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Republic of Poland: Technical Note on Stress Testing the Banking Sector

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FINANCIAL SECTOR ASSESSMENT PROGRAM

REPUBLIC OF POLAND

STRESS TESTING THE BANKING SECTOR

TECHNICAL NOTE

JULY 2013

INTERNATIONAL MONETARY FUND
MONETARY AND CAPITAL MARKETS DEPARTMENT

THE WORLD BANK
FINANCIAL SECTOR VICE PRESIDENCY
EUROPE AND CENTRAL ASIA REGION

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GLOSSARY

BFG	Bank Guarantee Fund
CAR	Capital Adequacy Ratio
EDF	Expected Default Frequency
EWS	Early Warning System
FSAP	Financial Sector Assessment Program
FSR	Financial Stability Report
KNF	Financial Supervision Authority
LGD	Loss-Given-Default
NBP	National Bank of Poland
NPL	Nonperforming loan
PD	Probability of Default
ROA	Return on assets
ROE	Return on equity
RWA	Risk-weighted Assets

EXECUTIVE SUMMARY

The Polish banking system is well capitalized and liquid, as confirmed by stress tests results. Polish banks are, in aggregate, resilient even under severe adverse scenarios. Some small banks could fail to meet minimum regulatory capital and liquidity requirements in these scenarios, but with little impact on the overall banking system.

Top-down solvency tests were conducted to assess the resilience of the banking system to adverse macroeconomic scenarios. The tests covered 20 institutions representing 85 percent of the assets in the system. Two separate tests, covering a five-year horizon, were conducted by the central bank and the Financial Sector Assessment Program (FSAP) team. Each test comprised four different scenarios: a baseline scenario and three different recession scenarios. Both tests showed that only small banks, together representing up to 30 percent of the assets in the system, may have problems meeting the Basel III capital requirements in the recession scenarios.

Some caution is required when interpreting the results of the FSAP top-down balance sheet solvency tests. The tests were conducted using representative banks since data confidentiality constraints prevented conducting them using individual bank data. The impact of the adverse shocks on the representative banks, however, may not necessarily reflect the reaction on the individual banks. To complement its balance-sheet test, the FSAP team conducted market-based solvency stress tests, which showed some smaller banks could face substantial declines in their capital asset ratios.

No bottom-up solvency tests were conducted specifically for the FSAP update. The Financial Supervision Authority (KNF), however, shared with the FSAP team the distribution of results corresponding to the annual regulatory bottom-up stress testing exercise conducted in 2012. While the scenarios were different and the horizon shorter (1½ years), the results were consistent with those of the top-down solvency tests.

A top-down liquidity stress test suggested the banking system could withstand large liquidity shocks. The test was conducted by the National Bank of Poland (NBP) and considered the simultaneous realization of several shocks including the withdrawal of foreign funding and domestic deposits among other shocks. Some small banks, representing 10 percent of assets in the system, could face difficulties covering liquidity needs. The forced sale of liquid assets could put some pressure in the secondary market for government bills and bonds.

The solvency and liquidity tests were complemented with a comprehensive set of sensitivity tests. These tests, also conducted by the NBP, comprised counterparty risk shocks, credit shocks, FX shocks, housing price shocks, and interest rate shocks. Counterparty risk shocks were the most severe, with banks breaching the minimum capital requirement representing around 14 percent of assets in the system. The impact of market risk shocks on credit losses and/or liquidity needs was small.

Interconnectedness risk in the system is limited. No specific contagion test was conducted in the context of the FSAP update. The central bank, however, shared detailed results of the domino-effect simulation reported in its December 2012 report. The results showed that only three commercial banks could trigger second round defaults, with the banks affected representing less than 2 percent of the assets in the system.

All the tests suggest the banking system is well capitalized to withstand large shocks. Small banks, however, could benefit from strengthening their capital base. Greater integration of the top-down stress tests and bottom-up stress test exercises will lead to stronger banking system surveillance and better-informed supervisory policy.

I. INTRODUCTION

1. **The Polish banking system is dominated by foreign-owned banks, which account for about two thirds of the system by assets**. The largest bank is a domestic bank that is partly owned by the state. The state also has controlling shares in three other banks. The banking system is not highly concentrated; the top 5 banks account for about 44 percent of system assets. Foreign banks have retrenched somewhat, however, and this deleveraging has led to some consolidation.

2. **Poland's banking system weathered the global financial crisis well**. Inevitably, though, the crisis was a period of intense stress for the banking system. The zloty depreciated sharply, raising the debt servicing burden on foreign currency-denominated mortgage loans, which were popular in Poland as they allowed borrowers to take advantage of lower interest rates elsewhere particularly in Swiss francs.[1] The broader economic deterioration weighed on asset quality of consumer and corporate loan portfolios. Liquidity strains emerged, as banks found it more difficult to hedge their portfolio of FX loans on the market. The Polish banking system is well-capitalized and liquid, and much of the capital is of high quality**.** Profits in 2011 and 2012 were historically high, and regulatory guidelines limiting dividends have also aided capital building. Should banks' own buffers be insufficient, foreign-owned banks can, albeit to varying extents, rely on support from their parent banks. Poland also has a deposit insurance scheme operated by the Bank Guarantee Fund (BFG).

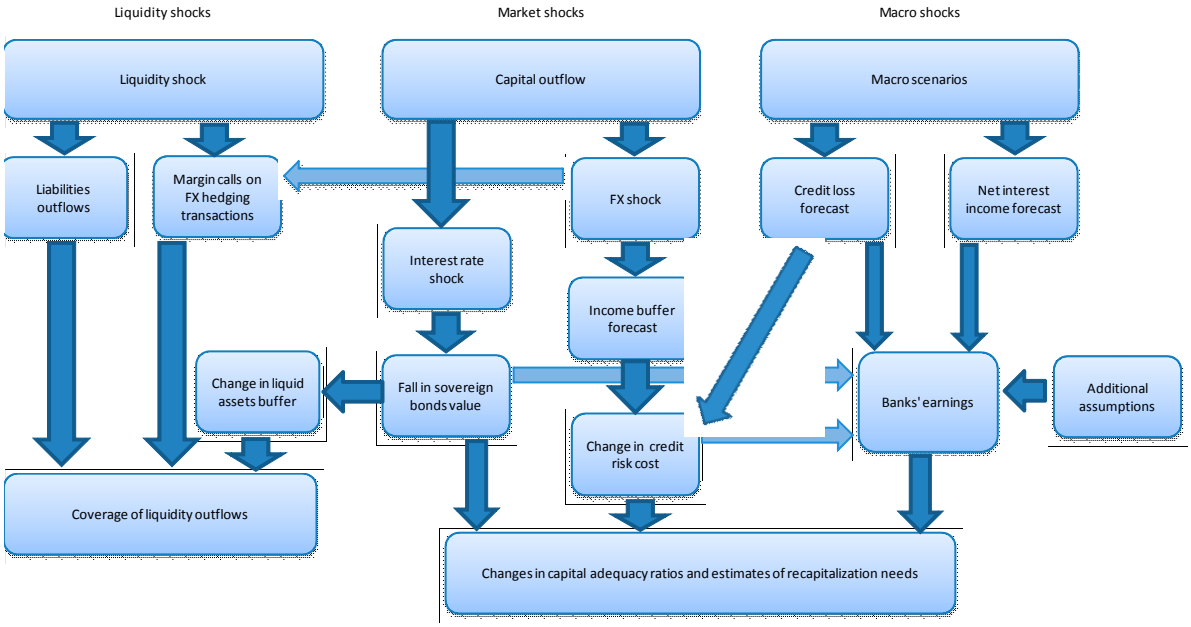
3. **Although conditions have improved, several factors could contribute to pressure banks' profits and asset quality**. External developments, coupled with weaker internal drivers of growth, have caused growth to slow sharply. Rising unemployment coupled with falling house prices and potential weakness in the zloty would translate into weaker asset quality and lower profitability. The uncertain outlook emphasizes the importance of evaluating the resilience of the banking system to potential adverse scenarios.

4. **Regulatory stress tests are regularly used by the authorities to assess the resilience of the banking sector to adverse shocks**. Twice a year the central bank (NBP) conducts a top-down macro stress test, including market risk shocks, and publishes the results in its semi-annual financial stability report (FSR). The macro stress test is complemented by a liquidity risk test and several sensitivity tests designed to evaluate the loss absorption capacity of banks to isolated credit risk and market risk events. Figure 1 illustrates the stress testing framework of the NBP. The Polish financial supervisory agency (KNF) has conducted an annual bottom-up stress test for the past three years. The test results are used to guide supervisory decisions such as the authorization to distribute dividends. In

[1] This effect was partly offset by the decreasing interest rates, as in case of most mortgage loans the interest rate is calculated as a given market rate (e.g., LIBOR CHF 3M) plus a fixed margin expressed in percentage points.

contrast to the central bank's stress tests, the results of the bottom-up tests are not generally made public.

Figure 1. Poland: National Bank of Poland Stress Testing Framework



Source: NBP.

5. **The regulatory stress tests are well designed, helping to identify risks and vulnerabilities**. Discussions with the authorities and market participants indicate that staff on both sides is highly knowledgeable about the functioning of the banking and financial system, a knowledge that is reflected in the design of the tests, the interpretation of the results, and the identification of vulnerabilities in the system. Market participants noted that regulatory stress tests were useful for checking the consistency of their risk management practices and for guiding their medium-term business strategy.

6. **In the context of the 2013 FSAP Update, the authorities worked with the FSAP team to conduct top-down stress tests**. The tests aimed to assess the resilience of the banking system to severe but plausible macroeconomic scenarios. These scenarios are hypothetical, and serve to guide the authorities in thinking about risks to the banking system and in preparing mitigating measures. The NBP conducted top-down solvency and liquidity stress tests based on scenarios agreed with the FSAP team. These tests were complemented with sensitivity tests to large isolated shocks affecting counterparty risk, credit risk, and market risk. The FSAP team also conducted a top-down stress test that inferred the risk of default from market data. While no bottom-up solvency stress tests were conducted in connection to the FSAP Update, the KNF made available to the FSAP team the results of its latest regulatory bottom-up stress test.

SUMMARY OF RECOMMENDATIONS

Recommendations and Authority Responsible for Implementation	Priority	Time Frame 1/
Enhance the coordination of the KNF's bottom-up stress tests and the NBP's top-down tests, and sharing of information.	Low	Medium

1/ "Immediate" is within 1 year; "near-term" is 1–3 years; and "medium-term" is 3–5 years.

II. SOLVENCY STRESS TESTS

7. **The NBP and the FSAP team conducted separate top-down solvency stress tests to assess the resilience of the banking system under different adverse scenarios**. Four different macroeconomic scenarios, in consultation with the FSAP team and the IMF country desk, were considered over a five-year horizon: a baseline scenario consistent with the IMF country desk projections, a V-shape recession, a U-shape recession, and a L-shape recession. The paths of the macroeconomic and financial variables in each scenario were calculated using the NBP's NECMOD macroeconomic model (Table 1). The scenarios entail growth rates well below the historical average for Poland.[2] The V-shaped scenario sees a sharp decline in year-on-year GPD growth, while the U-and L-shaped scenarios entail two consecutive years of negative growth. Given that growth in Poland stayed positive in 2009 after the Global Financial Crisis, these assumptions represent substantial stress.

8. **Capital requirements in the stress tests corresponded to those specified in the Basel III implementation timeline**. According to the NBP, there were no substantive differences between Tier 1 capital and core Tier 1 capital, while total capital was only moderately higher than Tier 1 capital due to low use of subordinated debt in capital. Hence, the relevant minimum capital requirement in the stress tests were set at 8 percent of RWA for the years 2013 to 2015; 8.625 percent of RWA for 2016; and 9.25 percent of RWA for 2017. The minimum Tier 1 capital requirement was set at 4.5 percent in 2013; 5.5 percent in 2014; 6 percent in 2015; 6.625 percent in 2016; and 7.25 percent in 2017. Both these requirements encompass the capital conservation buffer, at 0.625 percent in 2016; and 1.25 percent in 2017. Additionally, the results were also calculated without the capital conservation buffer. The minimum core Tier 1 capital requirements were used only to determine the dividend payout ratio (Table 2).

[2] The average annual real GDP growth rate in Poland between 2005 and 2011 was 4.5 percent.

Table 1. Poland: Macro-Stress Test Scenarios

		GDP (y/y) (%)	Unemployment rate (%)	CPI inflation (%)	EUR/PLN	USD/EUR	Wibor 3M (%)
Baseline	2012	2.2	9.8	3.8	4.2	1.3	4.9
	2013	1.7	10.7	2.6	4.1	1.3	4.2
	2014	2.3	11.4	2.3	4.2	1.2	3.7
	2015	2.9	11.5	2.0	4.2	1.2	3.6
	2016	3.4	11.2	2.4	4.2	1.2	4.0
	2017	3.5	10.3	2.7	4.0	1.2	4.8
V-shape recession	2012	2.2	9.8	3.8	4.2	1.3	4.9
	2013	-2.3	12.2	2.0	4.5	1.3	3.2
	2014	0.6	16.0	1.2	5.1	1.2	0.6
	2015	4.1	16.7	1.1	5.0	1.2	0.3
	2016	3.6	15.8	1.7	4.8	1.2	0.3
	2017	3.9	13.8	2.3	4.5	1.1	1.2
U-shape recession	2012	2.2	9.8	3.8	4.2	1.3	4.9
	2013	-0.8	11.6	2.1	4.4	1.3	3.5
	2014	-0.2	14.8	1.1	5.0	1.3	1.0
	2015	2.7	16.5	0.4	5.0	1.3	0.3
	2016	3.5	16.3	1.0	5.0	1.2	0.3
	2017	3.6	14.7	1.9	4.8	1.2	0.5
L-shape recession	2012	2.2	9.8	3.8	4.2	1.3	4.9
	2013	-1.3	11.8	2.0	4.5	1.3	3.4
	2014	-0.7	15.5	0.8	5.1	1.3	0.7
	2015	1.9	17.8	-0.3	5.2	1.3	0.3
	2016	2.3	18.4	0.0	5.4	1.3	0.3
	2017	2.2	17.9	0.7	5.4	1.3	0.3

Source: NBP; and Fund staff estimates.

Table 2. Poland: Dividend Payout Ratio Conditional on Capital Buffers

Buffer above minimum capital ratio (in percent)	Maximum dividend payout ratio (in percent of earnings)
0 - 0.5	0
> 0.5 - 1.5	20
> 1.5 - 2.5	40
> 2.5	40 to 100

Source: IMF staff estimates.

9. **The composition of the balance sheet of the banks was assumed static during the stress test**. Loans were classified into three categories: corporate loans, consumer loans, and mortgages. The balance sheet of a bank was assumed to grow at the nominal rate of GDP (if positive) provided it meet the minimum capital requirement.

10. **Dividend payouts were possible only when banks fulfilled capital adequacy requirements**. The dividend payout ratio depended on the bank's buffer over the minimum core Tier 1 capital requirement, and was set equal to the maximum payout ratio shown in Table 2 (in the range of buffer over 2.5 the dividend payout ratio was set at 75 percent).

A. Top-Down Balance Sheet Stress Tests[3]

11. **For the 2013 FSAP Update, the NBP used its stress testing framework to conduct a top-down solvency stress tests following guidelines agreed upon with the FSAP team**. The stress tests included the 20 largest banks comprising about 85 percent of the total assets in the banking system. The scenarios included a baseline scenario and three adverse scenarios (see Table 1).

12. **Satellite models mapped the scenarios into credit losses and net income**. The NBP used panel data models for interest income on loans, interest expenses, and credit losses (expressed as a ratio of loans, interest bearing liabilities, and credit portfolios respectively), and were estimated using quarterly data for the period 1997–2012. For credit losses, the loan portfolio was divided into three major categories: commercial loans, mortgage loans, and consumer loans. Model projections were subject to judgment-based adjustment to account for regulatory and market changes in lending standards.

13. **Changes in RWA were calculated following an approximate Basel II standardized approach**. The standardized approach was used to determine the initial RWA weights, which were kept fixed during the stress scenarios. The RWAs were adjusted to account for losses under the stress test horizon.

14. **In the NBP top-down stress tests, up to 30 percent of the analyzed group of banks may not meet Basel III capital requirements in the recession scenarios**. The erosion of capital buffers is mainly concentrated in the period up to 2015 and affects small banks (Table 4). The most severe scenario is the L-shape recession, which leads to total capital needs of about PLN 10.5 billion (out of which 2.5 billion would result from capital conservation buffer kicking in), equivalent to less than one percent of the assets in the banking system.

15. **The methodology of the FSAP top down stress test was based on a simple model of income and capital dynamics**. Namely, capital one period ahead was set equal to capital in the current period plus current period net income after subtracting credit losses and dividend payouts. The probability of default (PD) for each loan category was approximated as the ratio of the flow of nonperforming loans (NPLs) to total loans in the category. As with any accounting measures, NPLs may not reflect all forward looking information on losses.

[3] At the request of the authorities, the note does not disclose the model details.

Estimates of the loss-given-default (LGD) for each loan category, calculated as the NPL coverage by loan loss provisions, as well as the NPL flows were provided by the central bank. Changes in RWAs were calculated in according to Basel II (BCBS, 2006, International Convergence of Capital Measurement and Capital Standards, paragraph 272).

Table 3. Poland: Central Bank Top-Down Solvency Stress Tests—CAR Distribution by Percentile Buckets

	Representative bank, determined by its CAR percentile in the NBP stress test distribution					
Baseline scenario	Less than 10%	Between 10% and 25%	Between 25% and 50%	Between 50% and 75%	Between 75% and 90%	Above 90% >=90%
2012	10.94	11.50	12.78	14.45	16.44	18.94
2013	10.80	11.37	12.87	14.57	17.03	19.31
2014	10.59	11.02	12.40	14.12	17.12	19.50
2015	10.13	10.98	12.25	13.96	16.20	19.57
2016	9.8	10.9	12.1	14.1	16.3	19.6
2017	9.6	11.1	12.0	14.2	16.5	19.7
V-shape scenario						
2012	10.94	11.50	12.78	14.45	16.44	18.94
2013	7.08	9.68	10.65	13.10	14.92	18.56
2014	5.94	8.30	10.30	12.23	13.85	18.77
2015	5.58	7.47	9.65	11.53	13.50	18.13
2016	4.3	7.2	9.4	12.1	13.9	17.7
2017	3.2	7.4	9.4	12.3	13.5	17.2
U-shape scenario						
2012	10.94	11.50	12.78	14.45	16.44	18.94
2013	8.12	10.53	11.25	13.42	15.53	18.88
2014	6.28	8.15	10.15	13.14	15.53	19.16
2015	5.45	6.60	9.46	12.73	15.28	18.82
2016	3.7	6.3	8.8	11.8	14.0	18.3
2017	1.9	5.6	8.4	11.6	13.8	17.8
L-shape scenario						
2012	10.94	11.50	12.78	14.45	16.44	18.94
2013	7.72	10.20	11.04	13.35	15.17	18.75
2014	5.78	7.67	9.77	13.14	15.36	18.98
2015	4.87	6.04	9.05	12.74	15.26	18.81
2016	2.4	4.2	7.9	11.6	14.2	18.6
2017	0.7	3.8	7.8	11.9	14.4	18.3

Source: NBP.

16. **The FSAP top down stress test was performed using representative banks in each scenario**. Aggregation was necessary owing to data confidentiality constraints faced by the authorities.[4] For each scenario, the representative bank were defined by first dividing the sample of banks into six percentile buckets based on the regulatory capital adequacy ratio (CAR) test distribution at the end of the NBP stress test. Each representative bank was then constructed by aggregating the capital, credit risk exposures, and risk-weighted assets (RWAs) of all the banks in the corresponding bucket. Table 4 summarizes the characteristics of the representative banks for each scenario.

[4] The aggregation method was chosen to parallel a bank-by-bank analysis. The reader should keep in mind that aggregation could potentially underestimate risks since the representative bank may not reflect the strengths and weaknesses of the constituent individual banks.

Table 4. Poland: Characteristics of Representative Banks used in FSAP Top-Down Stress Tests

All figures in percent	Representative bank, determined by its CAR percentile in the NBP stress test distribution					
Baseline scenario	Less than 10%	Between 10% and 25%	Between 25% and 50%	Between 50% and 75%	Between 75% and 90%	Above 90% >=90%
Total capital	11.92	11.97	12.25	13.22	15.58	18.94
Tier 1 capital	10.15	9.04	9.95	11.73	12.59	15.65
Tier 1 Common equity	10.15	9.04	9.95	11.73	12.59	15.65
Total loans	100.0	100.0	100.0	100.0	100.0	100.0
of which: Residential mortgages	43.7	52.3	59.7	41.8	30.4	43.1
Consumer loans	29.6	15.3	19.1	26.9	22.4	15.4
Corporate loans	26.7	32.3	21.2	31.3	47.2	41.4
V-shape scenario						
Total capital	12.77	11.84	13.29	13.08	15.76	18.94
Tier 1 capital	9.46	10.95	10.37	11.24	14.19	15.65
Tier 1 Common equity	9.46	10.95	10.37	11.24	14.19	15.65
Total loans	100.0	100.0	100.0	100.0	100.0	100.0
of which: Residential mortgages	52.4	51.4	52.6	42.1	28.8	43.1
Consumer loans	23.1	21.1	22.0	23.5	31.1	15.4
Corporate loans	24.5	27.4	25.4	34.5	40.0	41.4
U-shape scenario						
Total capital	12.77	12.87	13.58	12.94	13.35	18.94
Tier 1 capital	9.46	12.21	11.04	10.09	12.15	15.65
Tier 1 Common equity	9.46	12.21	11.04	10.09	12.15	15.65
Total loans	100.0	100.0	100.0	100.0	100.0	100.0
of which: Residential mortgages	52.4	29.8	54.6	45.0	42.7	43.1
Consumer loans	23.1	23.7	16.4	25.7	26.4	15.4
Corporate loans	24.5	46.5	29.0	29.3	30.9	41.4
L-shape scenario						
Total capital	13.59	12.22	12.76	13.57	13.35	18.94
Tier 1 capital	11.52	10.38	9.88	10.98	12.15	15.65
Tier 1 Common equity	11.52	10.38	9.88	10.98	12.15	15.65
Total loans	100.0	100.0	100.0	100.0	100.0	100.0
of which: Residential mortgages	47.9	36.4	61.9	37.4	42.7	43.1
Consumer loans	20.6	25.2	20.6	22.4	26.4	15.4
Corporate loans	31.5	38.3	17.5	40.2	30.9	41.4

Source: NBP.

17. **Some caution is required when interpreting the results of the FSAP top-down balance-sheet solvency tests.** The tests were conducted using representative banks since data confidentiality constraints prevented conducting them using individual bank data. The impact of the adverse shocks on the representative banks, however, may not necessarily reflect the reaction of the individual banks.

18. **The results of the FSAP top-down stress test are consistent with the NBP top-down stress test**. Table 5 shows the evolution of CARs under each scenario. Overall, the representative banks corresponding to the bottom three buckets could face problems meeting CAR in the first two years of the recession scenarios. The strong rebound in net income

experienced after the third year helps banks in the top three buckets to make up for earlier losses. These representative banks represent around 30 percent of total loans.[5]

B. Top-Down Market-Based Stress Tests

19. **To complement the balance sheet stress tests, the FSAP team also conducted market-based top-down stress tests**. The tests were based on models capturing the effects of changes in economic growth on the dynamics of the default risk of a bank. The default risk corresponded to expected default frequencies (EDF) implied from equity prices and obtained from Moody's analytics. The EDF can be linked to the capital structure of the firm using a structural credit risk model. As a result, it is possible to map the stress scenarios into changes of the capital asset ratio of a bank. The annex describes the methodologies in detail.

20. **The results suggest some banks could face substantial declines in their capital-asset ratios.** Furthermore, the default of a few institutions cannot be ruled out under the adverse scenarios. The problems, however, are concentrated among smaller institutions and the high capital adequacy ratios in the system suggest that despite large declines, capital adequacy ratios could remain above regulatory minimum levels. There are some caveats in interpreting the results, though. Information from equity prices may be unreliable for many of the banks analyzed owing to the lack or scarcity of secondary market liquidity. Additionally, in many cases foreign parent banks hold controlling shares of the listed Polish banks, so that the information value included in the equity prices in free-float may be limited.

III. Bottom-up Solvency Stress Tests

21. **No specific bottom-up stress tests were conducted in connection with the FSAP update but the authorities shared the results corresponding to the latest annual regulatory test**. As with the top-down stress tests, results were provided in aggregate or in distributions to maintain confidentiality.[6] The test covered 32 banks accounting for 90 percent of the assets in the system; the KNF has gradually increased the coverage of the banking system over the three years the test have been conducted. Three 1½-year scenarios were considered: a baseline scenario incorporating the central bank's economic projections; an adverse scenario triggered by negative external shocks; and another adverse scenario driven by domestic shocks. Additional macroeconomic parameters, including unemployment rate, inflation, exchange rate, short and long term interest rates and residential real estate prices were specified as well (Table 6).

[5] The results are consistent with the FSAP team market-based top-down stress test (see Annex).

[6] The FSAP team discussed with the KNF the BU stress test methodology but did not scrutinize the individual bank results.

Table 5. Poland: IMF Top-Down Solvency Stress Tests—CAR Distribution by Percentile Buckets

	Representative bank, determined by its CAR percentile in the NBP stress test distribution					
Baseline scenario	Less than 10%	Between 10% and 25%	Between 25% and 50%	Between 50% and 75%	Between 75% and 90%	Above 90% >=90%
2012	11.92	11.97	12.25	13.22	15.58	18.94
2013	8.52	9.15	9.62	10.67	12.57	15.28
2014	8.44	9.48	10.02	11.23	13.49	15.98
2015	9.29	10.81	11.57	13.13	15.79	18.54
2016	9.6	10.7	11.4	13.5	17.0	18.9
2017	10.0	10.7	11.5	13.8	18.1	19.1
V-shape scenario						
2012	12.77	11.84	13.29	13.08	15.76	18.94
2013	5.13	5.22	6.47	7.72	8.71	13.88
2014	2.31	3.10	4.58	6.61	7.05	12.17
2015	2.35	4.92	7.89	10.81	14.84	16.16
2016	1.0	5.9	10.4	13.3	16.7	20.3
2017	-0.8	6.4	10.8	13.4	16.8	20.0
U-shape scenario						
2012	12.77	12.87	13.58	12.94	13.35	18.94
2013	6.11	6.77	7.63	8.00	8.78	12.95
2014	2.86	3.41	5.18	6.10	7.64	11.01
2015	1.41	2.66	5.12	7.11	9.23	12.82
2016	-0.1	2.7	6.5	9.7	12.9	18.2
2017	-2.7	2.1	7.4	11.9	16.1	23.1
L-shape scenario						
2012	13.59	12.22	12.76	13.57	13.35	18.94
2013	6.56	5.44	6.74	7.91	8.33	12.38
2014	3.02	2.22	4.20	5.94	7.01	10.24
2015	1.45	1.05	3.73	6.84	8.47	11.76
2016	-1.4	-0.8	2.7	7.6	9.5	12.8
2017	-3.6	-1.4	2.0	8.8	11.1	14.6

Source: Staff calculations.

22. **Compared to top-down stress tests, the bottom-up test factor in banks' measures and policy responses to the shocks**. Banks were allowed to factor in the impact of measures aimed at mitigating the shocks. The scenarios also accounted for policy responses by the authorities.[7] Banks were asked to use their own internal models to map the scenarios to the impact on credit risk parameters, and then evaluate the resulting impact on their financial condition and compliance with regulatory requirements. Banks submitted in some cases quite lengthy justification for their models and assumptions. In a limited number of cases, the KNF amended banks' responses using supervisory judgment.

[7] For instance, in the second scenario, interest rates are raised steeply to stem an outflow of capital.

Table 6. Poland: Bottom-Up Stress Test Scenarios

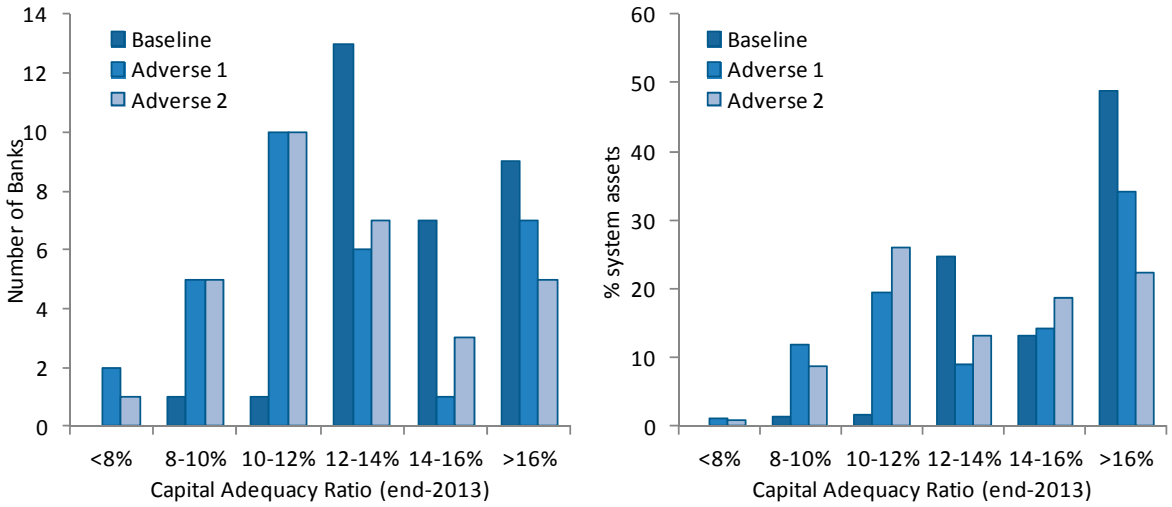
	2012				2013			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Baseline scenario								
GDP, year-on-year change (in percent)	3.5	3.2	2.7	2.3	2.1	1.8	2.1	2.4
CPI, yoy (in percent)	4.1	4.0	4.2	3.5	3.3	2.6	2.4	2.4
Unemployment rate, end of period (in percent)	13.3	12.4	12.2	12.8	13.4	12.6	12.4	13.0
WIBOR 3-month (in pecent)	4.94	5.13	5.21	5.17	5.00	4.90	4.92	4.93
Yield on 10-year Treasury bond (in percent)	5.50	5.17	5.43	5.38	5.36	5.39	5.40	5.42
EUR/PLN exchange rate	4.16	4.26	4.23	4.22	4.24	4.25	4.23	4.20
USD/PLN exchange rate	3.12	3.39	3.44	3.43	3.42	3.40	3.38	3.36
CHF/PLN exchange rate	3.45	3.55	3.53	3.52	3.48	3.46	3.41	3.36
Euribor, 3-month (in percent)	0.78	0.65	0.51	0.51	0.53	0.57	0.64	0.75
Swiss Franc Libor, 3-month (in percent)	0.11	0.09	0.05	0.10	0.05	0.10	0.10	0.10
Adverse scenario 1								
GDP, year-on-year change (in percent)	3.5	3.2	1.2	0.4	0.1	0.2	0.2	0.3
CPI, yoy (in percent)	4.1	4.0	3.9	4.4	4.8	5.1	5.3	5.5
Unemployment rate, end of period (in percent)	13.3	12.4	12.4	13.5	14.7	14.6	15.0	16.2
WIBOR 3-month (in pecent)	4.94	5.13	4.76	4.43	4.27	4.22	4.23	4.28
Yield on 10-year Treasury bond (in percent)	5.50	5.17	5.70	5.87	6.01	5.72	5.34	4.96
EUR/PLN exchange rate	4.16	4.26	5.68	5.77	5.82	5.71	5.65	5.51
USD/PLN exchange rate	3.12	3.39	4.66	4.77	4.81	4.76	4.67	4.52
CHF/PLN exchange rate	3.45	3.55	4.73	4.81	4.85	4.76	4.71	4.59
Euribor, 3-month (in percent)	0.78	0.65	0.51	0.52	0.53	0.52	0.52	0.51
Swiss Franc Libor, 3-month (in percent)	0.11	0.09	0.01	0.01	0.01	0.01	0.01	0.01
Real estate prices, quarterly change (in percent)			-10	-5	-5	0	0	0
WIG20 stock index, quarterly change (in percent)			-25	0	0	0	0	0
Funding cost, quarterly change (in bps)*			200	0	0	0	0	0
Adverse scenario 2								
GDP, year-on-year change (in percent)	3.5	3.2	2.3	0.9	-0.3	-1.1	-1.2	-1.4
CPI, yoy (in percent)	4.1	4.0	3.9	3.9	3.7	3.2	2.7	2.2
Unemployment rate, end of period (in percent)	13.3	12.4	12.3	13.4	15.1	15.4	16.4	18.4
WIBOR 3-month (in pecent)	4.94	5.13	7.00	7.00	7.00	7.00	7.00	7.00
Yield on 10-year Treasury bond (in percent)	5.50	5.17	7.60	7.80	8.00	8.10	8.20	8.40
EUR/PLN exchange rate	4.16	4.26	4.61	4.73	4.79	4.87	4.96	5.08
USD/PLN exchange rate	3.12	3.39	3.75	3.85	3.86	3.90	3.97	4.06
CHF/PLN exchange rate	3.45	3.55	3.84	3.94	3.93	3.96	4.00	4.06
Euribor, 3-month (in percent)	0.78	0.65	0.51	0.51	0.53	0.57	0.64	0.75
Swiss Franc Libor, 3-month (in percent)	0.11	0.09	0.05	0.10	0.05	0.10	0.10	0.10
Real estate prices, quarterly change (in percent)			-5	-5	-5	-5	-5	-5
WIG20 stock index, quarterly change (in percent)			-5	-5	-5	-10	-10	-10
Funding cost, quarterly change (in bps)*			200	0	0	0	0	0

* Apply to deposits and loans of the financial sector (non-resident) and derivatives.

Source: KNF.

23. **Like the top-down stress tests, the KNF's 2012 bottom-up stress tests indicate that the banking system will be resilient in an adverse scenario**. However, the two sets are not directly comparable because of the aforementioned differences in the scenarios. The bottom-up stress tests find that no more than two banks, representing about 1 percent of total banking system assets, fall below the regulatory minimum capital ratio in the adverse scenarios (Figure 2). These results were qualitatively similar to those reported by the NBP in its December 2012 Financial Stability Report (FSR).

Figure 2. Poland: KNF Bottom-Up Stress Tests—CAR Distribution



Source: KNF.

24. **The KNF complements the information from the bottom-up stress tests with onsite and offsite supervisory knowledge and peer analysis**. Onsite bank inspections are infrequent, though, so it is not clear if onsite expertise is up to date. The KNF also conducts a peer analysis across banks. However, there is substantial heterogeneity in the banking system and the lack of natural peers for some banks makes it difficult to draw conclusions from a comparison of their results with those of other banks.

25. **Banks indicated that the bottom-up stress testing exercise was useful for their internal strategic planning, complementing their own internal stress tests**. The tests highlight risks that they might have overlooked. Banks also conduct their own internal stress tests as a cross check. Internal practices vary considerably across banks depending on their size, business models, and how long they have had operations in Poland, which determines the amount of data available for calibrating their models.

Sensitivity tests

26. **Sensitivity tests suggest the banking system can withstand single adverse shocks**. The top-down stress tests were complemented with sensitivity tests modeled after those conducted by the NBP on a semiannual basis. These tests, performed by the NBP, included

counterparty risk shocks, credit risk shocks, a sharp depreciation, housing price shocks and interest rate shocks. Equity price shocks were ruled out since banks are little affected by stock market developments. Table 7 describes the sensitivity tests carried out for the FSAP Update, comparing them with the regular NBP's tests.

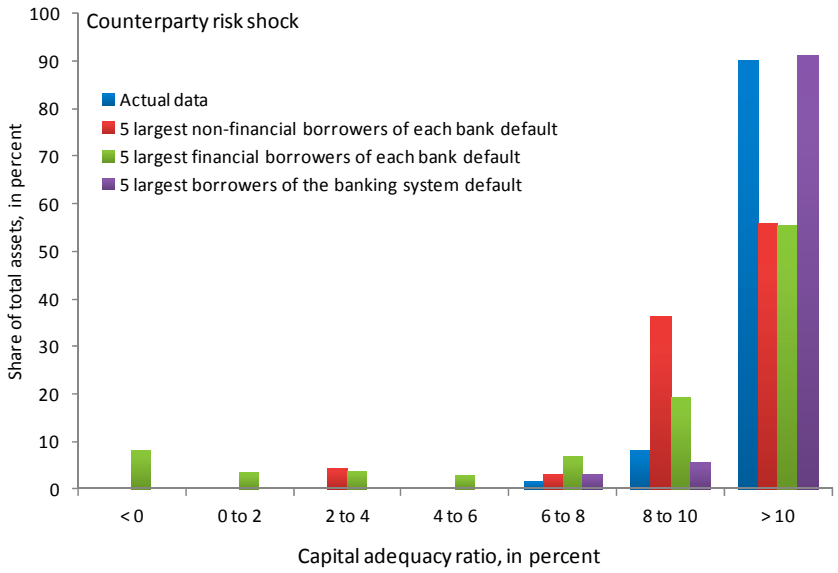
27. **The results of the sensitivity tests validate the results of the solvency stress tests, suggesting that problems arising from the recession scenarios could be manageable**. Under the most severe counterparty risk shock, a number of banks representing 14 percent of total assets in the system could breach minimum capital requirements (Figure 3). In the case of credit risk shocks, if one out of five performing loans becomes impaired, banks representing 30 percent of assets in the system would not meet the minimum CAR (Figure 4, left panel). Were LGDs to increase to 75 percent, banks with an asset share of 10 percent would breach the minimum CAR provided that neither collateral nor profits can be used to cover the losses (Figure 4, right panel). Market risk sensitivity tests had little impact on profits and losses and liquidity.

Table 7. Poland: National Bank of Poland and FSAP Update Sensitivity Tests

	NBP's Financial Stability Report sensitivity tests	FSAP Update sensitivity tests
Counterparty risk shock	Failure of three largest financial or non-financial borrowers for each bank. Failure of the three largest borrowers in the banking system.	Failure of five largest financial or non-financial borrowers for each bank. Failure of the five largest borrowers in the banking system.
Credit risk shocks	Maximum increase in the PD of performing loans that does not breach CAR. Increase in LGD to 25 percent and 50 percent of impaired loans.	Maximum increase in the PD of performing loans that does not breach CAR. Increase in LGD to 50 percent and 75 percent of impaired loans.
Foreign exchange shock	Included in NBP liquidity stress test.	Depreciation of 30 percent against the US dollar, the euro and the swiss franc; impact on open FX positions; credit risk of FX mortage loans, and liquidity needs of banks using FX swaps and cross-currency swaps
Housing price shock	Decrease in real estate prices by 10 percent together with deterioration of mortgage loans.	30 percent decline in housing prices; impact on mark-to-market value of banks' assets.
Interest rate shock	Included in NBP liquidity stress test.	300 bps parallel widening of government yield curve and corresponding impact on interest rate swaps. Bear flattening of the yield curve; 3-month rates widening of 300 bps and 5-10 year rates widening by 100 bps.

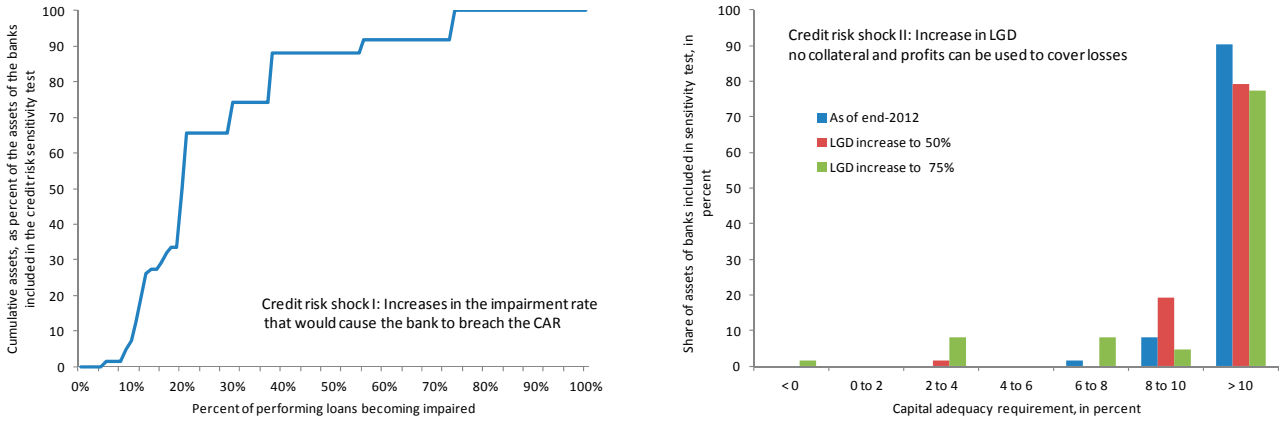
Source: NBP.

Figure 3. Poland: Counterparty Risk Shock



Source: NBP.

Figure 4. Poland Credit Risk Shock



Source: NBP.

IV. Liquidity Stress Tests

28. **The central bank conducted a liquidity stress test**. The test included the same twenty banks analyzed in the top-down stress tests. The test considered the simultaneous realization of several shocks as listed in Table 8 and their impact on the ratio of liquid assets to liquidity needs.

Table 8. Poland: Liquidity Stress Test—Shocks and Impact Channels

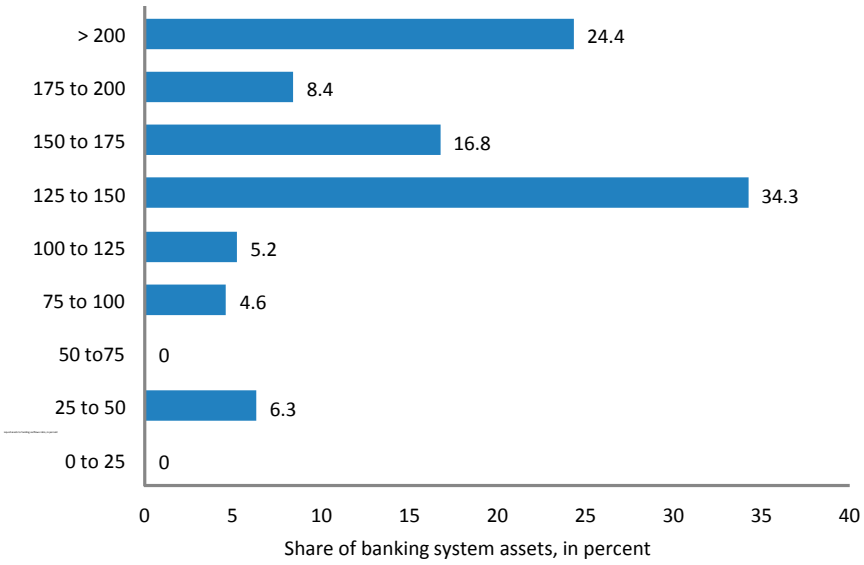
Type of shock	Impact channel
□ 30 percent depreciation of the currency against the euro, the US dollar and the Swiss franc.	□ Increase in the domestic currency value of FX liabilities. □ Increase in the value of domestic currency funds needed for hedging long FX positions in the balance sheet.
□ Parallel widening of the government yield curve by 300 bps	□ Decline in the value of the buffer of liquid assets (government bonds)
□ Foreign capital outflow	□ Withdrawal of 100 percent of deposits, 10 percent of loans and 25 percent of other liabilities with foreign institutions.
□ Drop in mutual confidence among domestic financial institutions	□ Closing of domestic interbank market; complete settlement of all short-term deposits.
□ Drop in confidence of banks' clients	□ Partial withdrawal of stable (core) deposits: □ Households: 5 percent □ Enterprises: 10 percent □ General government entities: 10 percent
□ Increased use of credit lines extended by banks	□ Activation of 10 percent of off-balance shet financing liabilities

Source: NBP.

29. **The results suggest the banking system is resilient to liquidity shocks though asset liquidation could put some pressure on secondary markets**. The average weighted coverage of liquidity needs by liquid assets exceeded 100 percent, with just four banks experiencing liquidity shortages amounting to about PLN 29 billion. These banks controlled slightly more than 10 percent of the total assets in the system (Figure 5). In the liquidity stress test scenario, banks would be forced to liquidate PLN 36 billion of money bills and PLN 10½ billion of government bonds. Given that the average daily market turnover for government bonds is about PLN 30 billion, asset liquidation could lead to some turmoil in secondary markets.

30. **The central bank conducts top-down contagion or domino-effect simulations on a semiannual basis.** The simulations cover both commercial banks and cooperative banks and detailed data on interbank claims and liabilities, including the names of all counterparties to a bank. The simulation assumes the netting of mutual assets and liabilities, i.e., should a troubled bank fail to repay its debt to another bank, then the latter, in order to minimize its losses, will likewise fail to repay its debt to the troubled bank. The simulation accounts for all types of loans and interbank deposits, regardless of their maturity, with insolvency defined as the breaching a capital adequacy ratio of 4 percent. Only commercial banks are allowed to fail in the first round of defaults.

Figure 5. Poland: Liquidity Stress Test Results



Source: NBP.

V. Interconnectedness Risk

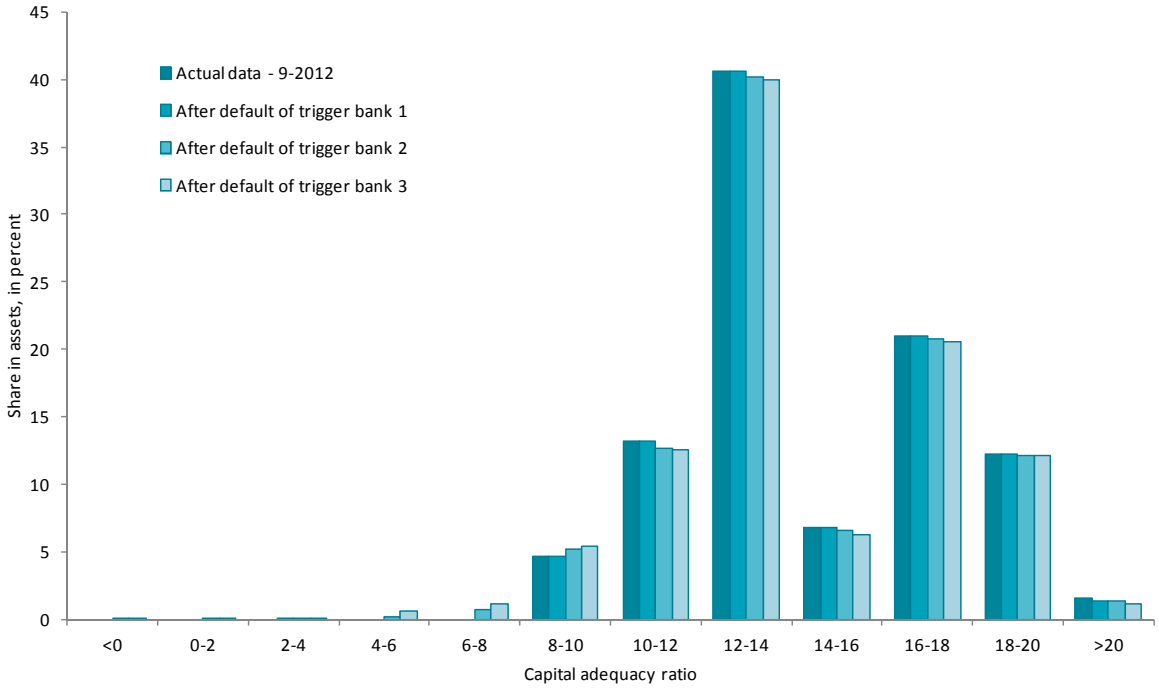
31. **The simulations indicate that interconnectedness risk is low with potential second round contagion effects affecting only small institutions**. The latest simulation results, reported in the bank's December 2012 FSR showed that there were three commercial banks that could trigger a domino effect in the system, with the second round of defaults comprising up to 14 commercial and cooperative banks. These institutions have a share of total assets in the banking system of less than 1¼ percent (Figure 6). Furthermore, the failure of one of the trigger banks did not affect the other trigger banks. The limited inter-connectedness risk arises from small transactions in the interbank market as banks have become more concerned with counterparty risk in the aftermath of the global financial crisis of 2008. However, even before the global financial crisis 2008 usage of interbank market as a funding source was rather limited. This is partly due to lower costs of attracting clients deposits or intragroup funding from foreign parent entities.

A. Other Monitoring Tools

32. **In addition to the regulatory stress tests conducted by the central bank and the supervisor, the BFG has developed an early warning system (EWS).** This system is designed with a view to detect stress in individual institutions early to anticipate preparation for payout. The system adopts a multidimensional approach, designed to take advantage of a granular and flexible database. It then combines the indicators from the database by applying a unique methodology that draws on reliability theory. However, more back-testing is

required to reduce the risk of type II errors and enhance the credibility of the model in preparing for payout.

Figure 6. Poland: Interconnectedness Risk—CAR Distribution Before and After the Failure of Trigger Banks



Source: NBP.

VI. Conclusion and Recommendations

33. **The domestic banking system is well capitalized, contributing to its resilience to large credit, liquidity, and market shocks**. Currently, capital levels at banks are well above those required by Basel III and capital is of high quality, reflecting the conservative stance of the KNF. Regulatory guidelines limiting dividend repayments have contributed to the substantial accumulation of capital buffers. Notwithstanding the ample capital base, banks enjoy high return on equity (ROE) and return on assets (ROA), partly owing to the strong growth of the Polish economy in recent years and the low level of bank penetration relative to other countries in the region.

34. **Stress tests, including those regularly conducted for supervisory purposes and in the context of the FSAP update, reflect banks' strong capital base**. Adverse scenarios would affect mainly small banks accounting for a limited share of assets in the system. Given the low level of interconnectedness in the system, second round defaults would be limited even in the remote event that a large bank defaults. Liquidity buffers appear adequate against the shocks but their realization and the ensuing sale of liquid assets could lead to volatility and downward price pressure on government securities markets.

35. **The FSAP team considers that there are natural synergies arising from the stress tests and the EWS.** Each system has advantages that can complement the other two. The authorities could develop a clearer understanding of the risks in the banking sector by enhancing cooperation and information sharing between the departments in each agency responsible for stress testing. Since the information from bottom-up stress tests is complemented with on-site supervision information, the KNF could examine whether it is appropriate to conduct on-site inspections more frequently.

APPENDIX I. STRESS TEST MATRIX: SOLVENCY RISK[1/]

Domain	Assumptions		
	Bottom-Up by Banks (if applicable)	Top-Down by Authorities (if applicable)	Top-down by FSAP Team (if applicable)
Institutions included	• N.A.	• 20 • Names undisclosed.	• 20, but data reported only by buckets (6 buckets) • Names undisclosed.
Market share	• N.A.	• 85 percent	• 85 percent
Data and baseline date	• N.A.	• Supervisory data. • Solo basis for domestic banks; solo basis for foreign subsidiaries. • Baseline date: 2012 Q4.	• Supervisory data. • Solo basis for domestic banks; solo basis for foreign subsidiaries. • Baseline date: 2012 Q4.
Methodology	• N.A.	• Central bank stress testing framework. • Balance-sheet model.	• Balance sheet model.
Stress test horizon	• N.A.	• 5 years	• 5 years
Shocks	Scenario analysis • Shocks to baseline real GDP growth agreed with IMF FSAP team; other macroeconomic and financial variables evolve conditional on GDP according to central bank models. Recession scenarios include V-shaped recession (4 percentage point negative shock to real GDP growth in year 1); double dip recession (2½ percentage point negative shocks to real GDP growth in years 1 and 2); L-shaped recession (3 percentage points negative shocks to real GDP growth in years 1 and 2 followed by a period of low growth). Sensitivity analysis (performed only by central bank) • Counterparty risk shocks: failure of largest five nonfinancial borrowers for each individual bank; failure of the largest five financial borrowers for each individual bank; and failure of the five largest borrowers in the system. • Credit risk shocks: maximum deterioration in the quality of performing loans that banks can absorb without breaching capital adequacy requirements; increase in the loss-given-default of impaired loans. • Market risk shocks: 30 percent currency depreciation against the US dollar, the euro and the Swiss franc; 30 percent decline in housing prices; parallel widening of the yield curve by 300 bps; bear flattening of the yield curve 300 bps widening in the short end of the curve; 100 bps widening in the long end of the curve.		
Risks/factors assessed (e.g., credit losses, profitability, funding costs, fixed income holdings of banks/sovereigns, exchange rate, taxes)	• N.A.	• Credit losses based on central bank satellite models. • Net interest income based on central bank satellite models.	• Credit losses based on staff PD calculations based on central bank NPLs projections. • Net income projections provided by central bank.
Calibration of risk parameters (e.g., PDs and LGDs—through the cycle, point in time, correlations in market risks, deltas	• N.A.	• Point in time.	• Point in time; LGDs assumed constant through stress test horizon.

Domain	Assumptions		
	Bottom-Up by Banks (if applicable)	Top-Down by Authorities (if applicable)	Top-down by FSAP Team (if applicable)
and vegas for options)			
Behavioral adjustments (e.g., nature of balance sheet growth, zero profit, dividend payout, asset disposal, lending standards, portfolio allocation)	• N.A.	• Balance sheet growth equal to nominal GDP growth (if positive) if all capital requirements are fulfilled. • Maximum dividend payout conditional on the bank's capital buffer over the minimum capital ratio, and consistent with Basel III recommendations; dividends paid out only if bank records profits. • Asset disposals and acquisitions over time should not be considered; the portfolio composition should remain unchanged over time, with maturing exposures replaced with similar ones.	• Balance sheet growth equal to nominal GDP growth if capital buffer is at least 2½ percentage points above the minimum Tier 1 capital requirement; if Tier 1 capital ratio falls below the minimum requirement, credit growth declines by twice the capital shortfall in percentage points. • Maximum dividend payout conditional on the bank's capital buffer over the minimum capital ratio, and consistent with Basel III recommendations; dividends paid out only if bank records profits with payout ratio not exceeding 25 percent. • Asset disposals and acquisitions over time should not be considered; the portfolio composition should remain unchanged over time, with maturing exposures replaced with similar ones.
Regulatory standards	• N.A.	• Hurdle rate: Basel III schedule. • Capital metrics: Basel III. • CET1, T1, CAR. • Changes in RWAs.	• Hurdle rate: Basel III schedule. • Capital metrics: Basel III. • CET1, T1, CAR. • Changes in RWAs.
Results	• N.A.	Scenario analysis • Distribution of CAR in the system, by share of assets.	Scenario analysis • Distribution of CAR in the system, by share of assets.
		Sensitivity analysis • Distribution of CAR in the system, by share of assets.	Sensitivity analysis • Distribution of CAR in the system, by share of assets.

APPENDIX II. STRESS TEST MATRIX: LIQUIDITY RISK[1/]

Domain	Assumptions		
	Bottom-Up by Banks (if applicable)	Top-Down by Authorities (if applicable)	Top-down by FSAP Team (if applicable)
Institutions included	• N.A.	• 20 banks • Names undisclosed.	• N.A.
Market share	• N.A.	• 85 percent	• N.A.
Data and baseline date	• N.A.	• Supervisory data, as of end-2012. • Solo basis for domestic banks; solo basis for foreign subsidiaries. • Baseline date: 2012 Q4.	• N.A.
Methodology (e.g., included in scenario analysis linking solvency and liquidity, separate test using ad hoc model/balance sheet)	• N.A.	• Separate test using balance sheet data.	• N.A.
Risks (e.g., funding liquidity shock, market liquidity shock, both)	• N.A.	• Exchange rate depreciation. • Widening of the government yield curve with no corresponding movement of the interest rate swap curve. • Foreign capital outflow. • Closing of the interbank market. • Partial withdrawal of stable deposits. • Increased use of credit lines extended by banks.	• N.A.
Output metric	• N.A.	• Ratio of liquid assets to liquidity needs.	• N.A.
Results	• N.A.	• Number of banks facing liquidity shortages and corresponding share of assets in the bank sample.	• N.A.

ANNEX. TOP-DOWN MARKET-BASED STRESS TEST

36. **The FSAP team conducted a top-down market-based stress test to complement its own balance sheet top-down stress test and that performed by the NBP.** The market-based test used as data input market estimates of the default risk of Polish banks to obtain implied changes of their capital-asset ratio under the macroeconomic scenarios.

37. **The results suggest some banks could face substantial declines in their capital-asset ratios**. Furthermore, the default of a few institutions cannot be ruled out under the adverse scenarios. The problems, however, are concentrated among smaller institutions and the high capital adequacy ratios in the system suggest that despite large declines, capital adequacy ratios could remain above regulatory minimum levels. The methodology and results are described in detail below.

Methodology

38. **Market-based top-down stress tests can complement standard stress tests**. The latter build on detailed and granular information on the sources of income of a bank, and its loan and trading books. In contrast, market-based tests use market information on the default risk of a bank to assess the impact of different stress scenarios on the bank's capital base. These types of tests factor in market participants' views on the soundness of a bank. Since banks are vulnerable to self-fulfilling runs, which need not be triggered by weak fundamentals but rather by market perceptions, the use of market-based stress tests is desirable. The methodology is explained concisely in the next section.

Linking the probability of default to the capital structure of the bank

39. **The starting point for the analysis is the link between the probability of default of a bank and its capital structure** (Merton, 1974)**.** Specifically, the probability of default of a bank, p, over a time horizon T, is related to the capital structure of the firm by:

$$(1) \qquad p = \Phi\left(-\frac{\ln(V/D) + (\mu - \sigma^2 T/2)}{\sigma\sqrt{T}} \right),$$

where V/D is the inverse of the debt-to-asset ratio of the bank, μ and σ are the growth rate and volatility of the asset value of the bank, respectively. Therefore, if the probability of default is known, the debt to asset ratio can be calculated from equation (1) assuming reasonable estimates for the growth rate and the volatility of the asset value of the firm. Once the debt to asset ratio is known, the capital to asset ratio, K/V, follows simply from:

$$(2) \qquad K/V = 1 - D/V\,.$$

As explained in Chan-Lau (2013) among others, there are several ways to obtain probabilities of default from different financial instruments.

Linking changes in the capital structure to stress scenarios

40. **The capital structure analogy suggests how to evaluate the impact of stress scenarios on the capital to asset ratio of a bank**. Basically, equations (1) and (2) suggest that it suffices to specify a model linking the probability of default of the bank to one or more of the economic variables, *X*, and market risk factors, *M*, specified in the stress scenario:

(3) $p_t = F(X_t, M_t)$.

Given the paths of the economic and market risk factors in a stress scenario, equation (3) determines the dynamics of the probability of default, and equation (1) and (2) determine the dynamics of the capital-asset ratio. The next section applies the methodology to evaluate the performance of Polish banks under different macro stress test scenarios.

Numerical implementation and results

41. **Market-based top-down stress tests were conducted for several Polish banks**. For each bank, the probability of default over a one-year horizon corresponded to the one-year Expected Default Frequency (EDF) calculated by Moody's Analytics. The EDF is the real-world probability of default obtained from a structural model conceptually similar to that of Merton (1974). The model combines observed equity prices, equity price volatility, and balance sheet data and is calibrated with historical default data (Bohn and Crosbie, 2003).

42. **Simple nonlinear models were estimated to link the behavior of the EDF to year-on-year changes of real GDP**. The sample data spanned the period 2006 Q3 to 2012 Q3 (Table 1 and Figure 1).[8] For some banks, models were estimated using only data for the period 2010 Q3–2012 Q3. In addition, the fit of the models for two banks was somewhat counterintuitive for growth rates exceeding 7 percent. These growth values, however, did not realize in the stress scenarios.

[8] The more sophisticated one-factor modeling approach of Hamerle, Jobst, Knapp, and Lerner (2008) was also used but it was not possible to fit the models to all the banks. The results for banks fitted with one-factor models were very similar to those reported here.

Table 1. Poland: Nonlinear Models for Banks' EDFs as a Function of Year-on-Year Real GDP Changes

Three different models were fitted to link banks' expected defaut frequencies to year-on-year regal GDP changes: (1) a one-term exponential model, $y = ae^{bx}$; (2) a rational polynomial, $y = (ax+b)/(x+c)$; and (3) a second degree polynomial, $y = ax^2 + bx = c$. The 95 percent confidence levels are shown within brackets.

Exponential curves

Coefficients	a			b		
Bank 1	10.40	(6.45 ,	14.36)	-0.56	(-0.76 ,	-0.36)
Bank 2	3.19	(1.92 ,	4.45)	-0.45	(-0.62 ,	-0.27)
Bank 4	25.49	(10.39 ,	40.59)	-0.34	(-0.56 ,	-0.12)
Bank 5	5.67	(2.88 ,	8.46)	-0.33	(-0.51 ,	-0.15)
Bank 8	1.60	(1.09 ,	2.11)	-0.52	(-0.67 ,	-0.36)
Bank 9	1.24	(0.97 ,	1.51)	-0.38	(-0.46 ,	-0.29)
Bank 10	9.02	(0.64 ,	17.41)	-0.58	(-0.93 ,	-0.23)
Bank 12	1.84	(1.28 ,	2.40)	-0.42	(-0.55 ,	-0.29)
Bank 13	51.90	(15.15 ,	88.65)	-0.35	(-0.57 ,	-0.13)

Rational polynomial curve

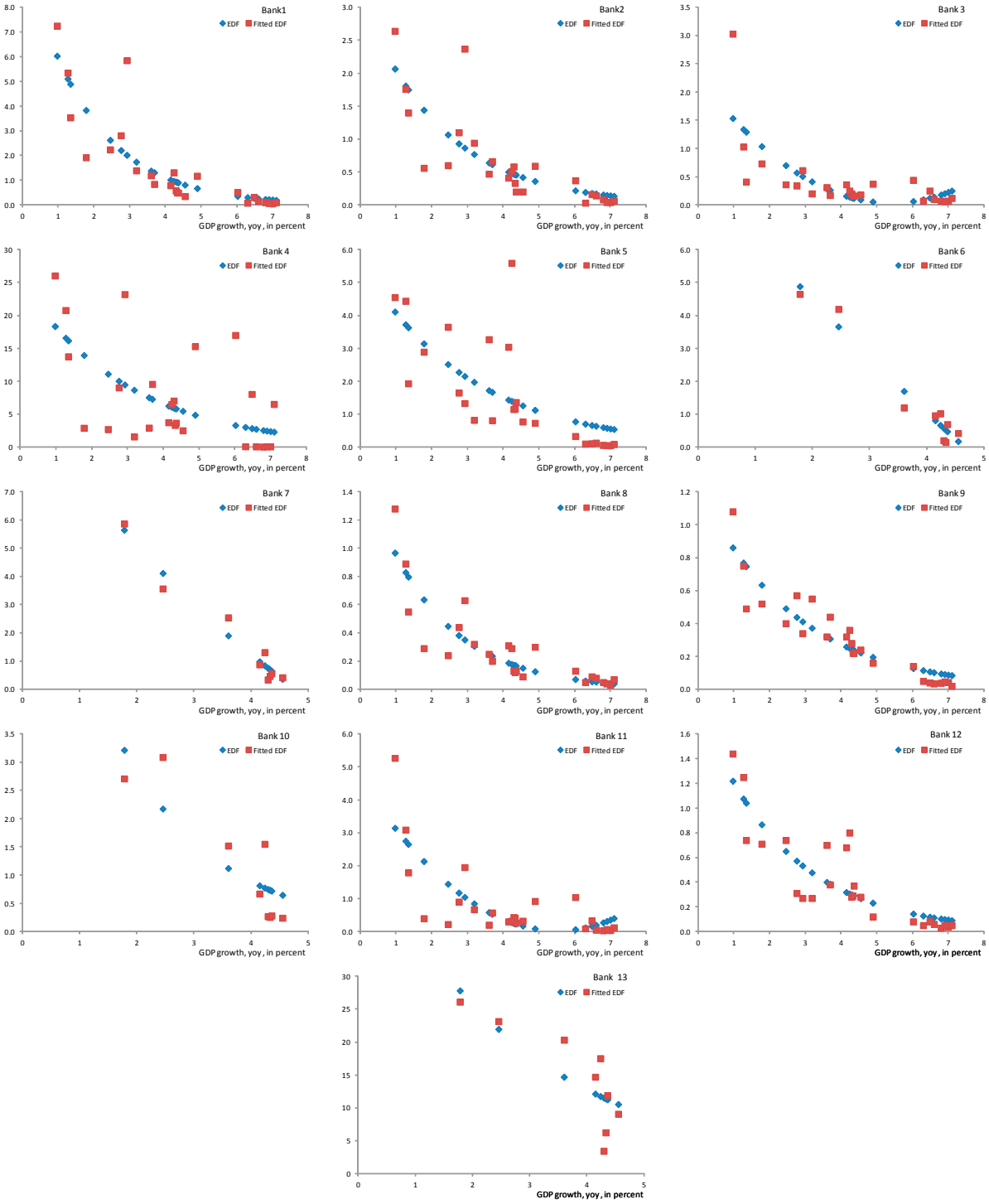
Coefficients	Bank 6			Bank 7		
a	-53.56	(-759.41 ,	652.29)	-19.56	(-112.67 ,	73.55)
b	249.71	(-3019.78 ,	3519.21)	93.75	(-341.96 ,	529.47)
c	29.82	(-385.67 ,	445.31)	8.65	(-40.16 ,	57.4665)

Polynomial curve

Coefficients	Bank 3			Bank 11		
a	0.08	(0.02 ,	0.13)	0.15	(0.06 ,	0.24)
b	-0.82	(-1.26 ,	-0.38)	-1.66	(-2.47 ,	-0.85)
c	2.26	(1.42 ,	3.10)	4.62	(3.06 ,	6.17)

Source: Moody's Analytics; and author's calculations.

Figure 1. Poland: Fitted Nonlinear Models for Banks' EDFs as a Function of Year-on-Year Real GDP Changes



Source: Moody's Analytics and author's calculations.

43. **Once the nonlinear models were estimated, it was possible to project changes in the capital-to-asset ratio under different macro scenarios**. The scenarios are summarized in Table 2. The scenarios comprise a baseline (slow-growth) scenario, and three different recession scenarios.

Table 2. Poland: Macro Scenarios, GDP Growth Year-on-Year

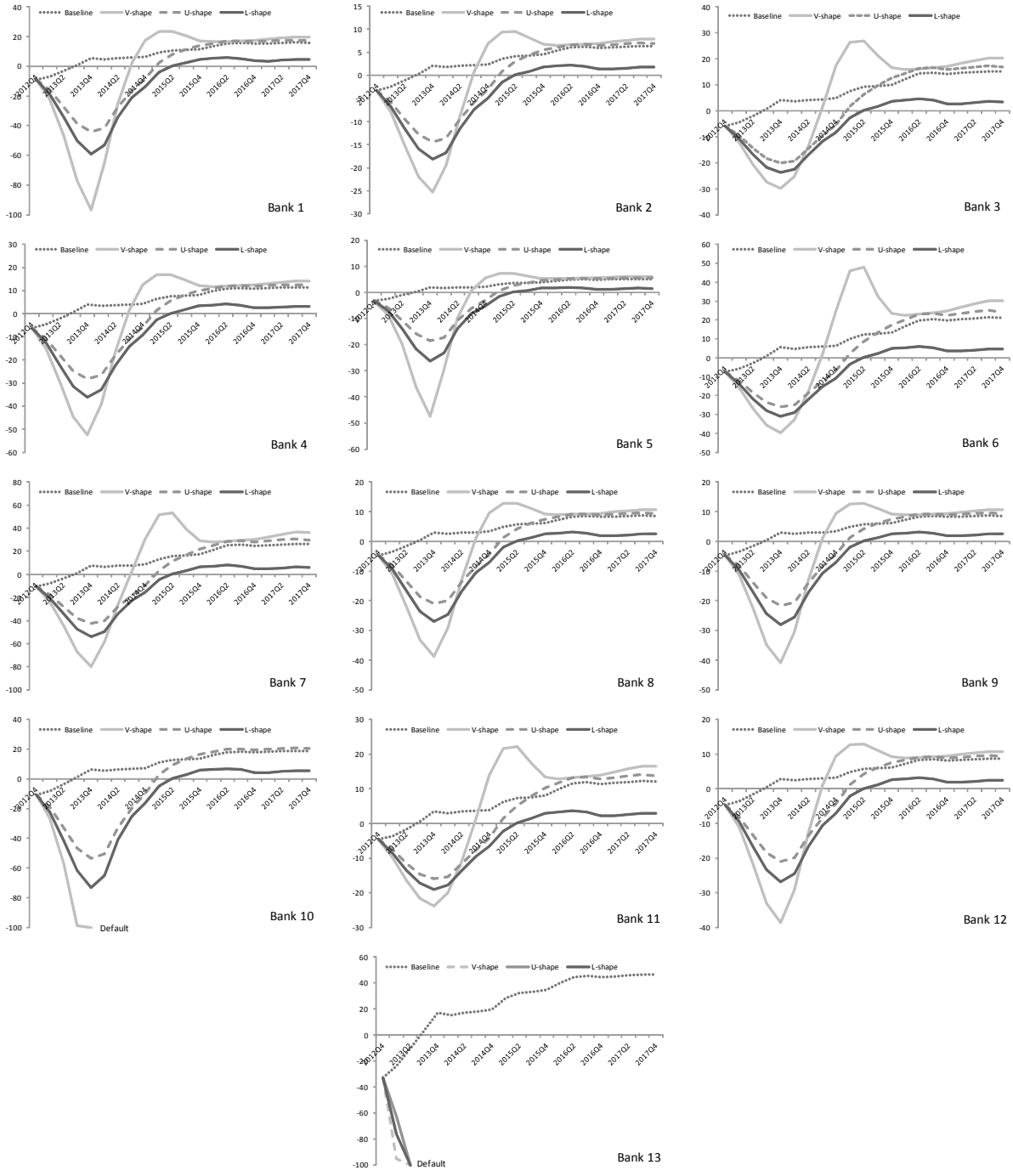
	Baseline	V-shaped recession	U-shaped recession	L - shaped recession
2012 Q3	1.78	1.80	1.80	1.80
2012 Q4	0.94	0.94	0.96	0.95
2013 Q1	1.14	-0.14	0.36	0.14
2013 Q2	1.49	-1.78	-0.52	-1.01
2013 Q3	1.87	-3.24	-1.28	-1.99
2013 Q4	2.33	-3.89	-1.63	-2.46
2014 Q1	2.25	-2.74	-1.47	-2.14
2014 Q2	2.32	-0.36	-0.52	-1.01
2014 Q3	2.36	2.00	0.33	-0.05
2014 Q4	2.40	3.66	1.02	0.55
2015 Q1	2.72	4.35	2.03	1.43
2015 Q2	2.89	4.38	2.60	1.83
2015 Q3	2.92	3.99	2.97	2.03
2015 Q4	2.98	3.60	3.26	2.28
2016 Q1	3.20	3.54	3.42	2.33
2016 Q2	3.40	3.58	3.58	2.39
2016 Q3	3.43	3.62	3.61	2.32
2016 Q4	3.39	3.66	3.55	2.16
2017 Q1	3.42	3.76	3.59	2.15
2017 Q2	3.45	3.84	3.64	2.21
2017 Q3	3.48	3.91	3.68	2.26
2017 Q4	3.47	3.91	3.64	2.26

Source: IMF staff estimates.

44. **In general, banks experience a decline in their capital asset ratios in the first two years of the recession scenarios**. The declines are reversed after the economy starts posting positive growth rates. Under the assumption that asset values remain flat or decline during the negative growth periods in the scenarios, the analysis shows that banks could suffer substantial capital losses ranging from 20 percent to 60 percent. In particular, it cannot be ruled out that certain banks could face recapitalization needs if the stress scenarios were to realize. As with any market-based model, some caution in interpreting the results is advised as secondary liquidity in the stock market could affect the reliability of equity-implied measures of default risk.

Figure 2. Poland: Changes in the Capital to Asset Ratio of Polish Banks under Different Macro Scenarios Relative to 2012Q3 Levels

(In percent)



Source: Moody's Analytics; and author's calculations.

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