Risk Specifications in Risk Efficiency Analysis

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Abstract**—** Recent efficiency models are based on the fact that the risk preferences are important factors affecting the profitability of a bank. The risk specifications in these models are generally based on a single parameter, such as market risk or standard deviation of predicted profit. This study, arguing that a single parameter will not be sufficient to specify the structure of different types of risks, aims to develop a multiparameter risk efficiency frontier. It is discussed that capital adequacy ratio formulations have some weaknesses that make them inferior risk parameters. It is also shown that different risk types may have differing effects on profitability. Since the amount of risk of different types assumed by a bank is also a part of its production plan, we argue that a multiparameter risk specification should be employed to have a complete efficiency frontier analysis.

Keywords**—**X-efficiency, Turkish Banking Sector, Risk Efficiency, Capital Adequacy Ratio, Stochastic Frontier Analysis

I. INTRODUCTION

The purpose of this study is to investigate the risk preferences on the efficiencies of banks. There is an enormous literature addressing the inefficiencies of banks. Since the introduction of X-efficiency by Leibenstein (1966), it has been used to analyze various issues, including assessment of effects of changes in government policies [16], cross–country efficiency researches [14], merger and acquisition analysis, and the evaluation of performance of an industry and determining the ranking of its firms. The vastly growing literature has developed not only different estimation methods, namely nonparametric and parametric methods, but also different approaches employing different objective functions.

The optimization concept differs according to the objective function. X-efficiency is an economic concept and differs from technical efficiency since it complements technical efficiency with allocative efficiency. Therefore, it focuses on not only the amount of output produced for a given input structure, but also the selection of input or output mix for given input and/or output prices. The choice of objective function determines the optimization concept, or the performance equation according to which banks are assumed to choose their input and/or output mix.

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Most of the studies in the literature employ objective functions focusing on cost-minimization or profit maximization [4]-[6]. The main deficiency of these models, which comprise only input and output parameters and their prices, is their negligence of risk. A few studies, to the best of our knowledge, have undertaken risk parameters as an input in X-efficiency models [1]. However, the risk level of the production plan applied by managers is an important factor affecting the profitability of the firm. While low risk decreases the expected profit, it prevents the bank from suffering harshly in case of unexpected events, such as economic crisis. On the other hand, high risk strategies would provide higher expected profits, but will also lead to higher expected returns and accordingly higher discount rates for future cash flows. Therefore, high risk plans, even though they provide higher expected profits, may lead to lower market values. Consequently, efficiency measurement by just looking at profit maximization while ignoring risks, may lead to wrong evaluations since banks with low risk strategy would be evaluated as inefficient since they have lower expected profit. Without doubt, the risk level of the production plan is a choice of the bank and there is a strict correlation between risk and return. To summarize, risk and return preference is an important consideration for banks and should be taken into account in efficiency analysis.

This argument has led to a new stream of literature, which models production equation according to risk aspects, instead of the traditional production function approach. Utility maximization model, introduced by Hughes and Moon (1995), assumes that bank managers select the optimum production plan according to utility they obtain from the production plan [9],[12],[15]. Risk isn't incorporated into the utility function directly. Instead of defining a utility as a function of expected profit and its standard deviation as a risk parameter, the model assumes that production plan, namely input and output mix, represents the risk and all other managerial preferences. It is considered that the probability distribution depends on the production plan. Using duality theory, most preferred, i.e. the ones that maximizes the utility of managers, input and profit demand equations are obtained, and these equations are regressed to obtain predicted profit, ER, and the standard deviation of the predicted profit, RK. Then, using these measures, a risk-return frontier is developed [15];

$$ER_i = \alpha_0 + \alpha_1 RK_i + \alpha_1 RK_i^2 + v_i - u_i \qquad (1)$$

where v_i and u_i are error and inefficiency terms. The critical aspect of the risk-return efficiency frontier developed by utility maximization approach is the specification of risk. Instead of well-known widely used types of risk, e.g. liquidity risk, and credit risk, the model defines the standard deviation of the predicted profit as the risk measurement.

Reference [19] applies utility maximization method on German Bank data set to compare the risk-return efficiency with traditional efficiency measures, namely profit maximization and cost minimization efficiency. He finds that efficient banks with low risk production plans are classified as inefficient in standard profit efficiency measures. He also finds low rank order correlation between risk-return efficiency and standard efficiency measures.

There exist other risk specifications used in efficiency models. The most popular risk variable incorporated in efficiency analyses is capital adequacy ratio. A relatively high capital adequacy ratio could signify that a bank is operating over cautiously and ignoring potentially profitable diversification. Despite the arguments in favor of the negative relationship between capital and earnings due to reduced risk on equity and therefore a lower expected return on equity, Berger (1995) finds a positive relationship between CAR and ROE and he concludes that higher capital is followed by higher earnings through reduced interest rates on uninsured purchased funds as a result of reduced expected bankruptcy costs. It is also argued that well capitalized banks face lower expected bankruptcy costs thus reducing the cost of funding and resulting in an increase in income. Reference [18], analyzing the performance of foreign and domestic banks in Korea prior to during and after the Asian financial crisis, show that capital adequacy ratio correlates positively with domestic bank performance measured as ROA and ROE. Reference [7] argues that a bank has a smaller incentive to avoid default if future profits are lower as a consequence of tighter capital adequacy requirements and in order to raise the amount of equity tomorrow the bank may choose to increase risk today.

A number of studies use other variables, such as macroeconomic factors or market based risk measures, as proxies for risk that is born by the banking industry due to their intermediation functions and operations. Reference [21] uses standard deviation of Return on Assets, along with bad loans, and capitalization as risk factors. Flannery (1981) examines whether market interest rate fluctuations have a significant impact on profitability and his results show that large banks have effectively hedged themselves against market rate risk and therefore they are not necessarily vulnerable to market rate changes. Reference [11] analyzes the variability in bank's credit risk and profitability by comparing the relative contributions of interbank variation and the variation through time to the overall variability in credit risk. It is argued that the aggregate demand and supply for loan finance will influence the riskiness and performance of the banking sector.

This paper aims to extend the existing risk-return efficiency literature by implementing a multivariate risk specification. We believe that the financial risks of banks have a very complex structure; therefore a complete risk efficiency model should be based on a multiparameter risk specification to be able to cover differing aspects of these parameters. Therefore, instead of using a single overall risk measurement, e.g. market risk or standard deviation of predicted profit obtained from utility maximization, we examine the risk behavior of banks in different dimensions covering major types of risks.

The remainder of the paper is organized as follows. Section II describes data and the methodology used in the study. Section III presents and discusses the research findings. Section IV gives a brief conclusion.

II. Data And Methodology

X-efficiency measures develop a frontier, consisting of best performing units, which is used as a benchmark to measure the relative performance of units in the sample [6]. These studies are based on two different approaches; the nonparametric data envelopment analysis and the parametric stochastic frontier analysis. Nonparametric data envelopment analysis uses linear programming to define the best performing units and therefore doesn't require any assumptions on the structure of the relationship between the output and input parameters. The major deficiency of this method is that it doesn't allow for random errors. The detailed information about nonparametric methods can be found in Cooper *et* al. (2004).

On the other hand, stochastic frontier analysis requires specifications about the functional form of the equation to be estimated. The stochastic frontier model can be written as (Greene, 2002);

$$y_{it} = f(x_{it}, z_i) + v_{it} - Su_{it} = \beta' x_{it} + \mu' z_i + v_{it} - Su_{it}$$
$$i = 1,...,N;\ t = 1,...,T, \qquad (2)$$

where the function "f" defines the cost or production function, which contains regressors, "x_{it}", such as, input quantities, output quantities, and/or their prices. The second parameter, z_i, represents the firm specific factors that are time independent, such as dummy variables for region and etc. The second and third terms in the model represents the deviations of firms from the frontier defined by function "f". The error term, "v_{it}", is an idiosyncratic normal distributed variable, which captures the measurement errors and other noises that are neglected by nonparametric models. The inefficiency term, "u_{it}", is restricted to be nonnegative and the sign of it, "S", takes a value of (+1) if it is a production function and (-1) if it's a cost function. These terms are assumed to be independent. In other words, the composed error term, "$v_{it} - Su_{it}$", the sum of two independent variables, is an asymmetric variable, with negative skewness for production functions and positive skewness for cost functions. Since the error term and inefficiency term are independent, the variance of the composed error term is equal to the sum of variances of the error and inefficiency term;

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \qquad (3)$$

The proportion of σ_u^2 to total variance is an important parameter which measures deviation from the efficiency frontier due to inefficiency;

$$\gamma = \frac{\sigma_u^2}{\sigma^2} \qquad (4)$$

If gamma is zero, it implies that error term dominates and that there is no inefficiency and all deviations from the frontier representing best performance units, result from error term. If gamma is close to one, we can conclude that the inefficiency term dominates and most of the deviations from the frontier results from inefficiency.

There are four alternatives for the distribution assumption of the efficiency term, "u_{it}" [20]. These are half-normal, exponential, truncated normal and gamma models. Reference [20] states that they have found some empirical evidence that the selection of distribution doesn't affect the ranking of units according to their efficiency and the list of firms in the bottom and top deciles. Therefore, they suggest the use of simple distributions, such as half normal or exponential, instead complex, but more flexible distributions, such as truncated normal or gamma.

The second question is how to estimate the stochastic frontier model with a panel data structure, as defined above. Reference [20] lists three alternative methods, namely panel data estimators, fixed effects and random effects approaches, and maximum likelihood estimator. Reference [20] states that, although there are conflicting evidence provided from previous studies which compare these methods, they are likely to generate similar efficiency rankings, where most professionals are interested. In this study, we use maximum likelihood method, to estimate our model which has a time independent efficiency term with truncated normal distribution.

The final issue to be decided is the parameterization of the inefficiency term. The time-invariant model assumes that the inefficiency term is constant over time. In other words, the time index on inefficiency term in Equation (2) drops and it is turned into "u_i". This doesn't seem to be rational especially for long panel data set. The efficiency may change due to technological developments, managerial change and new regulations. Time varying efficiency on the other hand relaxes this assumption and allows the inefficiency term change over time. Nevertheless, the cost of obtaining time varying efficiency term may be huge due to loss of degrees of freedom as the number of parameters to be estimated increases. One way to obtain time varying efficiency term is to use dummy variables for each period. However, this results in extra T-1 parameters to be estimated. Reference [17] proposes an alternative single variable time variant model;

$$u_{it} = \beta(t)u_i$$
$$\beta(t) = \exp[-\gamma(t-T)] \qquad (5)$$

where T is last period in the data set, γ is the changing parameter to be estimated. If γ is less than zero, then $\beta(t)$ increases as t increases, implying an increasing inefficiency. If $\gamma > 0$, $\beta(t)$ decreases leading to a decaying inefficiency, as t increases. For $\gamma = 0$, a time invariant model is obtained. Reference [17] employs maximum likelihood to obtain the estimates of the model.

Our sample consists of a panel of 15 banks covering the period from 2002 through 2006. We do not use the data prior to 2002 because the reporting of banks has significantly been changed following the banking and liquidity crisis of 2001 in Turkey. Also we only include commercial banks with retail banking business. Despite the fact that this period is marked by significant economic expansion and growth in the world economy and thus is not really a good period to see the consequences of risk taking behavior on the downside, it is a period when the regulatory constraints in the Turkish Banking system and banking supervision has significantly increased. The regression equation employed in the stochastic frontier analysis is given below;

$$\ln(OI/TA)_{it} = \beta_0 + \beta_1 CAR_{it} + \beta_2 DLTC_{it} + \beta_3 DPF_{it} + v_{it} - u_{it} \qquad (6)$$

where OI/TA is the operational income over total assets, CAR is the capital adequacy ratio, DLTC is the doubtful loans to total credit and DPF is the deposits to 3^{rd} party funds ratio. Table 1 shows the descriptive statistics of the data used in the analysis.

Table 1: Descriptive Statistics of the Data Used in the Analysis

Variable	Mean	Std. Dev.	Min	Max
OI/TA	0.090	0.035	0.025	0.200
DLTC	0.020	0.030	-0.060	0.167
CAR-A	0.194	0.114	0.041	0.734
CAR	18.386	7.088	8.647	44.512
DPF	0.705	0.096	0.470	0.881

A. The Variables Used in the Analysis

There exist different classifications for a financial institution's risks in the literature. In this analysis, we use 3 parameters to define the risk specification. These parameters are used to represent insolvency risk (CAR), credit risk (DLTC), and liquidity risk (DPF). Market risk and off-balance sheet risks are included in CAR. Some of the risks not included are eliminated because they are not relevant or significant for this analysis. To start with, sovereign risk is ignored, since it is fixed for all the banks in the sample. Other risks, such as operational risk, couldn't be included since there are no measurements available for operational risk.

Table 2 below reports the correlations between the risk parameters. Low correlations among the risk parameters shows that they don't interact.

Table 2: Pearson Correlations between Risk Parameters

	DPF	CAR-A	CAR	DLTC
DPF	1.00			
CAR-A	-0.20	1.00		
CAR	0.32	0.09	1.00	
DLTC	0.10	0.07	0.14	1.00

Capital Adequacy Ratio (CAR): Capital adequacy ratio is the ratio of equity to the sum of risk weighted assets and the market risk. There are different formulations for capital adequacy ratio, .e.g. Basel–II ratio, requiring the inclusion of operational risk. CAR is a broad measure of insolvency risk, which is defined as the likelihood of failure of a bank due to excessive and sudden losses in its assets. Capital serves as a buffer to absorb unexpected losses as such a higher CAR represents financial strength to weather downturns in the market although there is always a trade off between risk aversion and profit maximization.

Without doubt, there are some weaknesses of CAR specifications defined and used by regulators. Some of these weaknesses are eliminated with new specifications defined by Basel-II. In the contemporary formulation, government bonds issued by OECD countries, which are classified as risk free, implying a zero weight in the earlier version of the formulation, are weighted according to their country credit ratings. Therefore, we calculated two different capital adequacy ratios. CAR applies BASEL-I capital adequacy formulation. CAR-A is the adjusted capital adequacy ratio, which adds the government bond portfolios with a weight of 100% (as BASEL II requires) to the CAR ratio.

Another interesting point is the low correlations between the DLTC (doubtful loans to total credit) and both capital adequacy ratios, given in Table 2. This demonstrates another weakness of the current CAR formulation. For loans without any risk rating, CAR formulations differentiate borrowers only according to their segmentation, not their credibility. Therefore, borrowers of a particular segment are weighted equally regardless of their quality. This implies that capital adequacy ratios don't sufficiently represent credit risk.

Therefore, doubtful loans to total credit ratio is added in the analysis. Banks report their doubtful loans as a separate asset item in their balance sheets. Specific provisions are made against those doubtfuls and reported as a deduction from debt balances. Therefore, what actually appears in the balance sheet is the net doubtful debtor balances. The provisions on the balance sheet are calculated on expected recovery rates of such loans where the regulatory body sets the minimum required provisions based on certain criteria.

Ratio of net doubtful debtor balances to total credits is a commonly used indicator to measure credit portfolio quality in banks. However, to see the full picture in terms of the performance of the loan portfolio, the provisions for loans booked in the P/L should also be taken into consideration. Therefore, in this study, we compare the sum of the provisions expensed in the P/L during the period and the increase in net doubtful balances in B/S to total credits to reflect the total amount of credits that turn into doubtfuls /bad debts during the period. We believe this is more reflective of the quality of the loan portfolio.

Deposits to 3rd party funds: Liquidity risk is measured by the ratio of deposits to third party funds. Banks may find that in times of economic turmoil less reliance on bond issuance or bank loans reduces liquidity risk due to less dependence on market conditions. Deposits are a stable source of funding and are not expected to show much variability. What's more, the cost of deposits is expected to be lower than other sources of funding even though it is difficult to make a prediction for the cost of time deposits due to competition among banks to increase market share.

The dependent variable to measure efficiency is operational income to total asset ratio. It is a widely used ratio to calculate financial performance among practitioners. Its major advantage compared to net income based parameters is that it excludes nonrelevant factors such as extraordinary income and expenses.

III. Empirical Results

Due to two different capital adequacy specifications described, we employ different frontier equations for each capital adequacy ratio. Both time independent and time variant methods are applied. Since the time period covered in the analysis is only 5 years long, the time variant model isn't expected to provide any improvements.

Table 3 shows the results of the model with CAR. For both of the estimations, γ is calculated as 0.64, which shows that the 64% of volatility of the composed error term, comes from the efficiency term, "u_{it}". The Wald test shows the overall significance of the whole model at the 1% level of significance.

All of the coefficients except DLTC in both estimations are significant at 5% significance level. An interesting issue is the significant positive coefficient of CAR, which implies that lower risk has a positive impact on their profitability. In other words they have less income when they employ risky strategies. The positive relationship between CAR and profitability contradicts with the general wisdom.

Table 3: Estimation Results with CAR

	Time Independent	Time Variant
CAR	0.023555	0.024156
	(0.01)*	(0.01)*
Dep. / 3. P.F.	1.215571	1.384933
	(0.38)*	(0.50)*
DLTC.	1.423653	1.220795
	(0.84)***	(0.92)
C	-3.28615	-3.41623
	(0.28)*	(0.36)*
σ^2	0.1084	0.1058
γ	0.64	0.64
σ_u^2	0.0694	0.0674
σ_v^2	0.0390	0.0384
Wald chi2(5)	49.37	40.96
Log likelihood	-0.8593	-0.7278

The values in the parentheses are standard deviations of corresponding coefficient estimates.
*, **, *** indicates the significance at 1%, 5%, and 10% respectively.

One possible explanation is the zero weighted government bond investments in the risk weighted asset specification of CAR formulation. The crowding out in the Turkish economy results in large government bond investments. Since the government bond investments have zero risk weight, an increase in the government bond investment in the balance sheet leads to a higher operational profit while keeping CAR intact or even lowering if the investment is financed by an equity increase.

To tackle this problem, we define adjusted capital adequacy ratio, which adds the government bond investments with a risk weight of 100%, to the risk weighted asset measurement in the capital adequacy ratio formulation. Table 4 represents the results of estimations with CAR-A. The coefficients of all risk parameters except CAR-A are similar to the previous analysis. CAR-A has an insignificant positive effect on the profitability.

Higher funding with deposits results in higher operational income. As the deposits to third party funds ratio increases, the banks are able to rely more on their customers on producing funds and become less dependent on market circumstances and have lower liquidity risk. On the other hand, by increasing the proportion of deposits, banks are also able to reduce their costs, since deposits are generally cheaper than third party funds. Therefore, the liquidity risk measured in this sense, differing from other risk parameters, is expected to result in a higher profitability.

Loan loss provisions have a positive impact on operational income. Since operational income doesn't include the loan loss provisions, we expect a positive coefficient for operational income. However, a negative impact on net income may be expected, after the loan loss provisions are subtracted. As the quality of the loan portfolio decreases, the net interest income increases, since higher interest rates are charged for lower quality loans.

Table 4: Estimation Results with CAR-A

	Time Independent	Time Variant
CAR	0.110193	0.355451
	(0.27)	(0.32)
Dep. / 3. P.F.	1.83796	1.252
	(0.43)*	(0.57)**
DLTC	1.902317	2.467
	(0.95)**	(1.03)**
C	-3.25164	233.453
	(0.43)*	(0.36)*
σ^2	0.1154	0.1025
γ	0.55	0.50
σ_u^2	0.0639	0.0509
σ_v^2	0.0515	0.0516
Wald chi2(5)	22.12	15.40
Log likelihood	-9.5316	-8.6229

The values in the parentheses are standard deviations of corresponding coefficient estimates.
*, **, *** indicates the significance at 1%, 5%, and 10% respectively.

IV. Conclusion

In this paper we try to develop a multiparameter risk efficiency model. Three parameters are used for risk specification. Capital adequacy ratio is assumed to represent insolvency ratio. Since its denominator is the sum of market risk and the risk weighted sum of balance sheet and off-balance sheet assets, it is expected to reflect market risk and credit risk. However, it is shown that CAR and DLTC are not correlated, implying that it isn't a good indicator of the loan quality. Therefore, to measure credit risk, DLTC is also included. Next, to measure liquidity risk, deposits to third party funds ratio is employed. Since deposits are cheaper and less volatile compared to third party funds, we expect an increase in profitability as liquidity risk decreases, as opposed to other types of risks. This contradicts with the general wisdom arguing that as risk increases the expected profit also increases.

In view of this argument, we state that different risk types have varying effects on the profitability. Therefore, a single risk specification wouldn't be sufficient to reflect this complex structure in a risk efficiency frontier.

Consequently, we develop a three parameter risk efficiency model and reach three conclusions;

- Capital adequacy ratio formulations have some fundamental weaknesses that may be misleading.
- Liquidity risk, measured as deposits to third party funds, have a negative impact on profitability.
- Doubtful loans to total credit ratio has a positive coefficient as expected.

To summarize, we argue that different types of risks have different impacts on the probability of a bank. Some of these risks may be irrelevant, while some may have negative impact on expected profitability. What's more, risk types with positive impacts may have varying intensities. Some may have a more powerful effect. Without doubt, the amount of risk assumed by a bank is part of the production plan. Some banks may prefer to carry a higher market risk, while others may prefer a higher credit risk. Since these risks have differing effects on the profitability, a single parameter risk specification will not be sufficient to reach a thorough risk efficiency model.

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