A Linear Programming Model for Bank Balance Sheet Management

S GÜVEN[1]

Middle East Technical University, Ankara, Turkey

E PERSENTILI

Sabanci Holding, Istanbul, Turkey

Bank balance-sheet management which involves the determination of the size and composition of a bank's assets and liabilities over a multiperiod planning horizon is one of the most prominent issues in bank strategic planning. Not only management policy choices, but legal restrictions and minimum safety requirements, dictated by the economic and political environment operated in, mean a balance has to be struck between the conflicting objectives of profitability, liquidity and risk. Bank balance-sheet management is further complicated by the fact that decisions made at any point in time affect profits, liquidity and risk, not only at the time they are made, but in the periods that follow. This paper discusses a multiperiod linear programming model constructed for a commercial bank in Turkey, that takes into consideration this systematic relationship in the legal, financial and institutional setup of Turkey over the period 1987–1990. Sensitivity analysis results demonstrate the relevance of the model for informed policy choice, and the use of the model as a planning tool. © 1997 Elsevier Science Ltd

1. INTRODUCTION

THE DETERMINATION of the size and composition of the sources from which bank funds are to be collected, and how they should be distributed to the various uses is termed Bank-Balance Sheet or Bank Asset and Liability Management. Bank balance-sheet management is a complex problem, with multiple and conflicting objectives.

The first complexity arises from the time frame to be covered and the frequency or the length of time periods for which the balance sheet values have to be determined. This choice is dictated by, as well as determining, the decision variables of the model. Decisions concerning the management of funds over short periods of time are governed by considerations different from the management of funds over medium and longer time periods. However, choice of the time frame based on these considerations alone may not be enough since the economic environment operated in, through its effect on the flow of funds, might necessitate the incorporation of reasonably short periods into a medium-term model. This is of special importance in countries like Turkey and some Latin American countries, where not only annual but monthly inflation rates are high, and therefore impose changes on interest rates, maturity structure of deposits, loans and securities which are often unpredictable.

Models developed to date vary in the time perspective covered, ranging from one period models, annual models with quarterly time periods, to medium term nested linear programming models consisting of interrelated models

spanning different horizons [1]. Computational feasibility as well as the economic and legal environment operated in governs this choice. Mostly, deposits and interest rates are treated as known or determined by some other econometric model and assets such as cash, various maturity loans, securities and investments are solved for by the model. The major reason for this is that factors affecting the magnitude and maturity structure of deposits such as the quality of service, number of branches, etc are different from those that affect assets, and they are controllable in the long run rather than in the short or medium run. Most of the models in which deposits are treated as uncontrollable variables are deterministic linear programming models [2–4]. For handling uncertainty in deposits stochastic linear programming models were proposed as early as the 1960s [5], but appear to have become computationally feasible only recently [6]. Nonlinear models that treat both interest rates and size and type of assets as controllable variables are avoided for computational feasibility reasons as they are not very practical planning tools in real applications.

A second problem of bank balance-sheet management arises from a conflict of objectives. Commercial banks aim at maximizing returns both in the short, medium, and long runs to ensure competitiveness and survivability. This requires fund collection with minimum cost and investment into the highest return alternatives having minimal risk, while meeting depositor and borrower demands for cash at all times. However, attraction of additional funds usually necessitates incurring additional costs, and of course higher yield investments often bear higher risk. In countries like Turkey, Central Banks impose liquidity regulations on commercial banks limiting the percentage of funds to be invested into profitable alternatives. Resolution of such conflicts may be attempted with the help of goal programming [7, 8], but having to provide subjective utility functions that define the preference ordering of the decision maker between objectives, or the importance accorded by him to the degree of over or underachievement of specific objectives, renders the implementability of these models difficult [9, 10].

We describe in this paper a multi-period LP model constructed for a Turkish bank. The model takes into consideration the interactions between maturity and cost structures of the bank's liabilities, and the composition of its assets, where the entire balance sheet of the bank is treated as the portfolio for which financial planning is undertaken. The context is the legal, financial, and institutional setup of Turkey over the period 1987–1990. This economic and legal background is described first. Situation analysis, the model, basic assumptions, and the data used are discussed next, and finally the retrospective analysis of the bank's policy choices over the period 1987–1990 and how the model can be used as a planning tool are presented.

2. INSTITUTIONAL BACKGROUND

Banks in Turkey operate in an oligopolistic market. Of the several commercial and specialized banks some are private and some are state owned but subject to the rules and regulations set by the Central Bank (CB) and the Association of Banks. Before 1988, the CB set the ceiling for the interest rates of deposits, and the individual banks then set their rates accordingly. In 1988, this regulation changed and individual banks were free to set their rates without CB imposed ceilings. The result was an immediate price war between the banks which led to a drastic increase in the interest rate of deposits. As banks use a cost plus basis in setting the interest rate for loans, the increase in the interest rate of deposits resulted in a corresponding increase in the interest rate charged for loans. The demand for loans, which was already decreasing owing to the slowing down of the economy decreased further with the increase in the lending rates. Thus after a few months the damage of price competition was realized and since the end of 1988, a small group of banks acting as price leaders set the rates which are followed by others within a ± 5% range. So in the period under consideration (1987–1990) competition among banks was not based on price, but on other long term factors such as the number of branches, quality of service, etc.

However, it must be noted that these factors were not very effective in significantly increasing or decreasing the deposit share of individual banks due to the distortions introduced by other CB and government regulations. In Turkey public institutions and other institutions are not

free to choose the banks into which to deposit their funds. CB specifies the banks where these deposits are to be made based on the specialization of individual banks. During 1987 to 1990, regulation changes on public and other institution deposits that resulted in preserving the deposit share of state owned banks and their ranking contributed to the ineffectiveness of non-price competition. Therefore ranking in terms of total deposits has remained fairly stable and only slightly changed from year to year. The significance of this is that given total deposits the share of individual banks is almost constant, and cannot be affected by bank managements in the short to medium run. However, with the same share of deposits, maturity composition of time deposits can be altered to a certain extent based on the effective real interest rate differentials for different maturities. This can have a positive effect on narrowing the gap between asset and liability maturity structures.

Economic conditions effective in a particular period have a profound effect on the level of deposits that materialize, and on the average interest rates applied to deposits. Turkey's economic performance over the period 1987–1990 was far from stable. While GNP growth rates fluctuated from 8.1% in 1986 and 7.4% in 1987, to 3.4% in 1988 and 1.8% in 1989, inflation rates (measured by the wholesale price index) changed from 32% in 1987 to 68% in 1988, 70% in 1989, and 55% in 1990 [11]. Following the dramatic increase in the general price level, and the relaxation of CB imposed ceilings on interest rates, the interest rate for annual time deposits increased to 85% at the end of 1988 as noted above. However, with the slowdown in GNP growth rate, the demand for high cost loans declined and default on the part of loan customers in making due interest and principal payments increased. The combined effect of high interest expense and reduced loan demand with higher risk of default on the part of loan customers is reduced profits for most of the banks in the periods that followed (mainly in 1989). The bank under consideration is one of them.

In Turkey, loans extended by banks are required to be secured by collateral according to legislation. Therefore default on the part of loan customers in making due interest or principal payments does not result in complete loss of extended capital, but in cash flow problems in the short run during which the legal process becomes effective in redeeming it. The credit-customer information units of banks that gather information on creditworthiness and marketable collaterals of their loan customers disseminate information on any defaulted customer to all their branches. Thus rather than discriminating between customers according to their risk levels by charging them differential interest rates, banks very highly collateralize their loans and do not extend loans to customers who have defaulted on them. What is observed is a differential short and medium term interest rate for loans among banks rather than differential loan interest rates according to the risk level of customers of each bank as would be the case in markets where anomalies of this sort are not seen. The riskier loan customers try to obtain credit from smaller banks at a higher interest rate.

However, when the economy is expanding and loan demand increases, banks extend "spot credits". These loans are extended for at most 2 months at an interest rate much higher than for short-term loans as collateralization of these loans are much looser or even non-existent. As the name implies they are extended on the spot, based on special terms. Thus due to the nature of these loans (unsecured by collateral, irregular and unrepetitive), information on their incidence and their terms that would allow calculation of actual default cost to the banks is not disclosed.

Towards the end of the period under consideration, as the economy slowed down and uncertainty increased, not only the interest rate charged to loans increased, but the duration structure of loans changed. The share of short term loans in total loans increased as compared to the share of longer-term loans.

In this unstable environment, CB as the regulator of money circulating in the economy changed legal reserve requirements and liquidity ratios at irregular intervals. These changes considerably altered the funds that could be invested into profitable assets in each period. These developments, together with the liberalization of the foreign exchange regime of the country in the 1980s, introducing variety in money market instruments and financial activities, induced the requirement for more effective bank balance sheet management.

3. BANK ACCOUNTS AND LEGAL REQUIREMENTS

Commercial banks in Turkey have two seperate entries for domestic (TL), and foreign currency (FC) funds on their balance sheets, and income statements. A typical bank balance sheet consists of the following main asset accounts.

1. Cash in vaults and reserve deposits with Central Bank (non-interest bearing deposits of banks with the CB, determined as a legal percentage of the outstanding TL deposits of the bank, also called the first liquidity ratio).

2. Reserve requirement: banks deposit a legal percentage of deposits (reserve requirement ratio) in TL and FC in respective reserve requirement accounts with CB which are interest bearing accounts.

3. Deposits with other banks: very short term (overnight to a week) lending of TL funds to Interbank money market where banks borrow and lend money from and to each other anonymously with the intermediation of the CB, and deposits with other foreign banks of FC funds for short periods.

4. Portfolio of securities: major component being government bonds and treasury bills with common stocks, certificate of deposits (CDs), gold and other securities forming the remaining smaller part of the portfolio. Commercial banks are required to keep a legal percentage of total deposits as government securities (Second Liquidity Ratio). Investing in government securities after second liquidity requirement is satisfied, is also an investment alternative with interest income based on the interest rate arrived at in auction sales for government securities. During the period under consideration maturity dates for this alternative was 1 year for government bonds and 3, 6, or 9 months for treasury bills.

5. Equity participation: investment in other institutions, with its return being dividends or distributed profits.

6. Loans: the most important and profitable asset, but having a substantial component of risk associated with the borrower's inability to make due payments. There are two major categories: short term loans: given for at most 18 months, the principle of which is returned at maturity or upon return of the loan. Interest payments are made every 3 months (March, June, September, December) with the first

payment made on the first payment month following 3 months after the inception of the loan; and medium term loans: given for at most 5 years, the principle of which is paid in seven equal installments, every 6 months, starting after the second year of inception of the loan. Interest payment dates are the same as for short term loans. A loan is irregular if its due interest payments are not made. A legal process starts to redeem it, and usually a substantial part of the irregular loan is recovered through mortgages on customers' properties, but such disruptions cause cash inflow problems. Any parts of loans unrecovered are written off as sunk costs.

7. Other assets: mostly fixed assets such as bank premises, land, buildings, equipment, etc which are non-earning assets.

The main liability accounts of a typical Turkish bank can be enumerated as follows.

1. Deposits: there are four major types according to depositor categorization, each further subdivided into sight and time deposits with varying maturities.
   Savings and certificate of deposits which are mostly private deposits.
   Commercial institution deposits, 95% of which are sight deposits.
   Public institution deposits, with an interest rate set by the CB and the same for sight and time deposits.
   Other institution deposits. Institutions are not free to choose the banks into which their deposits are made but the CB specifies the banks where public and institutional deposits are to be made, based on the specialization of individual banks. Time deposits for all depositor types, other than public institutions, are monthly, 3-monthly, 6-monthly and yearly with increasing nominal interest rates applied to deposits when they mature. Foreign exchange deposits (FED) have the same maturity classification with no depositor categorization.

2. Borrowings from the CB, Interbank and the World Bank. Apart from the short term loans obtained from Interbank, these are mainly rediscount loans where the difference between the interest rates applied by the individual banks and the CB or the World Bank is the return of the banks.

3. Other liabilities such as accounts payable and accrued expenses.

4. Capital account, which, in addition to issued and paid-in-capital and retained earnings, consists of revaluation surplus and reserve funds. Each year banks are required to deposit 15% of their annual profits into CB as reserve funds on which they earn interest income at the rate of government securities. Revaluation surplus serves the purpose of more realistically valuing fixed assets in an inflationary economy where the loss in value in nominal prices is almost nil, whereas the book value rapidly converges to zero. The rate of revaluation is set by the financial authorities each year and is usually below the actual value loss.

The income statement of banks consists of interest and non-interest incomes and expenses. Interest income accrues from interest earning assets in the balance sheet. The interest rate charged for short-term loans is calculated on a cost plus basis where cost is determined as the weighted average of outstanding deposit interest rates and revised whenever bank management thinks that it is required. Taxable income excludes interest income of securities since securities are tax free.

4. ANALYSIS OF THE BANK'S PERFORMANCE

The bank under consideration, referred to as "the bank" in the text, determined the composition of future balance sheets by forecasting the values of the accounts based on historical data and experience, and reviewed their estimates every 3 months. We analyzed the actual changes in the main accounts of the bank for the years 1986–1990 to determine how effective the method used by the bank was. The main findings of the analysis are as follows:

1. Excluding the period between the second quarter of 1989 and first quarter of 1990, loans increased (using 1986 constant prices). The same is true for the share of loans in total assets. Exogenous factors were effective in the disruption of the increase in loans. High inflation and deposit interest rates, and low GNP growth rates, increased the risk of loan customers for banks. So the bank refrained from extending credit to risky customers. However, a comparison of loans to asset ratio and loans to deposit ratio of the bank with other banks disclose that these ratios are always slightly under the average of the twenty top ranking banks and the difference is significantly higher in 1989 (Table 1).

2. Short term loans constituted more than 70% of total loans throughout the period. The share of irregular loans in total loans increased significantly in the last quarter of 1988 and in 1989, when total loans decreased. It can be said that irregular loans increase with economic instabilities rather than with increased share of loans.

3. Liquid assets have increased in general. The rate of increase of liquid assets was higher in 1989 where loans significantly decreased. The ratio of liquid assets to total assets and to total deposits was higher for the bank especially in 1989 (Table 1). Based on the comparisons in Table 1 the bank can be termed a risk avoider, with this behaviour being magnified during the economically instable year 1989.

Table 1. Comparison of the bank with 20 major banks in the sector

	Year	The bank's performance (%)	Rank of the bank	20 banks average performance (%)*
Loans/total assets	1987	38.30	10	38.40
	1988	35.64	9	36.38
	1989	32.68	17	40.87
Loans/total deposits	1987	50.70	14	68.00
	1988	51.00	12	61.30
	1989	46.50	18	62.00
Liquid assets/total assets	1988	47.37	9	47.07
	1989	47.64	4	40.08
Liquid assets/total deposits	1988	67.70	15	68.50
	1989	67.80	8	61.30

*See [12].

4. With the exception of 1989, the bank's annual profits are positive in constant 1986 prices. The reason for making a loss in 1989 can be attributed to increased interest expense due to increased deposits with very high borrowing rates, decreased interest income due to decreasing loans and increased share of liquid assets in total assets with a much lower return.

The above findings indicate that the bank has a problem in setting the balance between liquidity, risk, and profit and in deciding on its asset portfolio with changing liability compositions.

5. THE MODEL

The linear programming model developed aims at determining an optimal sequence of balance sheet positions for the bank over a multi-period planning horizon. The planning horizon is defined to be N periods, in practice 48 monthly periods. The values of the accounts in the sequence of balance sheets are said to be optimal as they result in the largest possible present value of the bank's net profit over the planning horizon, subject to a variety of constraints. The constraints define the interactions between balance sheet accounts, balance of cash inflows and outflows, liquidity and other relevant legal considerations such as reserve requirements, the bank's initial balance sheet position, and maximum amount of funds that can be invested into alternatives, given the forecasted total deposits for the periods over the planning horizon. More specific definitions of the constraints are summarized below.

5.1. Constraints

1. Total interest and non-interest income for each period, where interest income is the sum of interest incomes from short and medium term loans, securities, commission return from CB borrowings, and interest income from reserve funds deposited with CB. For interest payment months, interest income of short and medium term loans is equal to the summation of interest payments of regular loans that have not matured or have not been returned as of period t, and interest payments of returned loans. For months other than interest

payment months, it is accumulated interest payments of loans returned in that period. Interest income of securities is estimated as the difference between selling and purchasing prices of securities, and for each period defined as the sum of interest income of matured securities and securities sold before maturity. Non-interest income is the sum of fee and commission income from loans, dividend income from participations, and other non-interest income.

2. Total interest and non-interest expense for each month, where non-interest expense is defined to be the sum of provisions set aside for short and medium term loans that had become irregular in the previous months. Non-interest expense is defined seperately for interest payment months and other months as the percentage of irregular loans to be converted into sunk costs are different for each month. Interest expense is calculated as the sum of interest payments of matured time deposits, and interest payments of time deposits that are withdrawn before they mature (at the rate of sight deposits).

3. Annual profit is the sum of 12 monthly profits where monthly profits are calculated as the difference between interest and non-interest incomes and expenses.

4. Cash balance equation defines the funds remaining in vaults at the end of each period and therefore transferred to the next period as the difference between cash inflows and outflows. First the liquidity requirement necessitates this sum to be greater than or equal to the legally required amount. Total cash inflow at the end of period t is the sum of returned principals and installment payments of loans, securities sold before and on maturity, interest and non-interest income, deposits made in period t, and cash transferred from the previous periods. Total cash outflow at the end of period is the sum of invested funds (loans, securities, participations), the sum of deposits that are withdrawn in period t (before and at maturity), interest and non-interest expenses (excluding non-cash expenses such as provision for irregular loans and depreciation), and additional funds required to satisfy reserve

requirement. In the third month of each year, 15% of the previous year's annual profit is deposited into CB as the reserve fund requirement.

5. Outstanding short and medium term loans at the end of each period t are defined to be the sum of outstanding respective loans at the end of period $t - 1$, funds lent, less the returned loans in period t. Total short term loans returned in period t is the sum of matured loans that have not become irregular, and loans returned before maturity. Total medium term loans returned in period t is the sum of installment payments of loans taken 2–5 years before period t, after provision for irregular loans. Similarly outstanding securities at the end of a period is equal to the outstanding securities at the end of the previous period plus new security purchases in that period, minus the securities that have been sold during that period. It is required that for each period outstanding securities be greater than or equal to the second liquidity requirement. Outstanding participations at the end of period t is the sum of outstanding participations at the end of period $t - 1$, and new investments made in period t, and should be less than or equal to 15% of outstanding loans for the same period (legal requirement).

6. Bank's policy constraints. To balance risk with profit the requirement that at least 25% of total funds invested in loans must be invested in securities and that outstanding loans should be greater than or equal to 50% of outstanding deposits is imposed for each period. To introduce a proxy for loan demands, as demand forecasts for loans are not available, an upper bound on outstanding loans is imposed which is 75% of outstanding deposits. This bound is lowered to 60% and 65% for 1989 and 1990, respectively, for the base run to reflect the case of decreased loan demand and increased risk of lending in these periods. As a proxy to the higher risk of medium term loans as compared to short term loans, outstanding medium term loans are restricted to at most 50% of outstanding short term loans.

Given these constraints the model answers the questions of how much cash and liquid assets to hold; which of several investment alternatives, such as short and medium term loans, securities with different maturities, and investment in other institutions with different yield, liquidity and risk characteristics to choose in each period; and what should be the amount of funds allocated to them so as to maximize the net present value of total profits over a multi-period time horizon.

6. BASIC ASSUMPTIONS AND DATA USED

6.1. Assumptions

● The total annual deposit share of the bank is given to the model assuming that it is determined based on an econometric model. The distribution of total deposits into sight and various maturity time deposits is based on past ratios. However, in determining the share of savings deposits with different maturity in total savings deposits and CDs, regression equations developed by us are used. The multiple linear regression equation that determines the share of savings deposits and CDs with maturity j in total savings deposits is a function of annual nominal interest rate applied to savings deposits and CDs with maturity j, the difference between interest rates applied to deposits with maturity j in period t and in period $t - 1$, annual inflation rate in period t, and the difference in the interest rates applied to deposits with maturity j and k (j different than k). The regression equations for each such deposit type were estimated using time series data for 60 months, and R^2s ranging from 80.7% to 92.4% taken to indicate satisfactory prediction.

● Maturity of short term loans is taken to be a year instead of the legal period of 18 months since it is observed that in practice more than 95% of the loans are returned within a year.

● Statistics on the share of loans that are returned in period $t + 1$, $t + 2,...t + 12$, that were extended in period t, is not collected in the bank, therefore the probabilities of returning the loans in 1 month, 2 months, etc are estimated based

on expert judgement, and different probability compositions are tried during sensitivity analysis.

• The probabilities of returning medium term loans before maturity are assumed to be zero since these loans are mostly used for financing medium term investment projects whose return may not materialize until the loan matures.

• Maturity of TL securities are assumed to be the same as government bonds and treasury bills (since they constitute more than 95% of total securities), that is 3, 6, and 9 months and 1 year. As they are also sources of liquidity and can be converted to cash whenever required at a selling price equal to the discounted face value of the security, it is assumed that securities sold before maturity are from securities with nearest maturity.

• It is assumed that dividend income from investments in other institutions accrue only once a year, starting from 12 months after the investment materializes.

• Interbank investments where transactions are done for very short periods such as overnight or for a week are not considered as an investment alternative in the model.

• Maturity of time deposits are taken to be equal to the legal periods of 1 month, 3 months, 6 months and a year. Since statistics on how much of total deposits in period t is withdrawn within 1 month, 2 months, etc up to maturity are not estimated, the probabilities of each time deposit type being withdrawn in each period before maturity are assumed to be decreasing functions of the time left until maturity.

• Probabilities of short and medium term loans becoming irregular in each period are estimated based on expert judgements since such statistics are not readily available.

Decisions made concerning the investment of funds in any period is reflected in the cash flow of the following periods. Thus the model must consider post terminal period incomes and expenses resulting from collection and investment of funds incurred during the planning horizon. So the terminal period value of interest incomes less interest expenses accruing from investments and deposits made during the

planning horizon is added to the objective function as a terminal value.

The data requirements of the model can be categorized as data related to sources, past investments, constant expenses and incomes and exogenous data related to economical developments. The available data that could be obtained from the bank were monthly balance sheets and income statements for the period 1986–1990, which provide information on outstanding positions of the accounts at the end of each month. The model requires monthly new deposits and net withdrawals, and data on the aforementioned probabilities. The existing monthly data on outstanding deposits and investments for 1986 were used in initializing, that is in estimating net additions to or withdrawals from outstanding totals. The criteria in this initialization phase was to estimate the required data that would provide interest income and expense totals for 1987 that are in close conformity with actual figures. Expert judgements were used in estimating the required probabilities. Constant expenses and incomes, and the interest rates of deposits and loans that were effective during the planning horizon are obtained from the bank. Other exogenous data related to economic and legal developments are obtained from CB sources and publications [11], and State Institute of Statistics Monthly Bulletins [13].

Using a matrix generator program to convert the data to MPS format, the model is solved by the MPSX software on an IBM 3090 mainframe. Lindo software on an IBM compatible PC was also used but not preferred owing to the speed of the solution on the mainframe.

7. RESULTS OF THE MODEL

Actual performance in a particular period is the result of policy choices made by the bank (such as the ratio of medium-term loans to short-term loans, the ratio of loan investments to security investments, etc) based on their expectation of economic developments for that period, the lagged outcome of decisions made in the previous periods (such as the principal and interest payment of loans extended in the past, cash flow from securities, etc), and actual as opposed to expected realizations of economic and exogenous factors. Since the purpose is to assess and demonstrate the comparative

Table 2. The ratio of base run results to actual bank performance

Months	RO1	RO2	RO3	RO4	RZ	RO1	RO2	RO3	RO4	RZ	RO1	RO2	RO3	RO4	RZ	RO1	RO2	RO3	RO4	RZ
			1987					1988					1989					1990		
1	0.93	2.03	0.82	1.00		0.84	1.05	0.77	0.57		1.00	2.15	1.02	0.13		1.20	2.38	0.78	0.04	
2	0.99	2.11	0.60	0.97		0.96	0.99	0.77	0.54		1.14	1.97	0.90	0.13		1.16	2.31	0.77	0.04	
3	1.09	2.04	0.52	0.95		0.92	0.92	0.62	0.52		1.20	1.71	1.03	0.09		1.11	1.96	1.07	0.04	
4	0.85	1.95	0.90	0.94		0.82	0.90	0.92	0.49		1.56	1.60	0.93	0.08		1.07	1.86	1.05	0.04	
5	0.78	1.88	0.93	0.85		0.88	0.89	0.91	0.39		1.56	1.58	1.06	0.08		0.91	1.80	1.40	0.04	
6	1.14	1.78	0.40	0.81		0.99	0.87	0.68	0.38		1.37	1.65	1.31	0.08		0.94	1.84	1.39	0.04	
7	0.96	1.53	0.53	0.80		0.96	0.82	0.75	0.38		1.20	1.70	1.33	0.07		0.98	1.82	1.46	0.04	
8	0.83	1.51	0.92	0.73		0.95	0.79	0.69	0.27		0.97	1.70	1.68	0.07		0.97	1.76	1.37	0.04	
9	1.09	1.44	0.55	0.73		1.22	0.82	0.94	0.20		0.88	1.78	1.69	0.07		1.00	1.72	1.68	0.04	
10	0.95	1.40	0.64	0.70		1.01	0.74	1.15	0.19		1.04	2.12	1.36	0.06		0.80	1.74	2.00	0.03	
11	0.92	1.31	0.64	0.62		1.07	0.69	1.50	0.16		0.97	2.02	1.24	0.06		0.67	1.65	2.16	0.03	
12	0.99	1.10	0.65	0.61	0.9	1.12	2.29	0.99	0.14	1.2	0.94	2.12	1.14	0.05	3.3	0.83	1.95	2.20	0.03	4.8

RO1: Ratio of outstanding short-term loans of the base run to actual bank performance.
RO2: Ratio of outstanding medium-term loans of the base run to actual bank performance.
RO3: Ratio of outstanding securities of the base run to actual bank performance.
RO4: Ratio of outstanding participations of the base run to actual outstanding participations.
RZ: Ratio of base run annual profits to realized profits.

advantage of the model in informed decision making, the approach used is to compare actual performance over the period 1987–1990 with the results of the model that simulates the banks policy choices, given the economic environment operated in. That is, had the bank management made the policy choices that they made based on their expectation of economic developments, but used the model in deciding on which among several investment alternatives to choose in each period, what would have been the amount of funds allocated to them, given the actual realizations of exogenous factors. The solution of the model using these specifications (that is, bank's data, policy choices, legal requirements, interest rates, inflation rates and the actual realizations of other economic and exogenous factors prevailing during the period 1987–1990) is termed the base run.

In obtaining base run results the model is solved once for the entire planning horizon (1987–1990) instead of on a rolling horizon basis that would have been the case when decision making for the future. The reason for this is that, in retrospective analysis, policy choices and changes made by bank management preceeding and following actual realizations of economic, legal, and other exogenous developments, as well as the developments themselves, are known for each period of the planning horizon.

The base run results obtained as such are compared with actual performance over the period 1987–1990. Table 2 provides this comparison based on the ratio of base run results to actual bank performance. The main findings can be summarized as:

- With the exception of the first year, annual profits are above realized profits and steadily increase throughout the planning horizon at constant 1986 prices as opposed to nearly stagnating actual profits. This is mainly due to higher medium term loans and lower short term loans extended as compared to actual performance.

- Security investments are less than the bank's in the first two years but this is reversed for 1989, 1990. The major reason for this is the increased cash inflow due to the investment decisions taken in the first 2 years and the investment of excess funds (not extended as loans due to increased risk of loan custumers) into securities rather than into other liquid assets as in actual practise.

- The significantly higher profit for 1990 is the result of the higher return and reinvestment in the previous periods. Furthermore as post terminal period cash flows, other than interest income and expense, and requirements are not taken into account, profitability seems to be the dominant concern for this year.

- Annual profit for 1987 is slightly less than that of the bank. This can be attributed to the initialization process and the initial data set used. To test the sensitivity of the model is solution to initial data the model solved using an alternative data set based on the assumption that most of the net investments were made in the second half of 1986 instead of being evenly distributed throughout the year. The results are considerably different from the base run as

initial data on past investments regulate cash inflow of the following periods.

Comparison of the base run solution with sensitivity analysis results, based on runs with alternative values of parameters and exogenous variables of the model, provide valuable insight as to the robustness and/or change in the direction of model results. A sample of sensitivity analysis results are as follows. When the probability of loans becoming irregular is increased for the second half of 1988 and for 1989 the size or magnitude of loans extended decreases due to the decreased cash inflow from interest and principal payments, resulting in decreased interest income and a reduction in profits especially in the last year. This result approximates actual performance more than the base run. However, it is not used as the base run because with wildly fluctuating parameters the results would have distorted the effect of the changes being measured.

As can be expected, when the probability of short term loans returning at maturity is higher than the base run, interest income increases, leading to higher annual profits. But because principal payments are made at maturity, liquidity decreases, compensated by increased investment in securities to satisfy liquidity requirements.

Since time deposits drawn before maturity receive interest at the rate of sight deposits, an interesting result is observed when the probability of time deposits drawn before maturity is higher than their values in the base run. Due to the reduction in total interest expense annual profits increase despite the slight reduction in short term loans and increase in securities. The major reason for this controversial result is the negative real interest rate applied to sight deposits in the inflationary environment of Turkey. An annual nominal 10% interest rate for sight deposits in an economy with inflation rate varying between 35% to 70% has a very positive effect on profitability when deposits are withdrawn before maturity.

As noted earlier the ratio of outstanding loans to outstanding deposits is required to be less than a specified value each year. In the base run for 1989 and 1990 this ratio was 0.6 and 0.65 as opposed to 0.75 in earlier years to reflect lower credit demand and higher risk of lending in these years. When this ratio is increased to 0.75

for 1989 and 1990, years in which the return of loans is high, a significant increase in short and medium term loans, and a decrease in securities, with a significant increase in annual profits, is observed. It is generally true that when interest rate increases the demand for loans decreases, especially when interest rate increase is accompanied by, or is the result of, a recession in the economy, leading to higher risk of default of credit customers. This experiment shows that when the risk of lending is underestimated or when credit demand is overestimated, investment in loans is higher than it should be, leading to higher profits that are not realistic. When this ratio is lowered, decreased loan investments are compensated by higher security investments, and lower profits.

As expected annual profits decrease when the ratio of medium term loans to short term loans are lowered. Thus bank policy regarding longer term credit risk is one of the major determinants of profitability.

In using the model as a planning tool, combined effects of multiple changes in the parameters and exogenous variables of the model must be analyzed to make more realistic decisions and to see the trade-offs between profitability, risk and liquidity.

8. USE OF THE MODEL AS A PLANNING TOOL

The model determines optimal future balance sheet compositions over a planning horizon based on forecasts of economic developments in the market. Annual inflation rates, legal reserve requirements, deposit interest rates, interest rate of securities, the rate of change of deposits, and the probabilities of loans becoming irregular and deposits being withdrawn before maturity as a function of these developments are some of the uncontrollable variables of the model. In a stable economy where changes in these economic variables are not frequent, forecasts of these variables over the planning horizon will be sufficent for model results to be valid. However, in a country like Turkey where substantial fluctuations are observed in almost all of these variables even from month to month, to base model solutions on forecasts of these variables over a time horizon of 48 months would be unrealistic. Since asset and liability

compositions have to be adjusted continuously with the changing economical developments, we suggest that the model be applied on a rolling horizon basis.

The procedure for such an application can be summarized as follows. If we define the planning horizon to be equal to N periods and the number of times a new solution obtained as n, where $n < N$, the model will be solved for the next N periods. The results will be implemented until the period when there is an unexpected change in economic conditions that induces or is the result of a change in deposit forecasts, loan demands, or any other parameter of the model. Then the model must be solved again for the next N periods with new forecasts or updated parameters following the change in economic conditions. The implemented investment decisions of the previous solution will be taken as the input or initialization data of the new solution. The frequency, n, can either depend on the changes in economic conditions or can be predetermined.

9. CONCLUSION

The model presented above is developed for one of the prominent commercial banks of Turkey with the purpose of demonstrating to bank management the flexibility of the model in systematically taking into consideration the trade-offs between profitability, liquidity, and risk, given the incompatible maturity structure of bank assets and liabilities, and cash flows. As the model is a pioneer, and it is true that the structure of data collection does not precede but follows model requirements, we recommend that the model be used for future bank balance sheet management after the existing data, and data collection structure has been reoriented for model requirements.

REFERENCES

1. Cohen, K. J., Maier, S. F. and Van der Weide, J. H., Recent developments in management science in banking. *Management Science*, 1981, **27**, 1097–1119.
2. Broddus, A., Linear programming: a new approach to bank portfolio management. *Monthly Review: Federal Reserve of Richmond*, 1972, November, 3–11.
3. Cohen, K. J. and Hammer, F. S., Linear programming and optimal bank asset management decisions. *Journal of Finance*, 1967, **22**, 147–165.
4. Cohen, K. J., Dynamic balance sheet management: a management science approach. *Journal of Bank Research*, 1972, **22**, 9–19.
5. Cohen, K. J. and Thore, S., Programming bank portfolios under uncertainty. *Journal of Bank Research*, 1970, **2**, 28–40.
6. Kusy, M. I. and Ziemba, W. T., A bank asset and liability management model. *Operations Research*, 1986, **34**, 356–376.
7. Eatman, J. L. and Sealey, C. W., Multiobjective linear programming model for commercial bank balance sheet management. *Journal of Bank Research*, 1979, **9**, 227–236.
8. Fortson, J. C. and Dince, R. R., An application of goal programming to management of a country bank. *Journal of Bank Research*, 1977, **7**, 311–319.
9. Korhonen, A., A dynamic bank portfolio model with multiple scenarios, multiple goals and changing priorities. *European Journal of Operational Research*, 1987, **30**, 13–23.
10. Kumar, G., Tayi and Leonard, P., Bank balance sheet management: an alternative multi-objective model. *Journal of Operational Research Society*, 1988, **39**, 401–410.
11. Central Bank of the Republic of Turkey, *Central Bank Annual Report*, Ankara, Turkey, 1986, 1987, 1988, 1989, 1990.
12. Abac, S. and Group IBAR, *Banks and the Banking System in Turkey'89* (in Turkish). IBAR Publications, 1990.
13. State Institute of Statistics, *Monthly Bulletin of Statistics*, Vol. I–XII. State Institute of Statistics, Republic of Turkey, Ankara, Turkey, 1986–1990.

ADDRESS FOR CORRESPONDENCE: *Assistant Professor Dr Sibel Güven, Department of Industrial Engineering, Middle East Technical University, Inönü Bulvari 06531, Ankara, Turkey.*