focused on a particular group of banks according to ownership structure or size. For instance, Mahmud and Zaim (1998) focused on private commercial banks, while Cingi and Tarim (2000) studied the efficiencies of 21 commercial banks (some state-owned and some private) with a deposit share of more than 1% in the banking sector.

Studies that allowed for *a priori* heterogeneity sometimes reached very different conclusions. For instance, Zaim (1995), Yolalan (1996), Ozkan-Gunay (1997), Emir, (1999), Mercan and Yolalan (2000), and Cingi and Tarim (2000), found that state owned banks were more inefficient than private and foreign banks, whereas Zaim (1995) and Denizer, Dinc, and Tarimcilar (2000) claimed that state owned banks were no less efficient than their private counterparts. Those divergent conclusions may be attributed to differences in methodology, as well as differences in the data sets used in the different studies.

In a very recent study, Isik and Hassan (2002) investigated input and output efficiency in Turkish banking, focusing on the impact of size, international variables, ownership-structures, and other variables. Their results suggest that heterogeneity in bank characteristics have significant effects on their measured efficiencies. They performed their analysis by estimating three separate annual efficiency frontiers for the years 1988, 1992 and 1996. They summarized their results for both separate and pooled frontiers for national and foreign banks, after failing to reject the null hypothesis of homogeneity across the domestic/foreign distinction.

In addition, to the best of our knowledge, there is only one empirical study of Special Finance Houses in Turkey, which is currently out-of-date. Agaoglu (1994) compared C.A.M.E.L. based financial ratios for the period for conventional banks and

SFHs in the period 1986-1991. Therefore, we believe that the current study is the first to perform a rigorous empirical efficiency analysis using a decade-long panel data set of all major banks in Turkey, and including Turkish SFHs in the analysis.

3. Data and Ratio Analysis

Data for 49 conventional banks was downloaded from The Banks Association of Turkey's (B.A.T) website which includes the balance sheets and income and expense statements of those banks from 1990 to 2000.⁴ Of the 49 banks, 13 are foreign banks or branches of foreign banks, 23 are domestically owned, 4 are state owned, and 9 are failed private banks that were transferred to Savings Deposits Insurance Fund (SDIF) during the period 1997-2000.⁵ By December 2000, the shares of state, private, foreign and SDIF banks' total assets in the sector were:⁶ 34.2%, 47.4%, 5.4% and 8.5%, respectively, c.f. BRSA Banking Restructuring Report (p.2).

The data for 4 special finance houses were obtained directly from the individual institutions. The data were gleaned from the quarterly financial statements that SFHs are required to report to the Central Bank of Turkey.

We shall now provide some descriptive statistics for the banks in our sample, in the form of financial ratios. Such ratios are commonly used to analyze the performance of banks. We report graphically selected C.A.M.E.L.-based (Capital adequacy, Asset quality, Management, Earnings, and Liquidity) financial ratio trends for different banks, categorized by ownership structure.

⁴ Original data was expressed in nominal Turkish Liras. We converted the data to real terms using the Turkish Consumer Price Index (CPI), with 1995 as the base year. We then converted all of the variables to real 1995 USD using the real exchange rate for 1995, which is the base year both for Turkish and U.S. CPI.

⁵ In year 2001, 9 more private banks failed and were transferred to the SDIF, making the total number of failed banks equal to 18. However, since our study covers the period until the end of 2000, we consider only 9 of them as SDIF banks. SDIF was run by the Turkish Central Bank during 1983-2000, and later transferred to the Banking Regulation Supervision Agency (BRSA) on August 31, 2000.

⁶ By the end of 2000, the total assets of Turkish banking sector were USD 155.2 billion, equal to 76.9% of the country's GDP.

3.1 Capital Adequacy

The 1988 Basle Capital Accord⁷ defined the Capital Adequacy ratio as the ratio of total capital to the sum of credit risk and market risk. Credit and market risks are calculated based on risk weights of 0%, 10%, 20%, 50%, or 100%, attached to various balance sheet assets. Along that scale, 0% weighting is attached to riskless assets (e.g. cash held in the bank), while 100% weighting is attached to the riskiest assets (e.g. claims on non-OECD foreign banks). The Basle Committee set a minimum capital adequacy ratio requirement of 8%, at least half of which must be in Tier 1 capital (consisting of equity and disclosed reserves). Because of the difficulty in determining the risk categories of balance sheet assets, and for the sake of parsimony, we used the leverage ratio (which does not weight the assets for default risk) as a proxy for capital adequacy for different types of banks. The leverage ratio is calculated by dividing equity capital by total assets. Figure 1 shows the trends of leverage ratios for different banks by ownership-type. Interestingly, SDIF banks had the highest leverage ratios both at the beginning and at the end of the decade. The reason for the later increase in equity capital for those banks can be explained by their restructuring and receipt of significant capital injections after being taken-over by the state. On average, foreign banks were the best capitalized for the period. State owned banks and SFHs seem to have been the least capitalized, even though SFHs increased their equity capital after being made subject to the banking law.

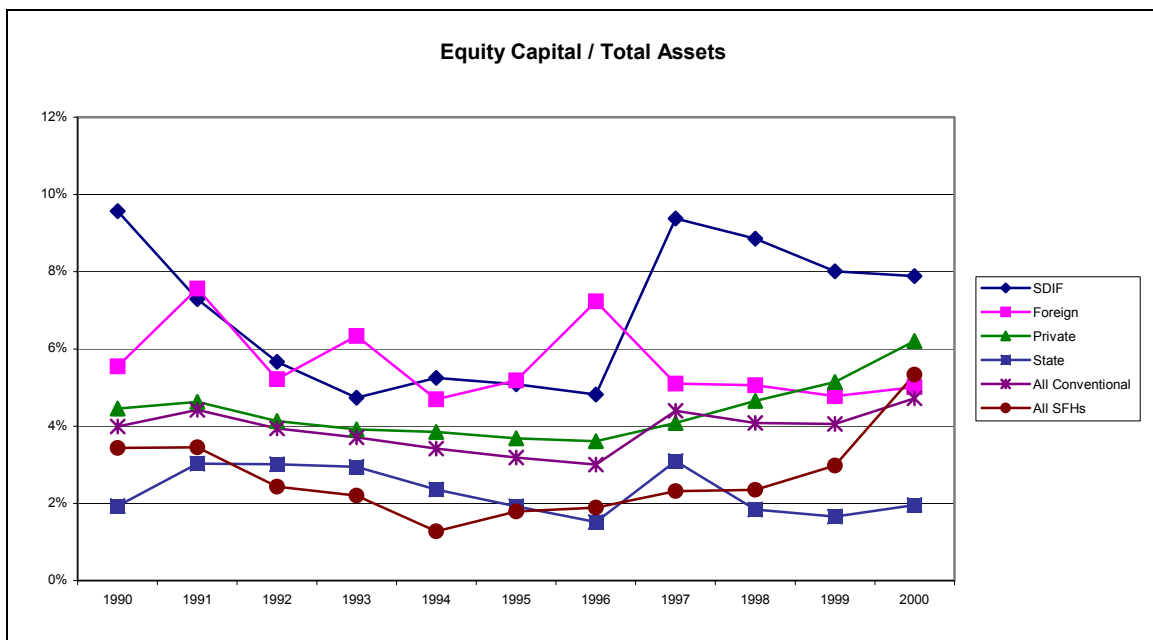


Figure 1

⁷ The Basel Committee introduced the new Accord in 2001, to be implemented in 2004. The new Accord focuses on improvements in the measurement of risks, i.e. calculation of the denominator of the capital adequacy ratio. The new framework attempts to account for operational risk as well as credit and market risks.

3.2 Asset Quality

Before investigating the quality of Turkish banks' assets, we focus on their usage of those assets, by investigating their loans-to-assets ratios. The loans-to-assets ratio is significantly different for SFHs (70% on average) and conventional banks (39% on average). Moreover, the loans-to-assets ratio for foreign banks dropped to 31% on average. This reluctance of conventional domestic and foreign banks to make loans is explained by the above mentioned profitability of borrowing abroad and investing the funds in high-interest-paying government bonds. This trend will become even more apparent when we analyze liquidity ratios.

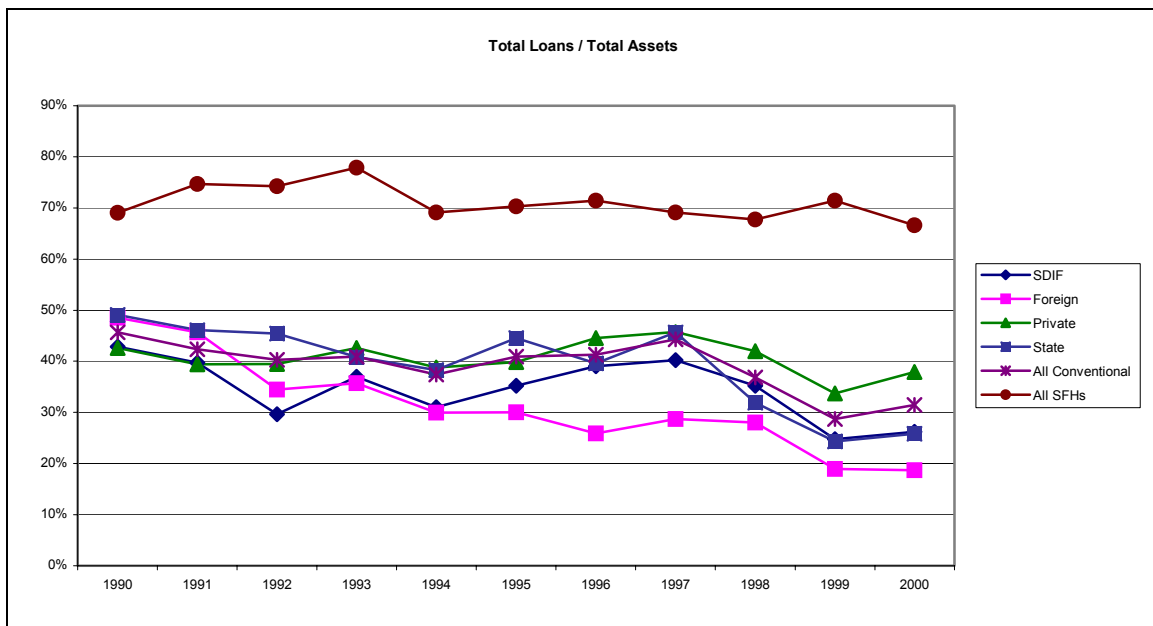


Figure 2

The ratio of nonperforming loans to total loans (NPL/TL) is a good indicator of loan-quality. We can see in Figure 3 that the average ratio of NPL/TL increased steeply for all banks towards the end of our sample period. This increase is particularly marked for SDIF banks, for which the ratio of non-performing loans reached a staggering 77% by 1999. On the other hand, this sharp increase may be attributed in part to the adoption of best accounting practices after those banks were taken over by the state, thus recognizing many previously hidden non-performing loans.

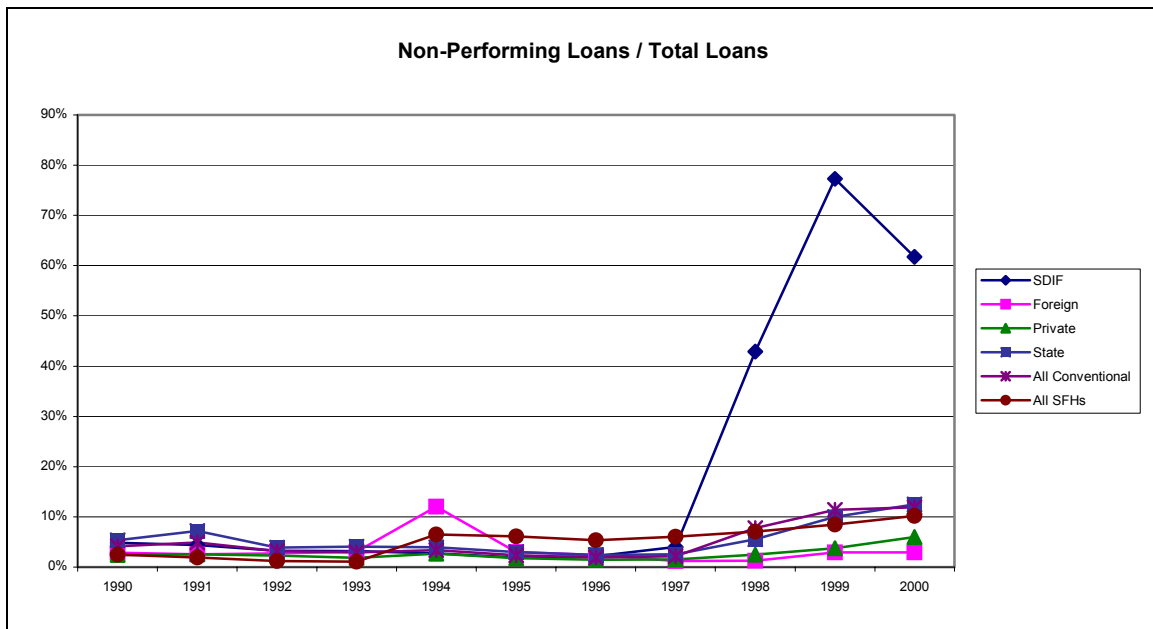


Figure 3

3.3 Management

To study management-efficiency, we consider the ratio of employee expenses to total assets. This ratio seems to have declined for conventional private banks, and to have slightly increased for SFHs, leading to convergence between the two groups around 2000. The secular decline for conventional private banks reflects the overall decline in bank-employment over the studied period. On the other hand, the increase in SFH employment expenses reflects the increase in branching from the mid-1990s. The earliest SFHs (Al-Baraka Turk, Faisal Finance and Kuveyt Finance House) were originally capitalized by Gulf-country owners who initially resisted opening many branches. However, as the domestically-owned Ihlas Finance House and Asya Finance House entered the Islamic finance market, and pursued aggressive branching strategies in 1995 and 1996 respectively, the older SFHs responded accordingly.

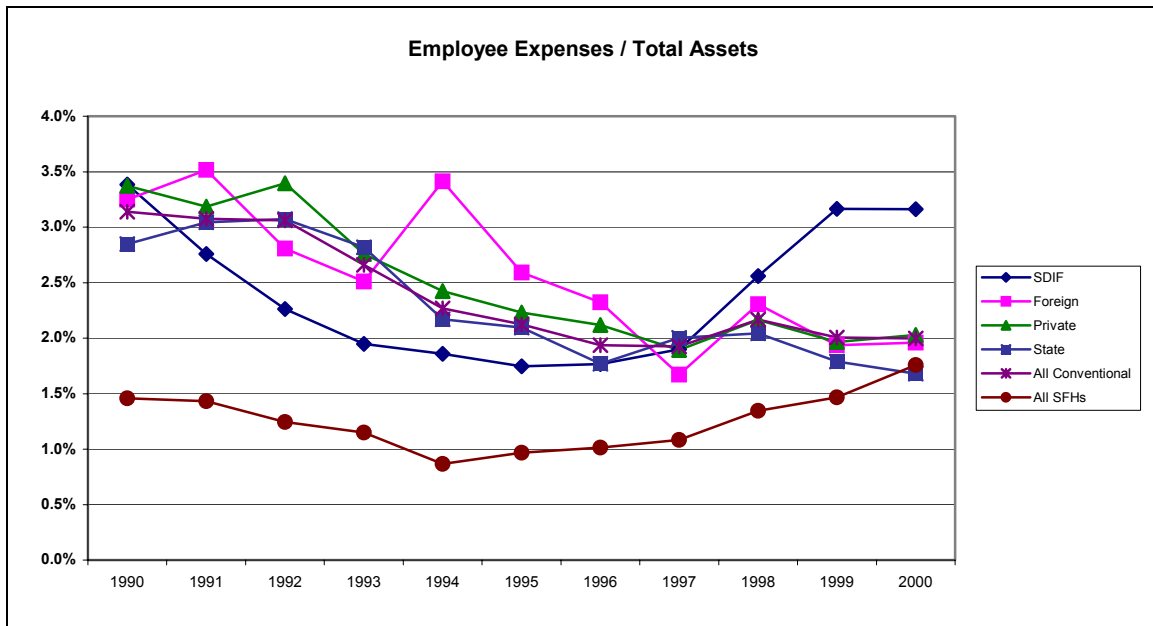


Figure 4

3.4 Earnings

Turkish banks' bad loans and maturity mismatch losses show up clearly in their earnings performance. Both the ROE (return on Equity) and the ROA (Return on Assets) profitability ratios are very low. SDIF banks consistently made losses while foreign banks appeared to be the most profitable in our sample. Foreign banks' short positions in foreign exchange proved profitable when the return on government bonds was greater than the cost of foreign exchange liability plus the devaluation rate.

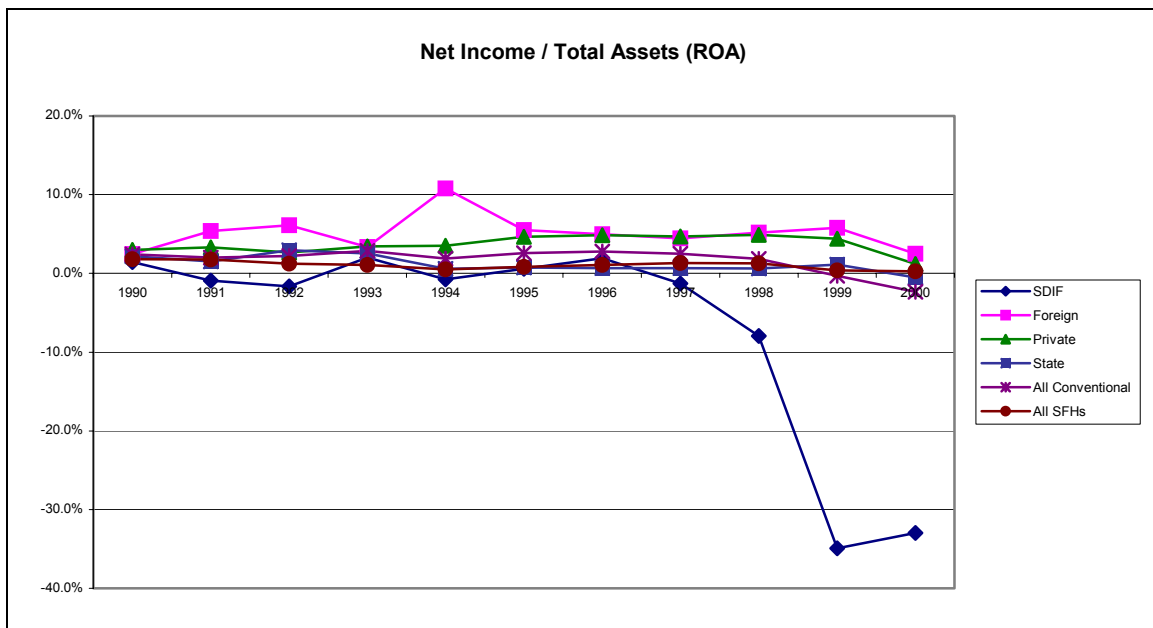


Figure 5

3.5 Liquidity

Liquid assets are defined as vault-cash, cash at the Central Bank and other banks, securities, and reserve requirement. SFHs had the most illiquid assets in our sample, followed by state banks. At the other extreme, foreign banks had the most liquid assets. This is explained by the fact that foreign banks' loan portfolios were the lowest as we have seen. Instead of making loans, foreign banks used the funds which they transferred from abroad to buy government papers. At the other extreme, SFHs' liquidity was the lowest since SFHs were not allowed to invest in government papers because of their very nature.⁸ Most of the liquid assets held by the SFHs in our sample consist of the obligatory 10% cash holdings stipulated in their banking law.

It is noteworthy that there was a systemic liquidity risk in the Turkish banking system in our sample that cannot be seen in Figure 6. The major source of liquidity risk in the system stemmed from maturity mismatches. The average maturity of assets in the system was one year, while the average maturity of the liabilities was approximately one month.

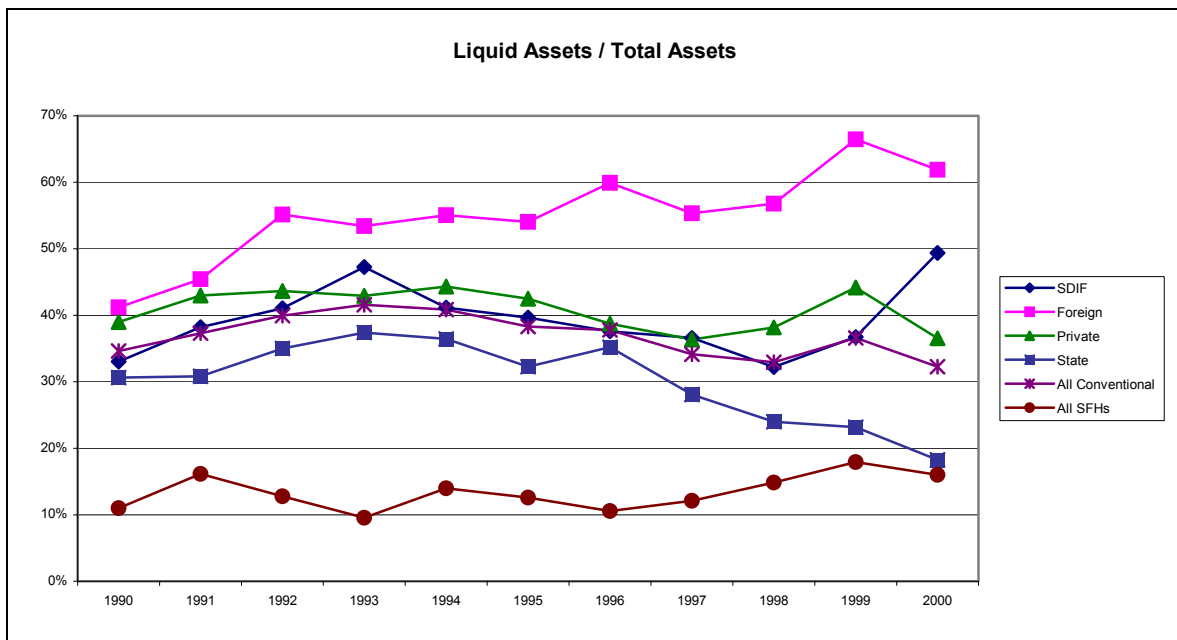


Figure 6

⁸ Recent introductions of so-called Islamic bonds in the form of *'ijara sukuk* and *salam sukuk* in Malaysia and Bahrain suggest that Islamic banks in other countries may soon have access to bond-like securities that would allow them to mimic the asset-composition of conventional banks.

4. Efficiency Analysis

4.1. Stochastic Frontier Analysis

A stochastic frontier analysis (SFA) consists of an estimation of a best-practice frontier, and comparison of the individual firms with that frontier. In this study, we use a stochastic cost frontier framework, assuming that each bank attempts to maximize output (loans) for any given level of inputs.⁹ Profit maximization may thus be modeled as cost minimization for any given level of output, and the production technology of banks can be represented by a dual cost function. The cost function thus determines the minimum expenditure needed to produce a given output with given input prices. Bank inefficiency is then measured by the difference between each bank's realized costs of production, and the theoretical minimum at the estimated frontier.

Although conventional banks are multi-product firms, we will be concerned in this study with a single output: loans. We focus on this one output since the SFHs in our sample issue virtually no securities during our sample period. Moreover, SFHs did not distinguish between short and long term loans, and thus we considered aggregated loans as the single output of the banks in our sample.

The cost frontier is obtained by estimating a cost function with a composite error term:

$$\ln C_{it} = \ln C(y_{it}, P_{it}, q_{it}, r_{it}; B) + u_{it} + v_{it},$$

where C_{it} is the observed cost of bank i in period t

y_{it} is its output

P_{it} is a vector of input prices

q_{it} is a quality index

r_{it} is a risk index

B is a vector of parameters

v_{it} is an i.i.d. $N(0, \sigma_v^2)$ error term

u_{it} is an i.i.d. $|N(0, \sigma_u^2)|$ (inefficiency) error term

We measured total cost as the sum of weighted interest expense and employee and fixed assets expenses. We follow the recommendation of Mester (1996) by weighting interest expense with the ratio of loans/total earning assets, to account properly for interest expenses if the only output is loans. The prices of inputs are approximated by dividing the related input expenses by the input levels. In our case, the price of labor P_1 is calculated as total employee expenses divided by total number of employees; the price of borrowed capital P_2 is calculated as weighted interest expense divided by total borrowed funds; and the price of physical capital P_3 is calculated as fixed asset expenses

⁹ This definition of loans as the output of banks is commonly labeled "the intermediation" approach to the study of bank efficiency, c.f. Mester (1996).

(depreciation and amortization) divided by total fixed assets. We shall normalize all prices by the price of physical capital, thus obtaining $P_1^* = P_1 / P_3$, and $P_2^* = P_2 / P_3$. Also, following Battese and Corra (1977), and Schmidt and Lovell (1979), we estimate $\sigma^2 = \sigma_v^2 + \sigma_u^2$, and $\xi = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ to simplify the likelihood function.

For our functional form, we selected the classical trans-log¹⁰ functional form (excluding error terms) which relates cost to output and input prices as follows:

$$\begin{aligned} \ln C_{it} = & \alpha_0 + \alpha_1 \ln y_{it} + \alpha_2 \ln y_{it} \ln y_{it} + \sum_j \beta_j \ln P_{j,it}^* + \frac{1}{2} \sum_l \sum_j \mu_{lj} \ln P_{l,it}^* \ln P_{j,it}^* \\ & + \sum_j \gamma_j \ln y_{it} \ln P_{j,it}^* + \lambda_r \ln r_{it} + \lambda_{rr} \frac{1}{2} \ln r_{it} \ln r_{it} + \lambda_{ry} \ln r_{it} \ln y_{it} \\ & + \sum_j \lambda_{rj} \ln r \ln P_{j,it}^* + \lambda_{rq} \ln r \ln q_{it} + \lambda_q \ln q_{it} + \lambda_{qq} \frac{1}{2} \ln q_{it} \ln q_{it} \\ & + \lambda_{qy} \ln q_{it} \ln y_{it} + \sum_j \lambda_{qj} \ln q_{it} \ln P_{j,it}^* \end{aligned}$$

Thus, the share of the l^{th} input in the total cost can be derived for each observation as:¹¹

$$S_{l,it} = \frac{\partial \ln C}{\partial \ln P_{l,it}} = \beta_l + \sum_j \mu_{lj} \ln P_{j,it}^* + \gamma_l \ln y_{it} + \lambda_{rl} \ln r_{it} + \lambda_{ql}$$

Molyneux et al (1996, p.164) listed the following five properties that estimated cost functions must satisfy:

1. *Homogeneity* of degree one in the input prices,
2. *Cost exhaustion*: the sum of cost shares is equal to unity,
3. *Symmetry*: the second order outputs and inputs parameters must be symmetric,
4. *Positivity*: the cost shares and the cost-elasticities must be non-negative, and
5. *Monotonicity*: the cost function is increasing in the input prices and in the level of output.

The conditions of linear homogeneity in input prices and symmetry imply:

$$\sum_j \beta_j = 1, \quad \sum_l \mu_{lj} = \sum_j \gamma_j = \sum_j \lambda_{rj} = \sum_j \lambda_{qj} = 0, \quad \text{and } \mu_{lj} = \mu_{jl}$$

The linear homogeneity restriction is imposed in estimation by normalizing total cost and prices (dividing them by the price of physical capital). Symmetry is easily imposed in the estimation. Finally, positivity and monotonicity will be verified after the estimation, to ensure that the estimate qualifies as a cost function.

¹⁰ Berger and Mester (1997) used the distribution-free approach as well as the stochastic frontier approach for both translog and Fourier specifications of the cost and profit functions. They concluded that the empirical findings in terms of either average industry efficiency or ranking of individual banks were similar across methods.

¹¹ In a Cobb-Douglas cost function, the factor shares would be constant coefficients. In our translog specification, the shares are potentially different at each observation.

4.2. Pooled Empirical Results

The parameter estimates for the estimated cost frontier for the pooled sample of 53 banks over 11 years are reported in Table 1, and the efficiency rankings of the banks is reported in Table 2.¹² Six foreign banks are ranked at the top, followed by a state-owned bank. Etibank and Sumerbank (both SDIF banks) rank 52nd and 53rd, respectively, while other SDIF banks are also ranked close to the bottom, thus supporting *a priori* claims of their inefficiency.

Table 1. Maximum Likelihood Estimation of the Cost Frontier with Pooled Data

	Coefficient	t-ratio
Constant	15.594	3.027
$\ln P_1^*$	0.175	0.261
$\ln P_2^*$	1.078	2.257
$\ln y$	-0.778	-4.007
$(\ln y)(\ln y)$	0.104	13.884
$(\ln P_1^*)(\ln P_1^*)$	0.058	1.332
$(\ln P_2^*)(\ln P_2^*)$	0.122	3.953
$(\ln P_1^*)(\ln P_2^*)$	-0.181	-2.914
$(\ln y)(\ln P_1^*)$	-0.029	-2.647
$(\ln y)(\ln P_2^*)$	0.032	3.014
$\ln q$	-0.210	-1.650
$\ln r$	0.657	1.756
$(\ln q)(\ln q)$	0.016	4.158
$(\ln r)(\ln r)$	-0.029	-1.164
$(\ln q)(\ln r)$	0.017	2.345
$(\ln q)(\ln y)$	0.022	4.548
$(\ln r)(\ln y)$	-0.031	-2.448
$(\ln q)(\ln P_1^*)$	0.002	0.263
$(\ln q)(\ln P_2^*)$	-0.004	-0.506
$(\ln r)(\ln P_1^*)$	-0.018	-0.702
$(\ln r)(\ln P_2^*)$	-0.004	-0.186
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.904	3.784
$\xi = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.872	23.997
Log-likelihood = -274.5		
P_1^* = Price of Labor/Price of Physical Capital		
P_2^* = Price of Borrowed Funds/Price of Physical Capital		

¹² The pooled parameter estimation was performed using the FORTRAN code of Coelli (1996) for panel data sets with missing observations. For the EC results in sub-section 4.3, we augmented the code to estimate two sets of parameters, together with a single pair (σ^2, ξ) , assumed to be the same for both types, utilizing the algorithm for EC log-likelihood function evaluation described in that subsection. The mixture model MLE is an ill-posed problem if we allow the two types to have different error-term variances.

Table 2: Inefficiency Estimates for Pooled Data

Banks	Type	Size (Total Assets)	Qual. size	Ineff. Measure	Eff. Rank
Societe Generale	Foreign	210,276,732	Small	1.033	1
Credit Lyonnais	Foreign	23,877,552	Small	1.060	2
Habib Bank	Foreign	26,953,184	Small	1.121	3
Banca Di Roma	Foreign	97,433,715	Small	1.126	4
West Deutsche	Foreign	403,052,223	Small	1.139	5
Abn Amro	Foreign	224,069,662	Small	1.268	6
Emlakbank	State	5,214,489,281	Large	1.296	7
HSBC	Foreign	1,030,277,431	Small	1.535	8
Oyakbank	Private	254,663,218	Small	1.569	9
Chase Manhattan	Foreign	300,623,612	Small	1.589	10
Vakifbank	State	6,921,179,394	Large	1.616	11
Kuveyt Turk	SFH	472,856,200	Small	1.692	12
Bank Mellat	Foreign	43,424,024	Small	1.721	13
Iktisatbank	Private	969,996,167	Small	1.886	14
Bnp-Ak	Foreign	511,483,483	Small	1.899	15
Sitebank	Private	114,051,755	Small	1.943	16
Alternatifbank	Private	912,193,243	Small	1.972	17
Ziraat Bankasi	State	23,202,875,652	Large	1.977	18
Halkbank	State	15,198,125,321	Large	1.987	19
Al Baraka	SFH	790,351,206	Small	1.990	20
Arap Turk	Foreign	344,919,514	Small	2.093	21
Bayindirbank	Private	366,430,541	Small	2.122	22
Faisal	SFH	181,852,962	Small	2.138	23
Kocbank	Private	3,014,108,496	Large	2.231	24
Pamukbank	Private	6,613,960,086	Large	2.278	25
Demirbank	SDIF	3,542,582,265	Large	2.382	26
Isbank	Private	11,033,130,158	Large	2.398	27
Yapi ve Kredi	Private	10,627,671,780	Large	2.399	28
Esbank	SDIF	1,342,115,142	Small	2.404	29
Interbank	SDIF	1,573,141,423	Small	2.479	30
Bank Ekspres	SDIF	440,593,905	Small	2.479	31
Garanti Bankasi	Private	9,355,274,277	Large	2.505	32
Tarisbank	Private	206,163,622	Small	2.544	33
Tekstilbank	Private	810,599,709	Small	2.548	34
Citibank	Foreign	898,950,897	Small	2.559	35
Finansbank	Private	2,839,314,061	Large	2.577	36
Kentbank	Private	1,272,373,442	Small	2.579	37
Korfezbank	Private	1,624,630,313	Small	2.586	38
Egebank	SDIF	1,124,659,575	Small	2.694	39
Disbank	Private	1,606,778,057	Small	2.818	40
Osmanli	Foreign	3,038,068,140	Large	2.863	41
Sekerbank	Private	1,193,976,660	Small	3.040	42
Anadolu	SFH	242,328,134	Small	3.063	43
Toprakbank	Private	1,539,466,574	Small	3.266	44
Adabank	Private	173,704,588	Small	3.303	45
Turkishbank	Private	133,022,166	Small	3.328	46
Yasarbank	SDIF	1,164,906,059	Small	3.381	47
Akbank	Private	10,414,374,616	Large	3.406	48
Imarbank	Private	1,101,321,285	Small	3.548	49
Turk Ticaret	SDIF	958,489,084	Small	3.569	50
TEB	Private	1,457,760,621	Small	3.746	51
Etibank	SDIF	1,169,489,077	Small	4.569	52
Sumerbank	SDIF	632,322,011	Small	5.559	53

However, those rankings in Table 2 may reflect heterogeneity in the technologies of banks in our sample, rather than inefficiency of the stated banks in using a common technology. For instance, consider a case in Figure 7, where firms A and B are assumed to use the common technology represented by cost function I (dashed curve). Notice in the picture the Firm B is more efficient in using this technology than Firm A (closer vertically to the dashed curve). However, if the frontier cost function for the two firms are estimated along with a number of other firms using the technology represented by cost function II (solid curve), we may estimate the hybrid cost function represented by the dot-dashed line. In this case, the estimated efficiency scores for A and B may be reversed. Numerous other erroneous efficiency results can be illustrated in similar cases, if heterogeneity of cost functions is ignored in estimation.

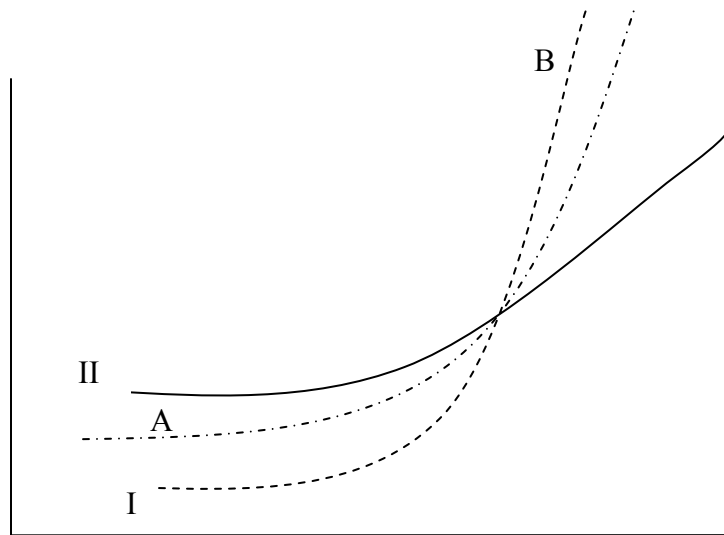


Figure 7

4.2. Homogeneity Tests

Efficiency rankings of firms can only be obtained under the assumption of that the ranked firms utilized the same production technology. We have seen that ignoring potential heterogeneity and pooling firms with different technologies may produce erroneous efficiency rankings in the pooled sample. In our sample of 53 banks, there are four obvious clear types of heterogeneity that may exist based on banks' size, ownership structure, or mode of operation. Therefore, before proceeding to perform our data-driven Estimation-Classification of bank technologies (cost functions), we consider tests of homogeneity across the most obvious *a priori* heterogeneity dimensions: (1) small vs. large banks, (2) private vs. state banks, (3) foreign vs. domestic banks, and (4) conventional banks vs. SFHs.

We use the most powerful likelihood ratio statistic to test the null hypothesis of homogeneity of banking production technology across each of those four dimensions. The likelihood ratio (LR) test statistic is computed as $-2 \ln \lambda$, where λ (the likelihood ratio) is computed as the ratio of the constrained maximum likelihood (under the null hypothesis of homogeneity) to the unconstrained maximum likelihood (computed by performing ML estimation for the two sub-samples separately).

Hence the likelihood ratio test statistic is:

$$LR = -2 \ln \lambda = -2 (\ln L_R - \ln L_{max})$$

If the homogeneity restriction is valid, then $\ln L_R$ should not be significantly smaller than $\ln L_{max}$, the unrestricted maximal value of $\ln L$. Table 3 shows the homogeneity test results. LR tests reject homogeneity along the small/large and foreign/domestic dimension. Since foreign banks are all small, the two effects are confounded. Most interestingly, we fail to reject the null hypothesis of homogeneity for private vs. state banks and for conventional banks vs. SFHs. We shall return to those results shortly.

Table 3. Tests of Homogeneity¹

	Test Statistics χ^2_{21}	Critical value ²	Decision
Small vs. Large	39.4	33.41	<i>Reject H_0</i>
Private vs. State-owned	15.26	33.41	<i>Fail to reject H_0</i>
Foreign vs. Domestic	196.8	33.41	<i>Reject H_0</i>
Conventional vs. SFHs	5.07	33.41	<i>Fail to reject H_0</i>

1. Log-likelihood value under null hypothesis (poolability) is -274.5

2. Critical value of the test statistics at the 1% level of significance

Those results may seem surprising. Indeed, Mahmud and Zaim (1998) studied only private Turkish commercial banks based on the view that large state-owned banks provide a different set of services to their customers than private commercial banks, and may therefore have different cost structures. In particular, state banks are required to extend concessionary loans to the agricultural sector, to small and medium sized enterprises, as part of a program promoting so-called “Specialized Loans”.¹³ It is reasonable to expect state banks that extended these specialized loans generously in the last decade would be expected to differ in their production (lending) technology from private banks. In our sample period 1990-2000, the ratio of specialized loans to total loans was 59% on average for state banks, while private banks that were not under any obligation to extend such specialized loans only dedicated 0.6% of their total lending to such activities.

In addition to those specialized lending restrictions, Ertugrul and Selcuk (2001) drew attention to other quasi-fiscal duties of state banks, driven implicitly by the resource allocation decisions of the government. They estimated the total burden (duty losses) of specialized loan policy and quasi-fiscal duties on the state banks at approximately USD 20 billion by the end of 2000.

Thus, many studies have allowed for different production technologies of private and state banks, given their different social, economic, and political roles. However, our empirical results suggest that those structural differences need not be represented in the form of cost-function heterogeneity. One explanation may be that our trans-log cost function does not include “duty losses” as a cost-item. Another explanation is the fact that we treat loans as the single output of banks, thus making no distinctions between specialized and regular loans.

Previous investigators of Turkish banking also reasoned based on *a priori* consideration that SFHs, which basically function as Islamic banks, use a different production technology than conventional banks. Of course, this view was undermined by careful studies of the functioning of Islamic banks, e.g. as in Aggarwal and Yousef (2000), which found that Islamic banks' operations diverged from the profit-sharing theory upon which they were based. Our efficiency analysis does not focus on the financial instruments used by SFHs but instead, tries to relate the cost of generating loans to input prices. This stochastic frontier approach supports the previous qualitative evidence that Islamic banks may not be any different from conventional ones in their production technology.

Therefore, we have explained the failure to find heterogeneity along the state/private and the Islamic/conventional dimensions. We now turn to the rejections of homogeneity along the large/small and domestic/foreign dimensions. We have already mentioned the confounding effects of foreign bank sizes in that analysis. We now need to

¹³ The focus on specialized lending varies substantially within the class of state banks. This difference can be seen in the Turkish names of those state banks. For instance, Ziraat Bank focuses on agricultural loans; Halkbank on small and medium enterprise loans; and Emlakbank on housing loans.

turn to a data-driven classification mechanism to disentangle the effects of country-of-origin and bank-size.

It is more parsimonious and epistemologically appealing to examine heterogeneity through a likelihood-function imposed classification, instead of relying on *a priori* apparent causes of heterogeneity. Towards that end, we model unobserved heterogeneity in banking technologies as a mixture model, and the classifications and the mixture components simultaneously using the EC (Estimation-Classification) estimator introduced in El-Gamal and Grether (1995).

4.3. Allowing for Unknown Heterogeneity

We observe data on output and input-prices and other RHS variables (y_{it}, \bar{x}_{it}) for $i=1, \dots, n$ banks, each over $t=1, \dots, T_i$ time periods. Let Θ be the parameter space indexing the likelihood function generated by the normal and half-normal residuals in our stochastic cost frontiers model. If we have two types of banks in our sample, parameterized by $(\bar{\theta}_1, \bar{\theta}_2) \in \Theta^2$, we need simultaneously to estimate the two parameter vectors $\bar{\theta}_1$ and $\bar{\theta}_2$, as well as the classifications of each of our 53 banks to one of the two groups. Thus, bank i 's data is assumed to be generated by

$$(y_{it}, \bar{x}_{it})_{t=1}^{T_i} \sim \prod_{j=1}^2 \left(f(\{y_{it}, \bar{x}_{it}\}_{t=1}^{T_i}; \theta_j) \right)^{\delta_{ij}}$$

where $\delta_{ij} \in \{0,1\}$ and $\sum_{j=1}^2 \delta_{ij} = 1$, and our likelihood function $f(\cdot; \theta)$ is parametrized by

the parameter vector $\theta \in \mathbb{R}^d$. The δ_{ij} 's are unknown parameters, which may be treated as missing data and integrated-out using the EM algorithm, c.f. Dempster et al. (1977), Redner and Walker (1984), and Little and Rubin (1987). Alternatively, the EC estimator of El-Gamal and Grether (1995), also known as the "maximum likelihood approach to classification", treats the δ_{ij} 's as parameters of interest, and maximize the likelihood function simultaneously over the δ_{ij} 's as well as $(\bar{\theta}_1, \bar{\theta}_2)$.

The EC algorithm is a computationally efficient means of obtaining EC-estimates, which are in turn asymptotically equivalent (as T goes to infinity) to EM estimates (ibid.):

- Search over $\theta = (\bar{\theta}_1, \bar{\theta}_2)$, for each candidate value of θ in the optimization search:
- For each bank i :
 - Calculate $lf_i(h; \theta_h) = \log f(\{y_{it}, \bar{x}_{it}\}_{t=1}^{T_i} | \theta_h)$ for $h \in \{1, 2\}$
 - Choose $h \in \{1, 2\}$ to maximize $lf_i(h; \cdot)$, call the maximal value $lf_i(\theta)$
(This corresponds to maximizing over the δ_{ij} for bank i)¹⁴
 - Sum the obtained log likelihoods $lf_i(\theta)$ over $i \in \{1, \dots, 53\}$, call the sum $lf(\theta)$
 - Return the outcome $lf(\theta)$ as the function evaluation at θ

¹⁴ The number of such configurations is $2^{53/2!} \approx 4,500,000,000,000,000$, hence a brute-force search over all possible δ_{ij} configurations is prohibitively difficult.

The classification approach (assigning each bank to the parameter group that maximizes its contribution to the likelihood function) induces a small-sample classification bias. EM estimation avoids such a bias by distributing each bank's likelihood contribution to the two groups in proportion to its posterior probabilities of belonging to those groups. The empirical results of El-Gamal and Grether (1995), and the Monte Carlo analyses of El-Gamal and Grether (1999) suggest that sample sizes of $T > 5$ tend to produce very small sample biases, to the extent that the large T approximation may be sufficiently precise to make a subsequent EM step for bias correction unnecessary.

The size of our classification bias is directly related to the distance between posterior probabilities over classifications on the one hand, and the (0 or 1-valued) δ_{ij} 's on the other. For any given classification of firms, a posterior odds ratio for each bank may be calculated as follows (assuming uniform priors):

$$\text{Posterior Odds Ratio} = \pi_{i,k} = \frac{l_i(\theta_k)}{\sum_{j=1}^2 l_i(\theta_j)} \quad \text{where } i=\{1, \dots, 53\} \text{ and } k=\{1, 2\},$$

$$\begin{aligned} \pi_{i1} &= E[\delta_{i1}] = \text{Prob}\{\delta_{i1}=1\} = \text{Prob}\{\text{Bank}_i \text{ belongs to Group 1}\} \\ \pi_{i2} &= E[\delta_{i2}] = \text{Prob}\{\delta_{i2}=1\} = \text{Prob}\{\text{Bank}_i \text{ belongs to Group 2}\} = 1 - \pi_{i1} \end{aligned}$$

If those probabilities are close to zeros and ones, then the data are strongly in agreement with the assignment of banks to types, and the classification-induced bias is minimal. We use the diagnostic statistic called ANE (Average Normalized Entropy) introduced in El-Gamal and Grether (1995), to judge the crispness of the classifications, i.e. the closeness of π_{ij} 's to zeros and ones:

$$\text{ANE}(2) = \frac{1}{n} \sum_{i=1}^n \sum_{j=1}^2 \pi_{ij} \log_2(\pi_{ij})$$

ANE always lies between zero and one, with small numbers reflecting crisp classifications and negligible small-sample biases, and large ANEs reflecting weak classifications and significant potential biases. ANE is zero when the π_{ij} 's are equal to the δ_{ij} 's, indicating very good behavior for the EC procedure. Thus, the EM algorithm and EC procedure results would coincide when ANE is equal to zero. If ANE is not sufficiently small, we have to use the EC estimates as initial conditions for the EM algorithm.

Our EC estimates are shown in Table 4. Of the 53 banks in our sample, 40 banks are classified into Group 1, while 13 banks are classified into Group 2. Group 2 banks are all small, and all but two of them are foreign, the two exceptions being the small

domestic banks Bayindirbank and Oyakbank¹⁵. The posterior odds are very crisp, i.e. close to zeros and ones. The collective diagnostic measure ANE is calculated as 0.072 which is sufficiently close to zero to conclude that small-sample classification errors, and classification-induced parameter estimate biases, are too small to warrant an EM correction.

Table 5 displays the cost function parameter estimates for the two groups. As discussed in Section 2, we need to verify the positivity and monotonicity conditions for both cost frontiers. To do so, we evaluated the shares for each observation using the estimated trans-log cost function to which the observation is classified. For each observation, we check that the cost function is non-decreasing and concave in input prices and that cost elasticities have a positive sign.¹⁶

In this regard, Group 1's marginal cost values with respect to P_1^* (the price of labor normalized by the price of physical capital) and P_2^* (the price of borrowed funds normalized by the price of physical capital) are positive for 91% and 99% of the observations, respectively. Those two marginal costs for Group 2 banks are positive for 95% and 98% of the observations, respectively. Two histograms for the marginal costs at the different observations are plotted in figures 8 and 9 for comparison of the two different technologies' response to prices. Our major finding in this regard is that Group 1 banks' costs seemed to be more responsive to changes in P_2^* (normalized price of borrowed funds), while Group 2 banks' costs were more responsive to changes in P_1^* (normalized price of labor).

This pattern is reasonable, since Group 2 banks are predominantly foreign banks, which had relatively high (foreign-national) employee cost disadvantages, while Group 1 banks had a relative disadvantage in short-term borrowing abroad (cost of funds). As we have noted previously, the high profitability of foreign banks was based on borrowing short-term funds from abroad, and investing in high-interest-rate Turkish government bonds.

Considering the coefficients of quality and risk indices, histograms of which are shown in Figures 10 and 11, we notice some other differences between the two groups. Namely, Group 1 banks' cost functions seemed more responsive to changes in the quality-of-loans index, while Group 2 banks' costs were more responsive to changes in the risk index.

¹⁵ Interestingly, Oyakbank started to operate as an Istanbul branch of Bank of Boston in 1984. In 1990, its status was changed to domestic-ownership as four domestic partners took ownership. One of those partners is OYAK (Armed Forces Pension Fund), which bought all of the bank's shares in 1993 and changed its name to Oyakbank in 1996. While Bayindirbank has always been a domestically owned bank, shareholders of the bank changed twice during the last decade, namely in 1992 and 1998. We believe that those changes in management of the two banks in the last decade may explain the classification of the former, and the misclassification of the latter.

¹⁶ In a Cobb-Douglas framework, the factor shares are constant coefficients. In our translog specification, the factor shares have to be computed at each observation. Therefore, we check for positivity of factor shares and elasticities by plotting histograms for the factor shares at all observations.

- Recall that the quality index was constructed as the ratio of non-performing loans to total loans, thus indicating lower quality for higher values of the measure. Hence, the marginal cost with respect to q is expected to be positive. We have seen that foreign banks (the dominant type in group 2) relied mainly on government bonds, rather than loans, for interest income. Therefore, it is not surprising to find that the other banks have cost functions that are more sensitive to the percentage of non-performing loans.
- Also note that the risk index is calculated as the ratio of equity capital to total assets, indicating lower risk for higher values. Hence, the marginal cost with respect to r is expected to be negative. Again, our results show that group 1 banks' costs are more sensitive to their risk exposure, due to their inability to capitalize on the lower risk arbitrage opportunities that foreign banks could afford by borrowing abroad at low interest rates.

Tables 6 and 7 show the new rankings for Groups 1 and 2, respectively. The 6 foreign banks that took the top efficiency ranks in the pooled analysis were classified by the EC-estimator into the smaller Group 2. As we have previously seen, the profitability of those banks relied mainly on buying high-interest government bonds, and hence they did not resort to risky lending. Those six banks retained their top-ranking in Group 2, with minor changes. The non-foreign banks allocated to this group were Bayindirbank and Oyakbank, which ranked at or near the bottom of the group.

Once those banks were separated from the rest of the sample, the SFHs claimed the top ranks in Group 1, mainly due to their relatively low ratios of non-performing loans.¹⁷ At the other extreme, Etibank and Sumerbank, both SDIF banks, still share the bottom efficiency rankings in Group 1 due to their high non-performing loans ratio. On the other hand, there seems to be no general pattern for state banks' rankings in Group 1. The most efficient state bank in the group was Ziraat Bank (which focuses on agricultural loans) at the 4th rank, while the lowest ranked state bank was Halkbank, in the 33rd position. Based on this pattern of classifications, we have to conclude that state banks are not significantly less efficient than private banks.

5. Conclusions

In this paper we modeled unobserved heterogeneity in banking technologies as a mixture model and investigated the efficiencies of 53 Turkish banks using likelihood-based stochastic frontier analysis for the period 1990-2000. In contrast to previous efficiency studies which tend to draw conclusions on the pooled estimates or estimates based on a priori classifications, the data-driven EC estimates point mainly to distinctions between small and foreign banks vs. large and domestic ones, respectively.

We do not find evidence of heterogeneity between state and private banks. In spite of the fact that state-owned banks suffered from significant “duty losses” during our sample period, they do not seem to be generally inefficient relative to private banks. Taking into

¹⁷ Islamic financing is equity-based, i.e. fully collateralized, thus reducing the risk of non-performance.

account the valuable social role played by those banks, our results put into question the validity of popular advice for privatization of state banks.

We also found no evidence that "special finance houses" (sometimes labeled as Islamic banks) used a different technology compared to conventional banks. This is not surprising given the documented emulation of conventional banks' debt-financing by Islamic banks. Interestingly, Islamic banks seem to be relatively efficient among other banks that share their banking technology, despite limitations caused by high reserve requirements, and their inability to hold government bonds during our sample. This suggests that Islamic banks do not have a destructive effect on the financial sector, even if they drew funds away from conventional banks. To the extent that they also help to mobilize funds that are otherwise hoarded outside the formal financial sector, they may play a valuable role in the economies of countries with large Muslim populations.

Our findings suggest that during the last decade foreign banks in Turkey took advantage of their ability to borrow short-term from abroad and invest in high interest Turkish government bonds. Private banks pursued the same strategy, but they had a clear disadvantage in borrowing abroad.

Table 5. Maximum Likelihood Estimation of Group 1 and Group 2

	Group 1			Group 2		
	<i>Coefficient</i>	<i>Std Error</i>	<i>t-ratio</i>	<i>Coefficient</i>	<i>Std Error</i>	<i>t-ratio</i>
Constant	24.264	1.949	12.451	22.890	1.312	17.445
$\ln P_1^*$	-0.609	0.453	-1.343	-1.336	0.341	-3.914
$\ln P_2^*$	1.763	0.519	3.399	2.622	0.559	4.689
$\ln y$	-0.888	0.242	-3.671	-1.731	0.284	-6.088
$(\ln y)(\ln y)$	0.090	0.007	12.784	0.092	0.016	5.643
$(\ln P_1^*)(\ln P_1^*)$	0.075	0.062	1.199	0.138	0.032	4.366
$(\ln P_2^*)(\ln P_2^*)$	0.147	0.034	4.290	0.058	0.057	1.020
$(\ln P_1^*)(\ln P_2^*)$	-0.252	0.078	-3.222	-0.223	0.076	-2.924
$(\ln y)(\ln P_1^*)$	-0.010	0.021	-0.476	0.081	0.011	7.073
$(\ln y)(\ln P_2^*)$	0.029	0.016	1.836	-0.109	0.019	-5.719
$\ln q$	0.088	0.144	0.613	-0.720	0.199	-3.623
$\ln r$	0.867	0.431	2.013	-4.948	0.967	-5.119
$(\ln q)(\ln q)$	0.022	0.004	5.181	0.021	0.009	2.354
$(\ln r)(\ln r)$	-0.066	0.028	-2.374	-0.173	0.064	-2.696
$(\ln q)(\ln r)$	0.011	0.008	1.286	0.070	0.014	5.045
$(\ln q)(\ln y)$	0.014	0.005	2.589	0.033	0.013	2.539
$(\ln r)(\ln y)$	-0.053	0.016	-3.264	0.081	0.027	2.945
$(\ln q)(\ln P_1^*)$	-0.011	0.010	-1.025	0.043	0.013	3.364
$(\ln q)(\ln P_2^*)$	-0.003	0.009	-0.349	-0.053	0.013	-4.027
$(\ln r)(\ln P_1^*)$	-0.008	0.033	-0.236	0.267	0.052	5.126
$(\ln r)(\ln P_2^*)$	0.013	0.026	0.491	-0.209	0.049	-4.262
The common parameters:						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.424	0.027	15.954			
$\xi = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.769	0.017	44.840			
Aggregate log-likelihood = -159.3						

Table 6: Inefficiency Estimates for Group 1

Banks	Type	Ineff. Measure	Eff. Rank
Faisal	SFH	1.1036	1
Al- Baraka	SFH	1.1068	2
HSBC	Foreign	1.1072	3
Ziraat Bankasi	State	1.1280	4
Adabank	Private	1.1309	5
Kuveyt-Turk	SFH	1.1442	6
Sitebank	Private	1.1453	7
Anadolu	SFH	1.1454	8
Alternatifbank	Private	1.2362	9
Tarisbank	Private	1.2692	10
Iktisat	Private	1.2952	11
Pamukbank	Private	1.3879	12
Kocbank	Private	1.4279	13
Korfezbank	Private	1.4495	14
Tekstilbank	Private	1.4540	15
Bank Ekspres	SDIF	1.4758	16
Kentbank	Private	1.4761	17
Vakifbank	State	1.4824	18
Turkishbank	Private	1.4930	19
Esbank	SDIF	1.5025	20
Egebank	SDIF	1.5095	21
Demirbank	SDIF	1.5231	22
Interbank	SDIF	1.5475	23
Emlakbank	State	1.5914	24
Finansbank	Private	1.6138	25
Yapi ve Kredi	Private	1.6744	26
Imar	Private	1.6875	27
Disbank	Private	1.7064	28
Garanti	Private	1.7629	29
Isbank	Private	1.7725	30
Yasarbank	SDIF	1.8267	31
Sekerbank	Private	1.8461	32
Halkbank	State	1.8495	33
Osmanli	Foreign	1.8618	34
Toprakbank	Private	1.8729	35
Akbank	Private	2.1147	36
TEB	Private	2.1365	37
Turk Ticaret	SDIF	2.1534	38
Etibank	SDIF	2.3187	39
Sumerbank	SDIF	2.5576	40

Table 7: Inefficiency Estimates for Group 2

Banks	Type	Ineff. Measure	Eff. Rank
Societe Generale	Foreign	1.0842	1
Habib Bank	Foreign	1.0858	2
Credit Lyonnais	Foreign	1.1536	3
Bank Mellat	Foreign	1.2017	4
Chase	Foreign	1.2051	5
Banca Di Roma	Foreign	1.2787	6
West Deutsche	Foreign	1.3941	7
Abn Amro	Foreign	1.4659	8
Arap Turk	Foreign	1.7349	9
Oyakbank	Private	1.9175	10
Bnp-Ak	Foreign	2.2914	11
Citibank	Foreign	3.2921	12
Bayindirbank	Private	4.1516	13

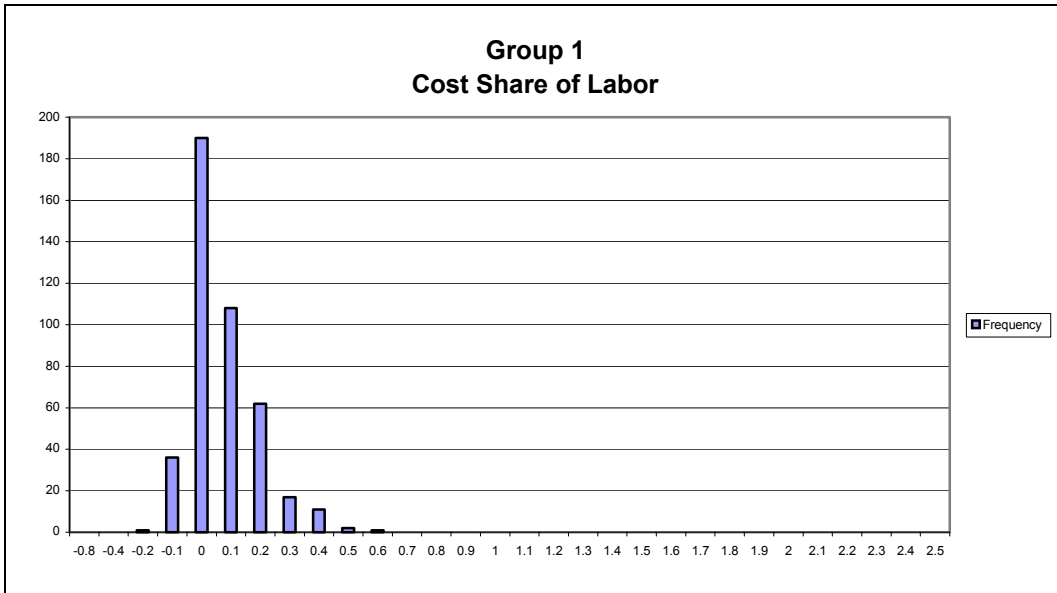


Figure 8a

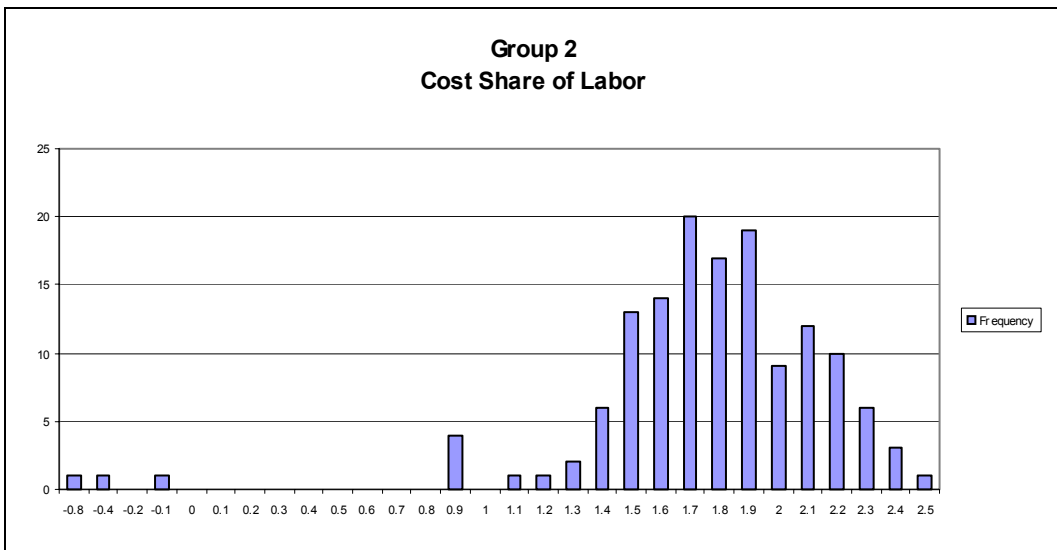


Figure 8b

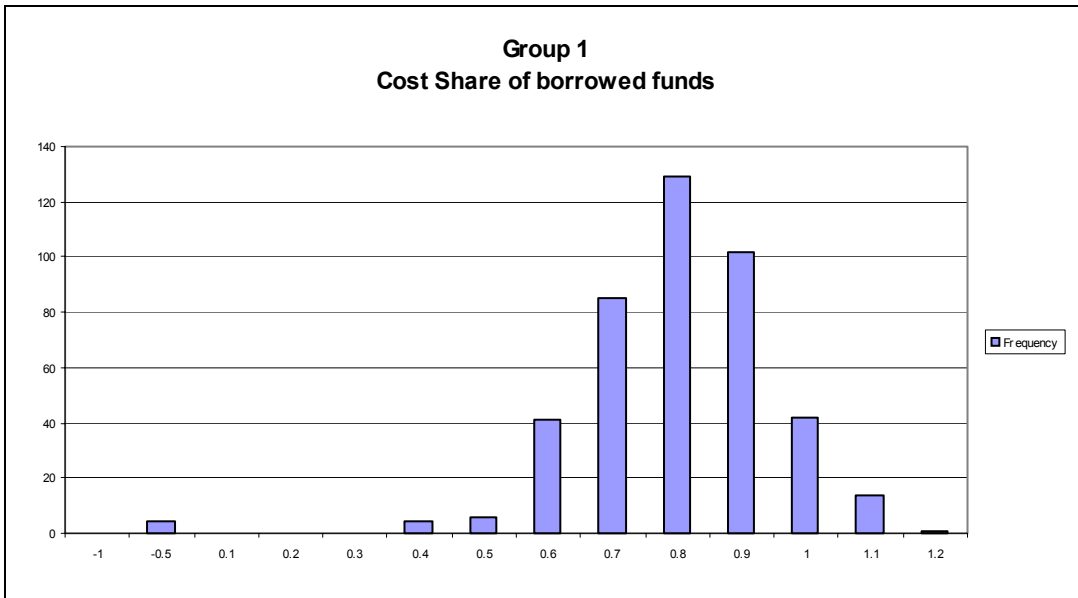


Figure 9a

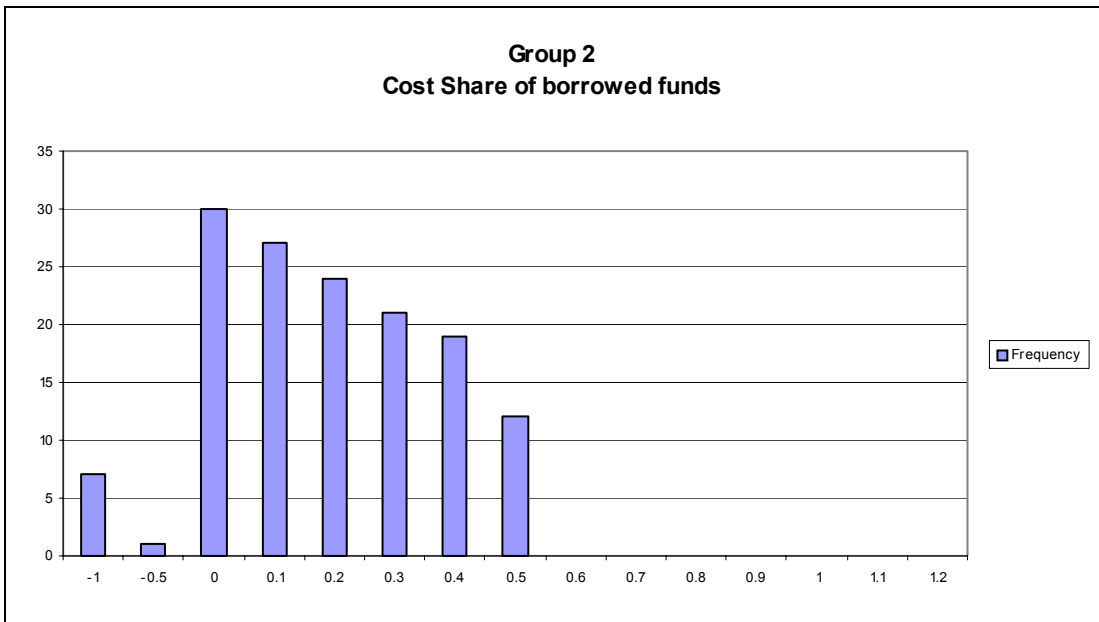


Figure 9b

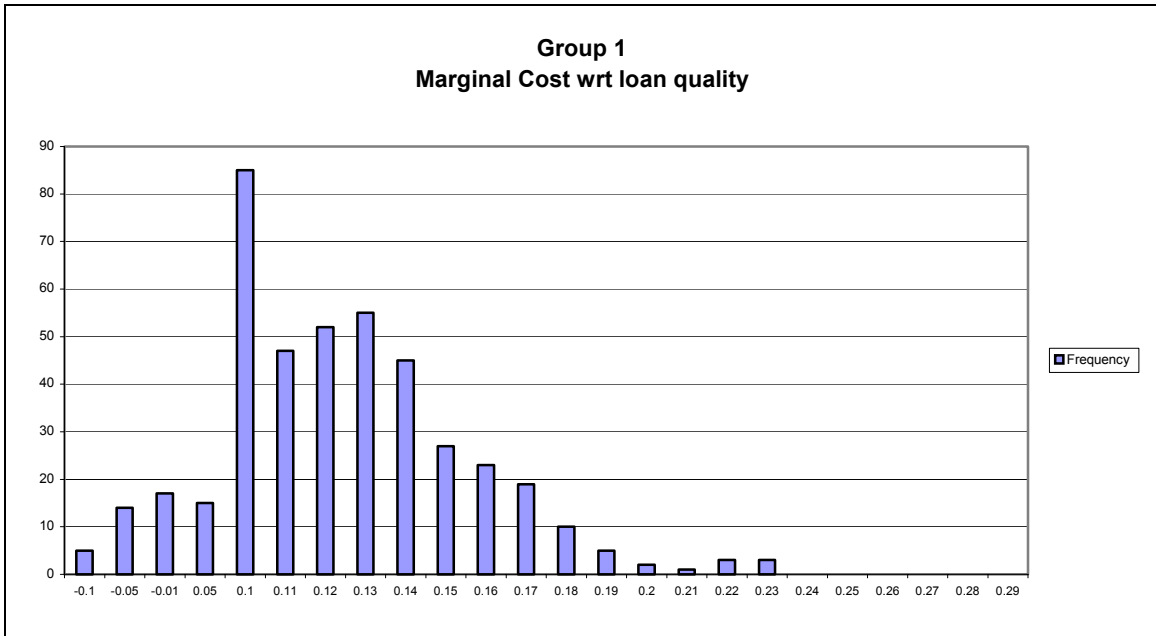


Figure 10a

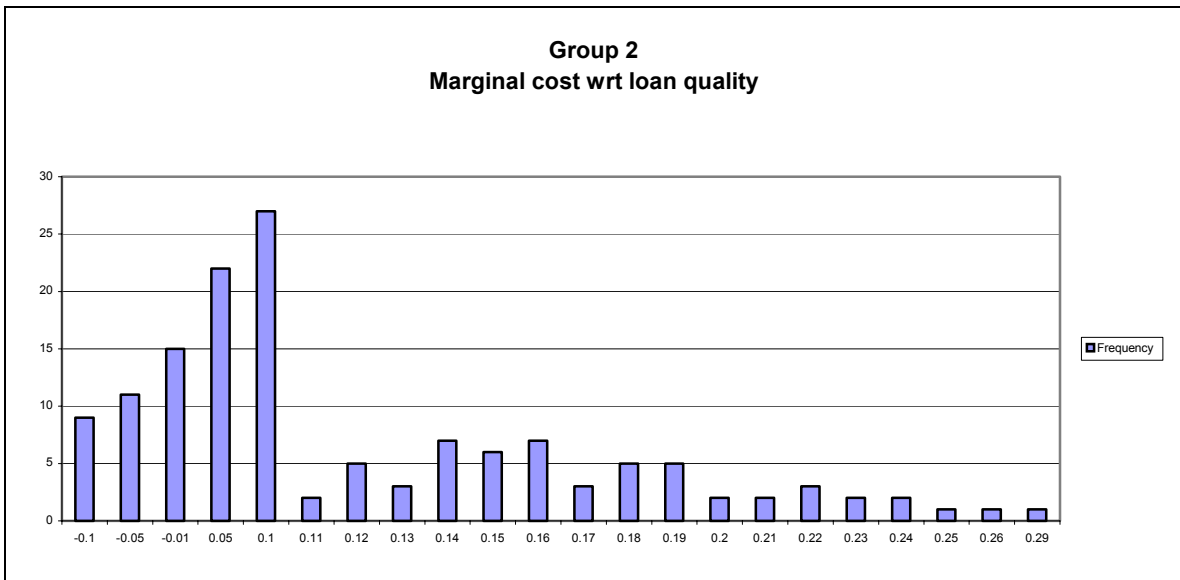


Figure 10b

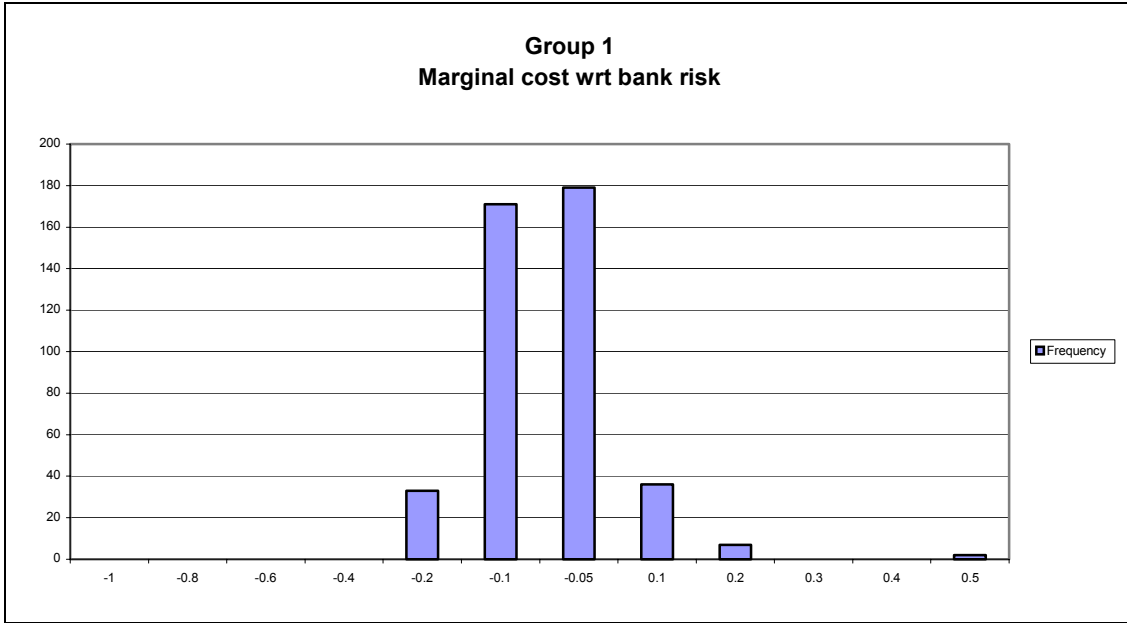


Figure 11a

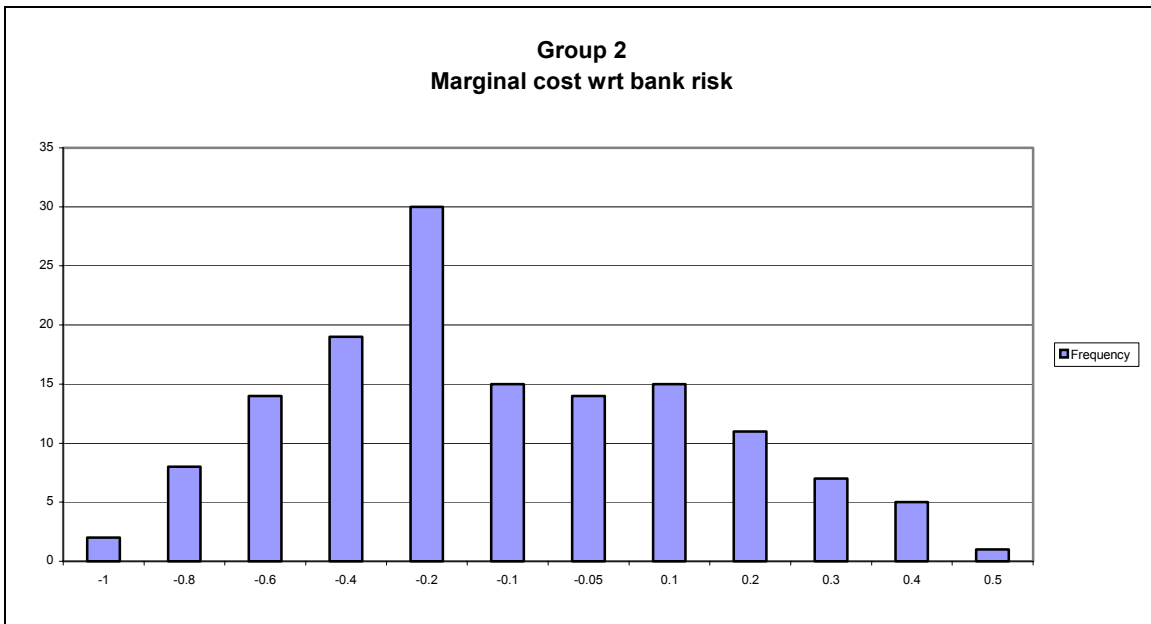


Figure 11b

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