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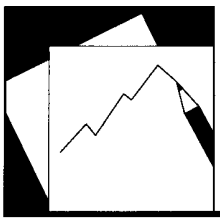

IMF Working Paper

Stressing to Breaking Point: Interpreting Stress Test Results

DeLisle Worrell

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IMF Working Paper

Monetary and Capital Markets Department

Stressing to Breaking Point: Interpreting Stress Test Results

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Authorized for distribution by S. Kal Wajid

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Abstract

This paper illustrates how stress tests of banking systems may be designed to evaluate banks' reaction to shocks of increasing intensity, up to the point where regulatory norms are breached, or banks become insolvent. This approach offers useful insight and guidance for regulatory policy and intervention, using existing methodology and data. The illustrations presented in this paper are a small sample of the wide variety of shocks, scenarios, and assumptions to which this approach may be applied.

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[1] Thanks for helpful comments and suggestions to Martin Cihak, Tonny Lybek, Winston Moore, Miguel Segoviano, Kal Wajid, and participants in seminars at the IMF and the Central Bank of Barbados. Responsibility for the views and conclusions rests solely with the author.

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I. INTRODUCTION

Stress testing has become an essential part of the toolkit for financial risk assessment in the climate of intensified international scrutiny of financial stability that has followed the financial crises of the mid-1990s. The present paper argues in favor of an approach to stress testing that starts with relatively benign changes, and observes the behavior of target financial soundness indicators as the severity of the stress is increased. The approach may be applied to a wide variety of shocks and calamitous scenarios, and the main burden of this paper consists of illustrations of a selection of possible applications in the area of financial risk assessment.[2] The paper focuses on the impact of shocks and adverse scenarios on the capital adequacy of banks and the banking system, and in particular how quickly the risk weighted capital adequacy ratio (CAR) falls to the statutory minimum required by the regulatory authority, and further to the point of insolvency.

This approach highlights a neglected dimension of stress tests—i.e., the speed with which capital is eroded as stresses intensify. This may help in setting priorities for action to fortify the financial system and increase resilience. It is to be expected that the factors which cause the most rapid erosion of capital as stress intensifies, are the ones which will yield the greatest gain in resilience from remedial action. The approach also facilitates the setting of benchmarks, against which financial market developments may be assessed, thereby augmenting to the information content of early warning signals. As will be illustrated in this paper, it can be seen what magnitude of shock puts the system on a trajectory to reach breaking point, well in advance of that eventuality.

The approach may serve to inform judgmental choices in the parameterization of stress tests and stress scenarios, perhaps the most contentious issue in the practical application of this methodology. The recommended guideline of choosing "plausible but improbable" events includes an impractically large number of possibilities. Perhaps because of this, it is often difficult to publicize the results of stress tests without adversely affecting confidence levels in financial markets. Market participants wonder why particular selections are made from the many possible "plausible but improbable" eventualities, and conclude that the events chosen for scrutiny are judged to have higher probability than others. The approach recommended in our paper offers a way around this dilemma.

It is also possible to test the system's sensitivity to assumptions using the recommended approach. In writing stressful scenarios, it is often necessary to make arbitrary assumptions about unknown parameters of the economic and financial structure, such as the impact of foreign currency transactions on interest and exchange rates. This paper presents an illustration of the way in which the sensitivity of the results to the choice of assumption may be evaluated.

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[2] The approach is also applicable to other scenario writing exercises, such as those frequently conducted for debt and current account sustainability analysis. My thanks to Winston Moore of the University of the West Indies for this observation.

The suggested approach is not new, but it deserves to be more widely used. The example which inspired this paper appears in IMF (2003), page 22 (Figure 1). It shows the extent of erosion of the capital of four Barbadian banks, with increasing proportions of their loan portfolios becoming impaired. Some European financial regulators are reported to use the approach for preparing confidential risk assessment reports for internal use, and some analysts use a similar "threshold" approach,[3] but little is published.

The substance of this paper consists of illustrations of how banks and financial systems may be stressed to breaking point. The choice of illustration is guided by issues that have been to the fore of financial stability concerns in a majority of countries in recent times—credit quality, the impact of interest and exchange rate changes, the implications of rapid credit growth, and the possible consequences of large foreign exchange inflows on the capital account, followed after some interval by a sudden reversal. The illustrations all use hypothetical data, for a banking system constructed of six individual banks, with made-up balance sheets, capital adequacy, liquidity, and credit profiles. Although fictional, the banks were modeled on arbitrarily selected real entities, to ensure plausible results. The tests were conducted using standard methodology, as described for example in IMF and World Bank *FSAP Handbook* (2005).[4]

II. Credit Risk Assessment

The most straightforward credit risk assessment procedure measures the impact on the CAR of a substantial increase in impaired credit. The approach to this test suggested in this paper involves observing the evolution of the CAR as the impaired portfolio grows by increasing percentages.[5] Figure 1 illustrates the risk exposure of the mortgage portfolio of our hypothetical banking system, and three of the six banks that make up the system. The chart shows that the banking system remains well capitalized even if 50 percent of the total mortgage portfolio were written off. Banks B and C are affected only mildly, but bank A clearly has a much larger proportion of mortgages than the other banks, and its CAR falls below the Basel 8 percent norm if its mortgage losses reach 45 percent of the mortgage portfolio. Charts such as this one could be drawn for all major categories of credit; a comparison among them would reveal which sector was most sensitive to an erosion of credit quality, for each bank and for the system as a whole.

[3] See, for example, Cihak (2007), pps. 45–49.

[4] IMF and World Bank (2005), Appendix on stress testing.

[5] The calculations were done without taking account of accumulated profits, in order to simplify the exposition, but in practice they could easily be incorporated into the analysis.

Figure 1. The Capital Adequacy Ratio After Losses on Mortgages

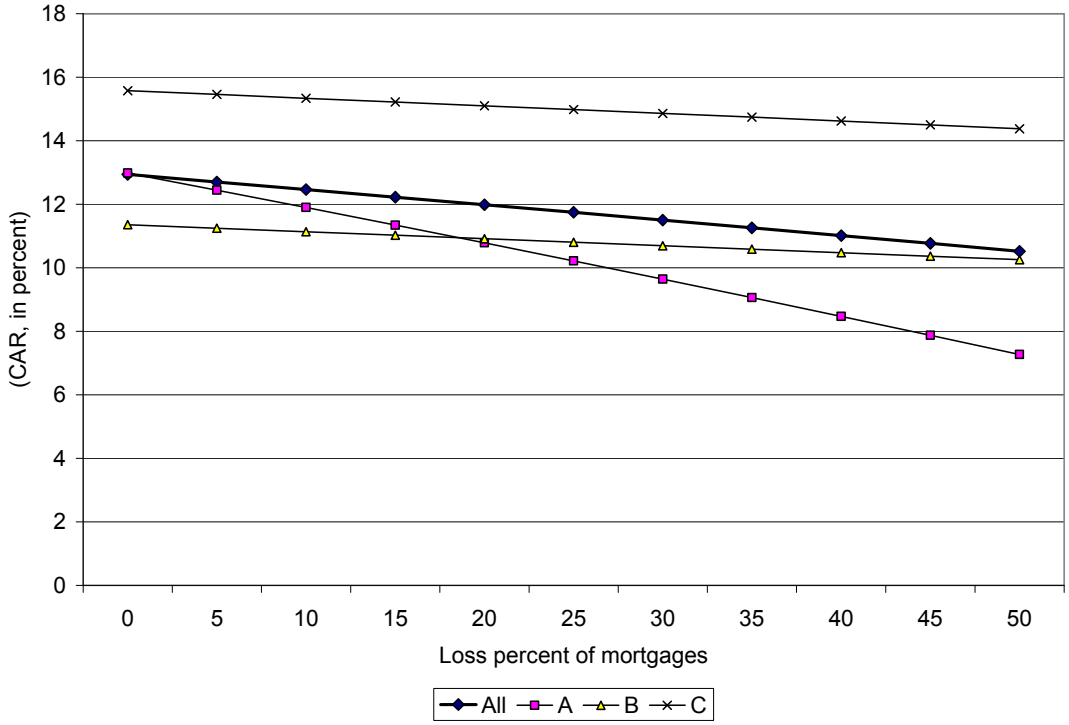
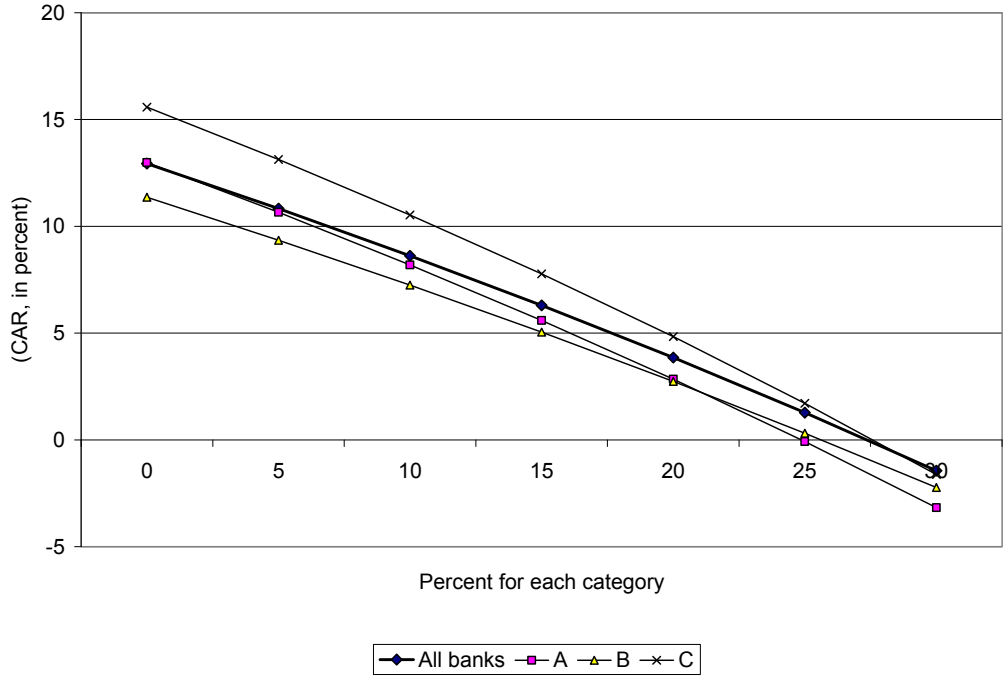


Figure 2 takes the risk assessment a step further by considering shocks that impact three categories of credit simultaneously—mortgages, loans to households, and loans to exporters. A uniform loss of a little over 10 percent of the loans in these three categories is sufficient to depress the CAR to 8 percent, and at a uniform loss of about 27 percent the banking system becomes insolvent. Bank C, with the highest CAR, is the worst affected; and Bank B, with the lowest CAR, is the least affected, but the difference between banks is not great.

Our third illustration of credit risk assessment examines the impact on the CAR over time of migration of loans from a better to a worse loan quality classification. Bank regulators use five classes of quality to describe bank loans—loans which are current and fully documented are classified as "pass"; current loans about which the regulator has some concern, perhaps because minor documentation is incomplete, may be classified as "other loans especially mentioned" (OLEM); and there are three categories of loans which are not current—"substandard," "doubtful," and "loss." The probability of loss increases with each category, up to 100 percent in category 5. To reflect this, regulators require banks to set aside provisions, which are higher for each successive category, and which we assume, in line with standard stress test practice, are deducted from capital.[6] The regulators in the hypothetical banking system require provisions of 1 percent, 3 percent, 20 percent, 50 percent, and 100 percent for the 5 categories of loan, in that order.

[6] i.e., no account is taken of the possible impact of current period net earnings which, if positive, could cushion the impact on the CAR.

Figure 2. The Capital Adequacy Ratio After Losses on Mortgages and Export and Personal Loans



Consider the loan migration pattern presented in Table 1, which shows the proportion of loans in the category from the left hand column that migrates to the category in the top row. The cell *A2*, for example, is the proportion of pass loans that migrate to OLEM. The table shows a simple matrix where loans migrate only to the next worse category, but it is possible to introduce any desired degree of complexity.

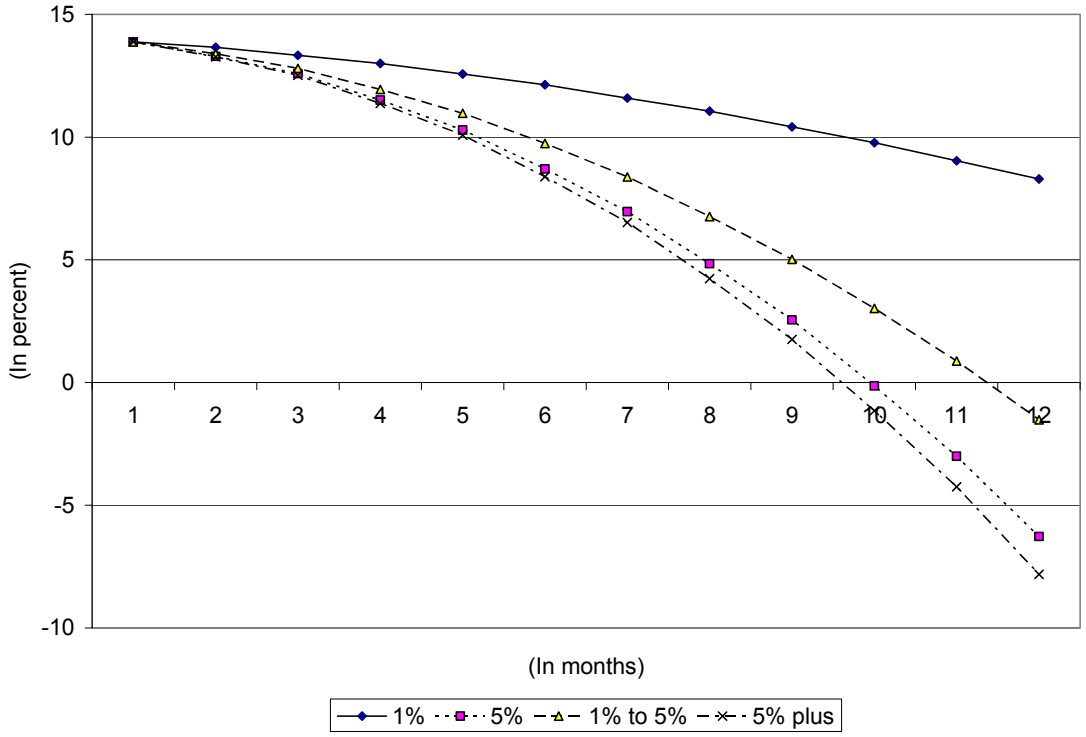
Table 1. Nonperforming Loan Migration Matrix

	Pass	OLEM	Substandard	Doubtful	Loss
Pass		0.01	0.00	0.00	0.00
OLEM			0.01	0.00	0.00
Substandard				0.01	0.00
Doubtful					0.01

Figure 3 shows the evolution of the CAR for the banking system over a 12-month period, if the loan migration each month follows the pattern of Table 1, with migration coefficients only on the matrix diagonal. A 1 percent monthly migration rate, as represented in the table, results in a fall of the CAR from 14 percent to 10 percent in 12 months. If the migration rates range between 1 and 5 percent, the CAR falls below 8 percent in 11 months. If migration rates between the categories are a uniform five percent, the CAR falls below 8 percent in 7 months, and equity becomes negative in the eleventh month. An exercise such as that

illustrated in Figure 3 may be used to set priorities for remedial action, starting with recent observations of nonperforming loan (NPL) migration.

Figure 3. The Capital Adequacy Ratio with Different Migration Patterns



III. EXCHANGE RATE RISK

Figure 4 shows the direct effect of exchange rate changes on each of the six banks in the system. Bank F is the only one with a large net foreign liability position, and it is therefore the only one to suffer a deterioration of its CAR as a result of exchange rate depreciation, and the only one to benefit from exchange rate appreciation. A depreciation of 50 percent reduces its CAR from 18.6 percent to a level just above the statutory 8 percent minimum. Banks A, B, and C have balanced external positions, and are largely unaffected by exchange rate changes. Banks D and E stand to make large gains from their positive net foreign asset positions in case of a devaluation, and are therefore vulnerable in case of an exchange rate appreciation.

Figure 5 shows the impact of exchange rate changes on the banking system when we take account of possible indirect effects through the impairment of credits to firms and households that make losses as a result of the exchange rate change. The chart compares the total impact with the direct impact (the sum of the changes shown for individual banks in Figure 4) for each exchange rate change. There is some loss from indirect effects, that reduces the total direct gain from any percentage devaluation, but the effect is very small. This results from

the fact that foreign currency loans to residents in the hypothetical banking system are a small proportion of the total, and it is plausible to assume that these are the credits that are adversely affected by an exchange rate depreciation.

Figure 4. The Effect of Exchange Rate Changes on the Capital Adequacy Ratio.

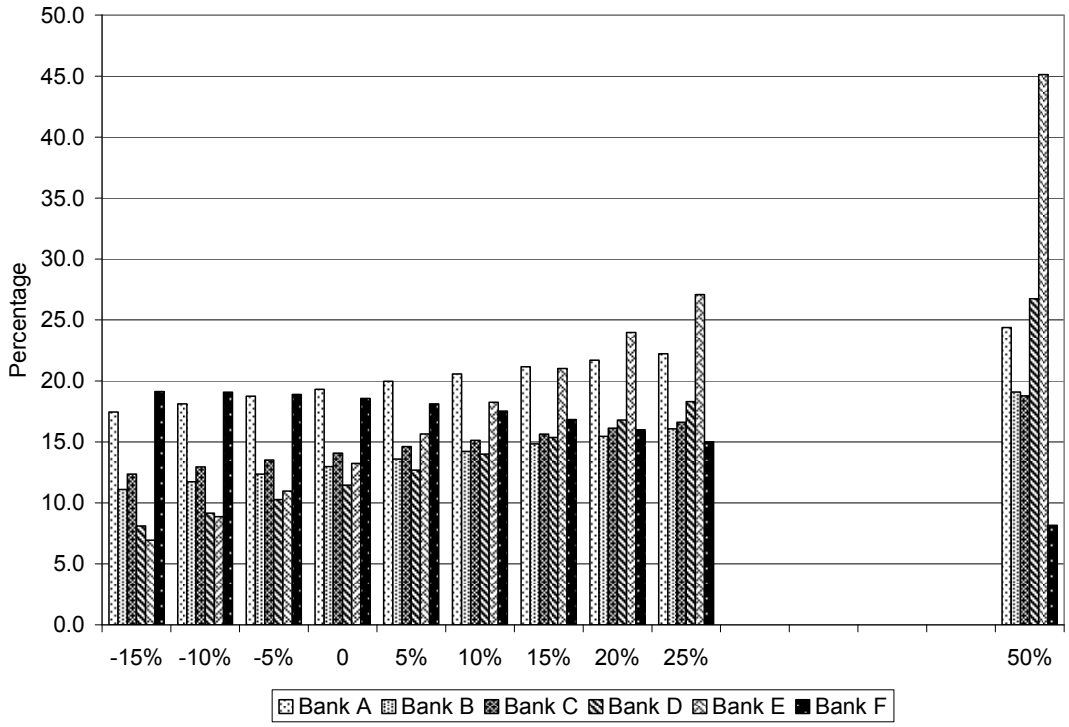


Figure 6 reinforces the conclusion that indirect foreign exchange risk is not significant in this banking system, by showing how losses increase as the proportion of impaired foreign currency loans to residents increases. Even if the losses on such loans are as high as 50 percent, the diminution of capital gains from devaluation is minor.

IV. INTEREST RATE CHANGES

Banks all have net liability positions in the short term maturity "buckets"—they gain when the interest rates fall and lose when they increase. In Figure 7, a 50 percent increase in interest rates leaves the CAR of the banking system a little above 8 percent, but Bank B's CAR falls below 8 percent when interest increases by 25 percent, and Bank C falls below the norm at a somewhat higher percentage increase. However, no bank is susceptible to modest increases in interest rates.

Figure 5. Banking System Capital Adequacy Ratio, Devaluation Effects

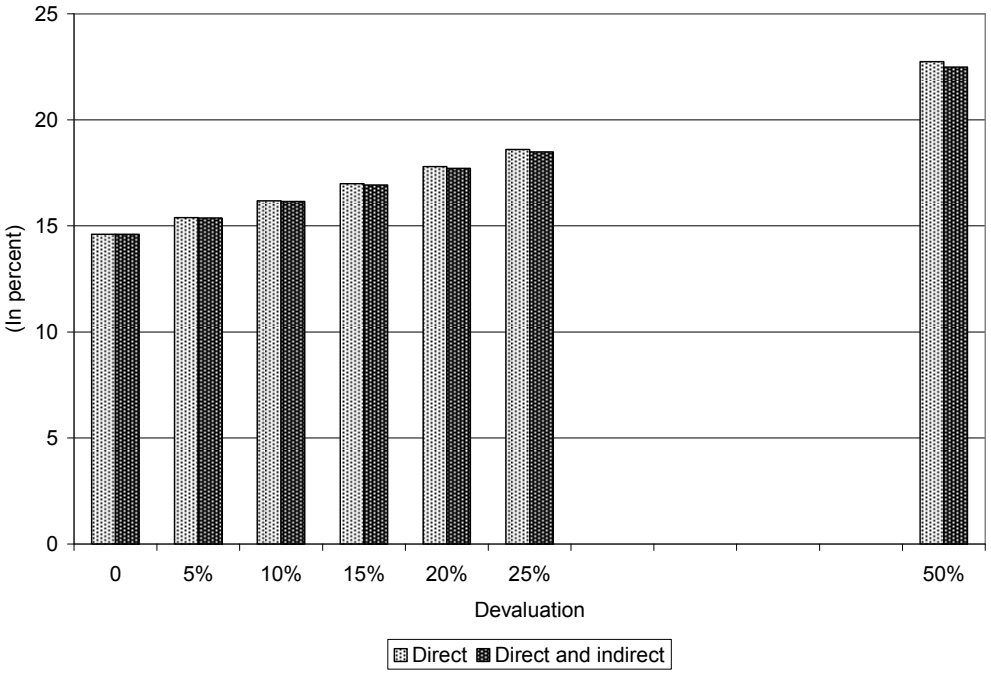


Figure 6. Total Devaluation Effects: Different Losses on Foreign Currency Loans

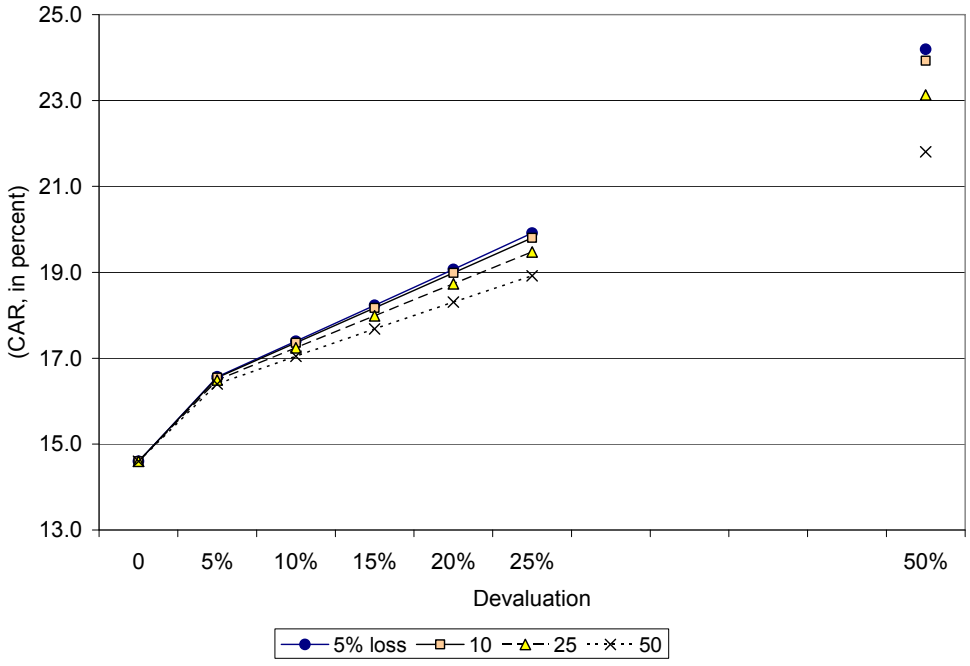


Figure 7. The Capital Adequacy Ratio After Interest Rate Shocks

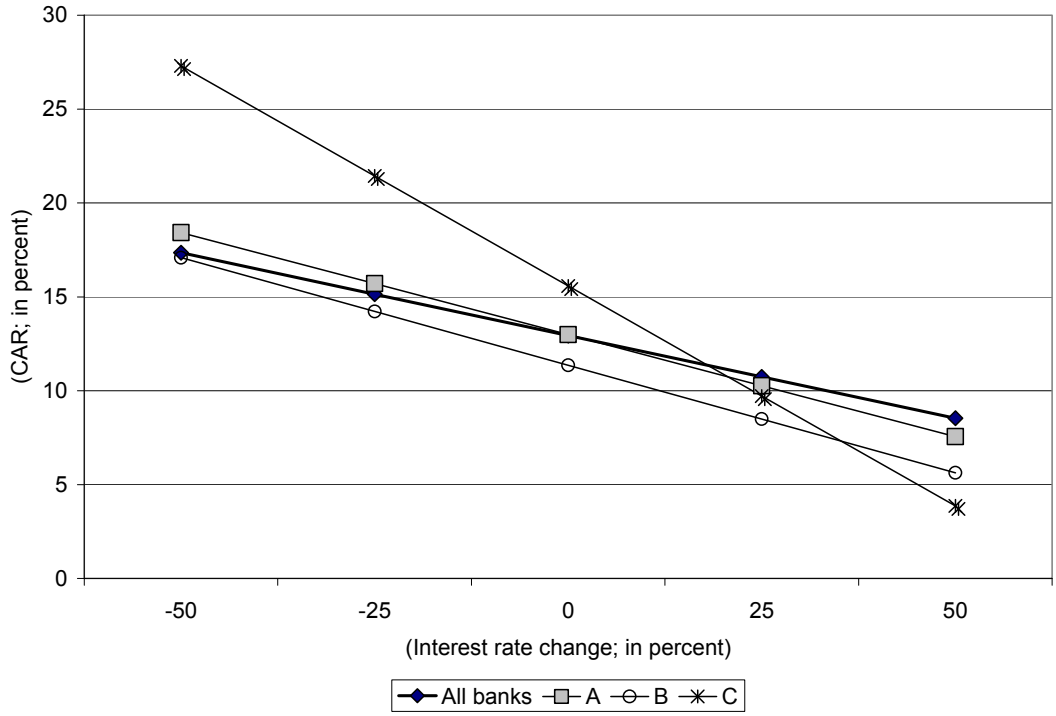
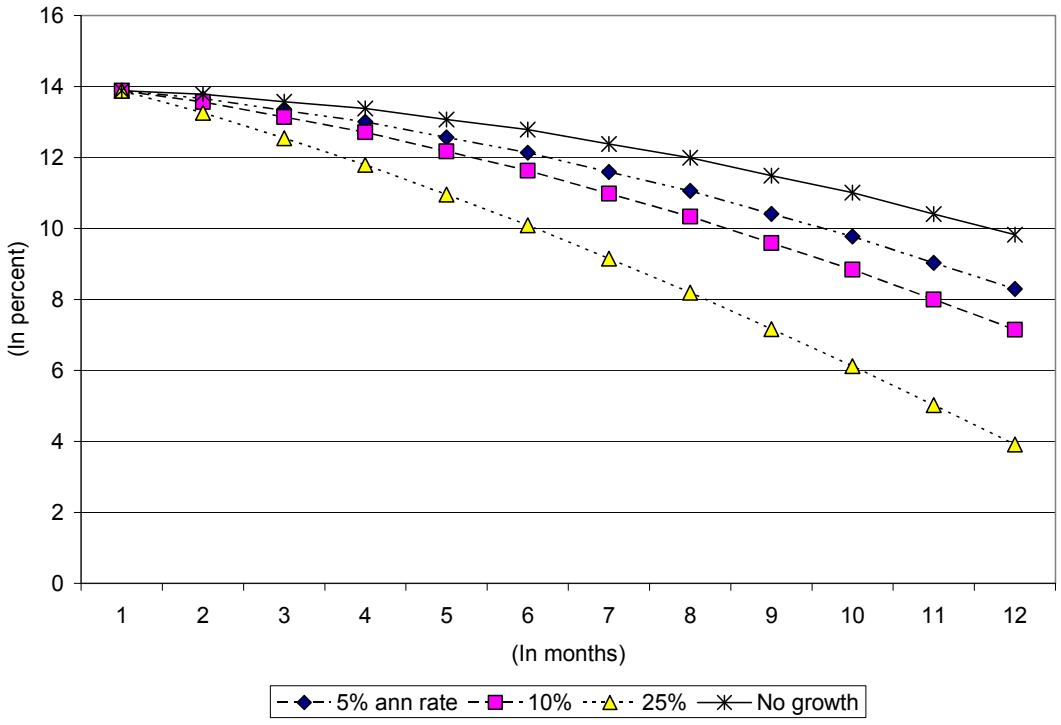


Figure 8. The Capital Adequacy Ratio with Various Rates of Credit Growth



V. CREDIT GROWTH

The impact of credit growth on the CAR depends on the rate of growth of credit, the initial NPLs ratio, and the NPL migration matrix. Figure 8 shows how the CAR is affected by different rates of credit growth, starting with the actual NPL of the hypothetical banking system, and the one percent diagonal migration matrix shown in Table 1. With a 5 percent monthly credit growth rate, after 12 months the CAR would have fallen to almost 8 percent, compared with the 10 percent CAR with zero growth that appeared in Figure 3. If credit were to grow at the monthly rate of 5 percent the CAR would fall to 8 percent in the eleventh month, and if the monthly growth rate reached 25 percent the CAR would fall to 8 percent in the eighth month, all with the uniform 1 percent migration pattern.

Figure 9 shows how the system behaves with different NPL migration patterns, with the same (five percent monthly) credit growth rate. If NPL migration rates range between one and five percent, as compared with the uniform one percent of Figure 8, the CAR falls to eight percent by the seventh month, and after 12 months the banking system's equity is exhausted. If there is a uniform five percent migration pattern, these effects take place one month earlier.

Figure 9. The Capital Adequacy Ratio with Various Loan Migration Rates

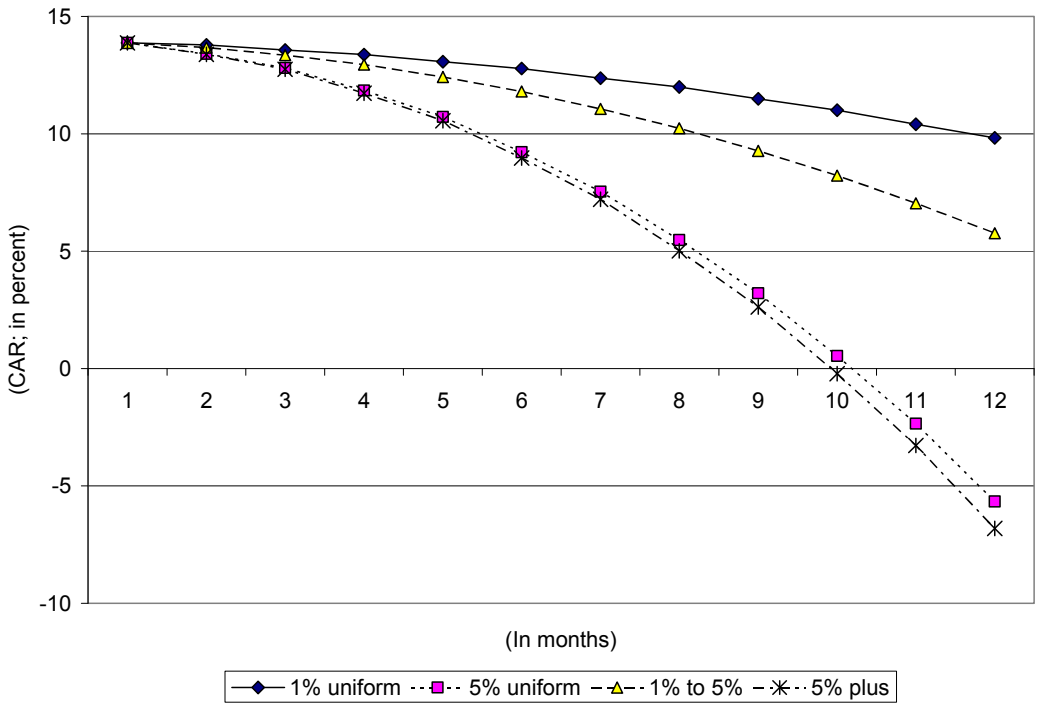
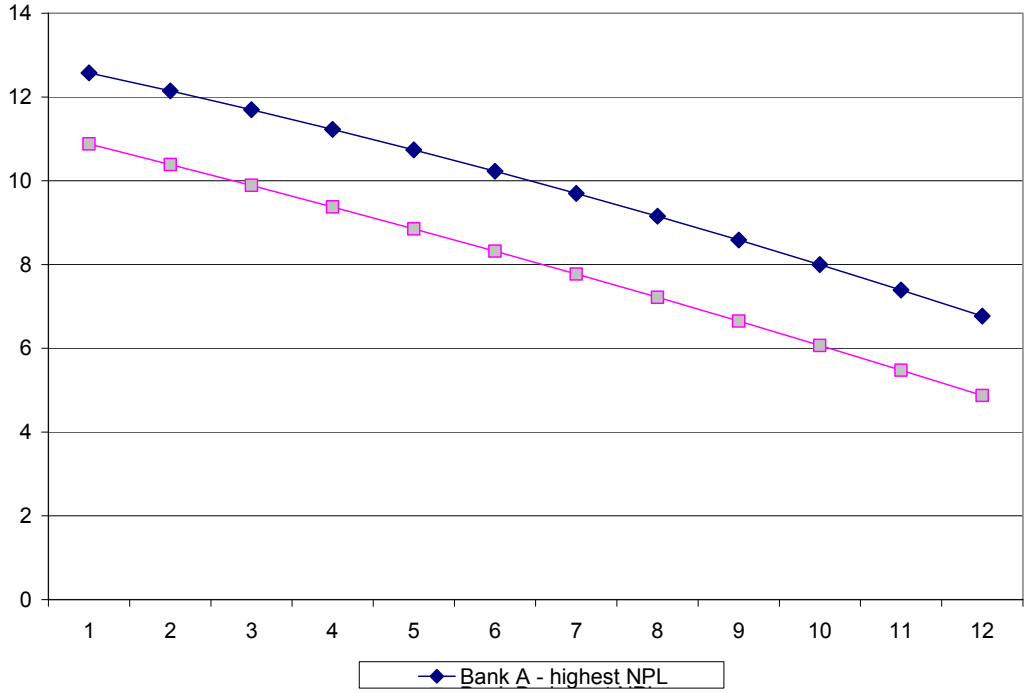


Figure 10 compares the impact, on banks with the highest and lowest NPL ratios, of the five percent monthly growth rate and the one percent NPL migration. The difference in NPL ratios does not affect the rate at which the CAR declines. Bank A, with an initial NPL ratio of

19 percent (the highest for the banking system), suffers a CAR decline of six percentage points, about the same as for Bank B, which has the lowest initial NPL ratio (six percent of loans).

Figure 10. Banks with Different Initial Nonperforming Loans



VI. Combined Scenario

Figure 11 illustrates the first steps in developing a scenario that combines all the elements discussed so far—the impact on the CAR of credit growth, an exchange rate change, NPL migration, and an interest rate change. Four alternative scenarios ((b) – (e)) are shown in Table 2, each one of which alters just one parameter from a rate of one percent per month, to five percent per month, compared to the base scenario (a).

With credit growth of 5 percent per month and all other parameters set to 1 percent per month, the CAR falls below 8 percent in the eighth month, and ends at less than 2 percent in the twelfth month. With a uniform NPL migration rate of 5 percent per month the CAR falls below 8 percent in the fourth month, and banks' net worth would become negative by the sixth month. Increasing the exchange rate deterioration and interest rate by five percent is relatively innocuous (see Figure 11).

Figure 11. Credit Growth, Devaluation, Nonperforming Loan Increase, and Interest Rate Fall

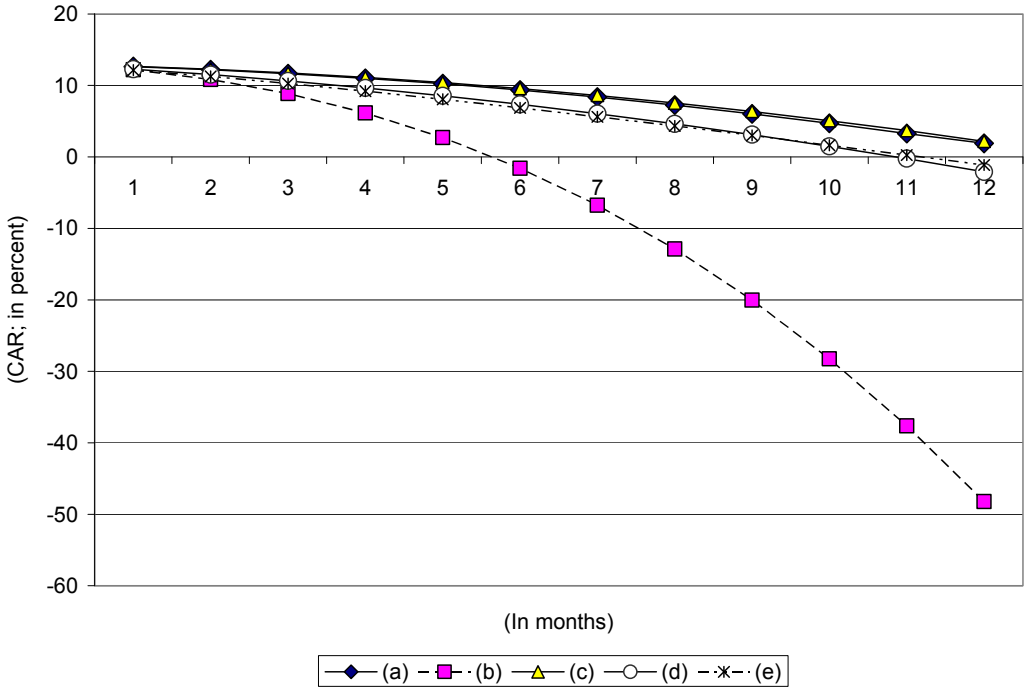


Table 2. Parameters of Combined Scenarios

	(In percent per month)			Interest Rate Change (In percent point per month)
	Credit Growth	Exchange Rate Change	NPL Migration	
(a)	1	1	1	1
(b)	1	1	*5*	1
(c)	1	*5*	1	1
(d)	1	1	1	*5*
(e)	*5*	1	1	1

Although it is not illustrated in this paper, it would be informative to use each one of these scenarios as a point of departure for a family of scenarios, with increasing intensity of one parameter, holding all others unchanged. This might then be extended to combinations of these changes, in what might become a dense map of possibilities for the evolution of the CAR. This could provide a rich template against which to evaluate the actual experience of the banking system as it evolves over time, possibly serving to sharpen early warning signals.

VII. Capital Inflow and Reversal

Table 3 illustrates how the approach of stress intensification may be applied in writing complex scenarios, involving many assumptions. The scenario represents a foreign capital inflow for 12 months, which triggers a constant monthly rate of exchange rate appreciation, monthly reductions in interest rates, and monthly NPL migration. There is a sudden reversal in the thirteenth month, which causes a depreciation of the exchange rate, a rise in interest rates as the monetary authorities attempt to slow the outflow, and a further deterioration of NPLs.

Table 3. Parameters for the Capital Flow Scenario

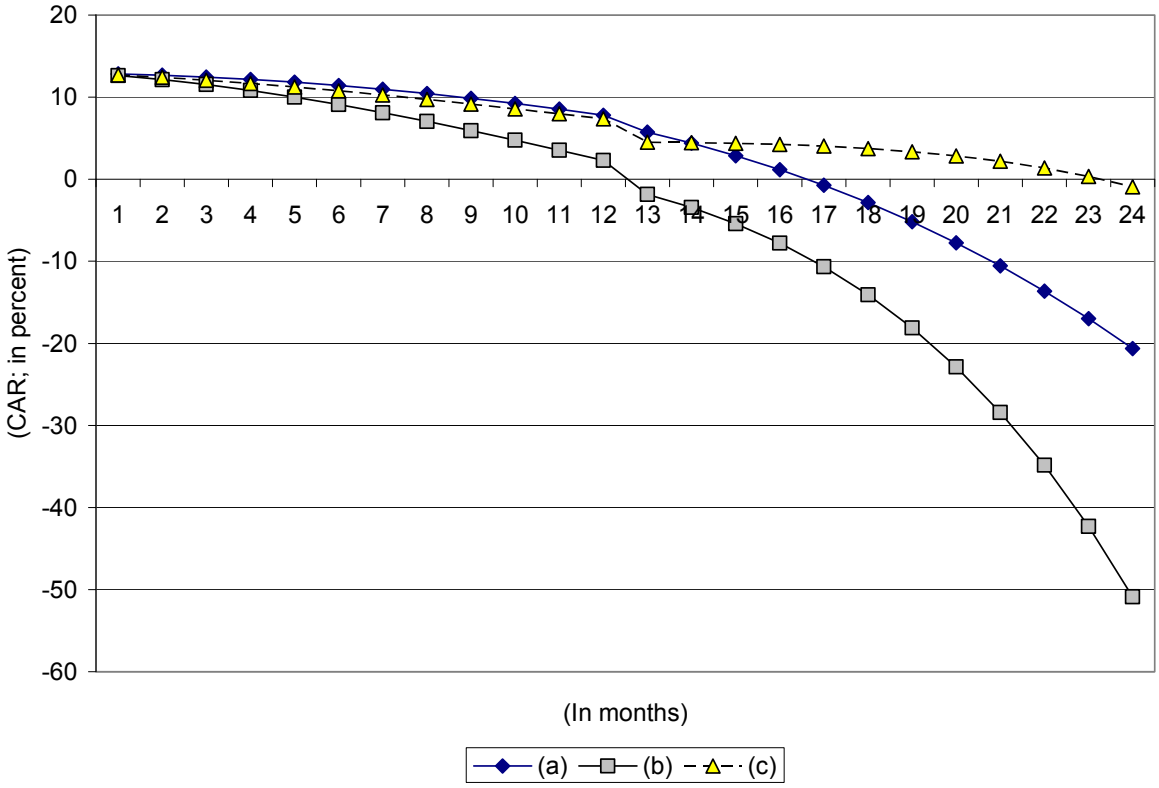
	(In Percent Point Per Month)		Interest Rate Change (In Percent Point Per Month	NPL Migration (In Percent Per Month)
	Credit Growth	Exchange Rate Change		
(a) inflow	1	-1	-1	0.1
(a) outflow	-2	2	2	0.5
(b) inflow	1	-1	-1	0.5
(b) outflow	-2	2	2	1.0
(c) inflow	5	-5	-5	1.0
(c) outflow	-10	10	10	2.0

The impact of the three scenarios listed here—(*a*), (*b*) and (*c*)—on the CAR of the banking system is shown in Figure 12. In the initial scenario, CAR falls to 8 percent by the 12th month, and equity is exhausted in the 23rd month. With higher NPL migration rates, equity becomes negative in the 17th month. In the third, more severe, scenario the CAR falls below 8 percent in the 8th month, and below zero by the 13th month. Scenarios such as these may be constructed for a large number of possibilities, including varying assumptions about the length of the inflow and outflow periods, as well as increasing the intensity of the shocks.

VIII. Summary

Using a hypothetical but realistic system of six banks, we demonstrated how the approach of stressing to failure may be applied to evaluate exposure to a number of risks of common concern. This hypothetical system is especially sensitive to credit quality, both the original level of NPLs and NPL migration. The impacts of exchange rate and interest rate changes are mild in comparison. The risk exposures as a result of rapid credit growth, and capital inflow and sudden reversal, therefore depend on their impact on NPLs. If they cause a rapid build-up of NPLs, banks may become insolvent in a relatively short time, but if credit quality remains high, the system remains well capitalized even with severe shocks. This assessment provides an illustration of how the stress-to-failure approach might be applied in practice.

Figure 12. Capital Inflow and Reversal



The approach adds to the insight that may be extracted from stress tests, using available methodologies and information. All the tests used in the illustrations employ well-accepted methodologies, and a dataset of commonly used FSIs and banking data. Measuring the way the system weakens, as stresses increase, helps in interpreting and evaluating early warning signals, and provides regulators with information for making timely responses. In the illustrated banking system, for example, regulators would be advised to pay special attention to credit quality indicators, and to intensify scrutiny of any bank which appeared to be weak in this area, or any bank where the NPL migration pattern was worse than average.

The paper should not be seen as an argument for the specific types of stress test illustrated, but rather an attempt to promote the general approach of changing stress parameters in a systematic way, and "observing" the way in which the system degrades as the stress is increased. This might be done using more sophisticated techniques (along the lines of Monte Carlo experiments), using parameters derived stochastically, and incorporating more realistic scenarios, for example bank balance sheet effects, contagion among banks and macroeconomic linkages among stress test parameters.

Appendix Tables

Table 4. Capital Adequacy

(In millions of U.S. dollars; unless otherwise specified)

Bank	Capital	Tier 1	RWA	CAR (In Percent)
A	110.8	106.8	853.4	13.0
B	68.1	65.6	599.6	11.4
C	113.3	96.7	727.0	15.6
D	83.8	148.3	670.8	12.5
E	108.6	102.1	868.8	12.5
F	74.6	66.6	601.8	12.4
Total	**559.2**	**586.1**	**4,321.4**	**12.9**

Table 5. Loan Distribution

(In millions of U.S. dollars)

Bank	Construction and Land Development	Tourism	Personal	Grand Total
A	105.2	34.7	305.7	894.2
B	14.7	21.0	230.0	529.1
C	20.4	26.2	363.7	634.5
D	26.5	16.9	165.9	622.0
E	57.6	70.2	313.4	784.3
F	9.2	27.5	233.2	474.3
Total	233.7	196.5	1,611.8	3,938.3

Table 6. Loan Quality

(In millions of U.S. dollars; unless otherwise specified)

Bank	Pass	Olem	Sub	Dbt	Loss	NPL (In percent)
A	564.5	158.3	144.3	24.2	2.9	19.2
B	456.7	38.8	21.2	9.5	2.9	6.4
C	553.5	31.1	25.4	13.4	11.1	7.9
D	161.0	409.3	17.0	11.9	22.8	8.3
E	468.0	174.3	96.3	36.8	8.9	18.1
F	426.1	12.5	25.1	4.9	5.8	7.5
Total	2,629.8	824.3	329.3	100.8	54.3	12.3

Table 7. Foreign Assets and Liabilities

(In millions of U.S. dollars)

(a) Assets

Banks	FC Cash	Balance Due	Foreign Investments	Loans Denominated in Foreign Currency
A	7.661	127.226	208.665	422.158
B	3.203	42.817	0	0.004
C	3.848	35.230	89.213	16.159
C	4.350	46.040	114.842	13.526
E	1.277	170.572	110.934	3.793
F	2.436	11.081	31.204	15.224
System	22.775	432.966	554.858	470.864

(b) Liabilities and Net

Bank	Other Foreign Assets	Total	Balances Due	Foreign Currency Deposits	Other Foreign Liabilities	Total	Net Assets Denominated in Foreign Currency
A	16.156	781.866	70.271	724.284	10.152	814.859	-32.993
B	0.808	46.832	2.607	48.208	0.219	51.253	-4.421
C	7.446	151.896	15.115	134.118	4.446	158.125	-6.229
D	0.879	179.637	3.574	81.667	0.887	87.015	92.622
E	1.741	288.317	9.256	185.419	1.606	197.887	90.430
F	0	59.945	0.314	6.418	79.359	165.45	-105.505
System	27.030	1,508.493	101.137	1,180.114	96.669	1,474.589	33.904

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