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ADB Working Paper Series on Regional Economic Integration

A Macroprudential Framework for the Early Detection of Banking Problems in Emerging Economies

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Asian Development Bank

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The ADB Working Paper Series on Regional Economic Integration focuses on topics relating to regional cooperation and integration in the areas of infrastructure and software, trade and investment, money and finance, and regional public goods. The Series is a quick-disseminating, informal publication that seeks to provide information, generate discussion, and elicit comments. Working papers published under this Series may subsequently be published elsewhere.

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Abstract

This paper develops an analytical framework that can be used to anticipate problems in the banking system and enable supervisors to take mitigating actions at an early stage.

This paper has two components. First, it develops an early warning indicator that is intended to capture a number of the systemic risks that can affect the banking system as a whole. Second, it develops a methodology to detect problems at the individual bank level in an effort to identify those firms with financial vulnerabilities.

For the systemic component of our methodology, the final output is a banking system vulnerability index to facilitate bank monitoring tasks, as well as some disaggregated subcomponents that are intended to display the relative importance of the different risks (e.g., liquidity, currency, and interest rate risks). Regarding the assessment of the soundness of individual institutions, the paper uses a methodology based on cluster analysis that incorporates the results of the previous framework.

There is an empirical application of the systemic component that is based on the 2001 Argentine banking crisis. It shows that the proposed vulnerability indicator started to increase steadily beginning in 1999, following 2 years in which it had remained flat, and it finally peaked in mid-2001, which was just before the onset of the crisis.

Executive Summary

This paper develops a methodological framework to help bank supervisors anticipate eventual problems and take mitigating actions at an early stage.

We develop a proposal applicable to banking systems as a whole in order to support systemic monitoring. In addition, we propose a particular methodology for the early detection of problems facing individual entities in order to facilitate preventive actions and avoid eventual contagion risks.

As opposed to the traditional early warning indicators approach (à la Kaminsky), which relies on econometric modeling and historical data, our methodology makes use of stress-testing practices such as those recently used to analyze the soundness of banks in industrialized countries, which rely on projected macroeconomic and financial scenarios.

In regard to the systemic part of our methodological proposal, the final output is an overall banking vulnerability index to facilitate bank monitoring tasks, as well as some disaggregated subcomponents that are intended to display the relative importance of the different risks (e.g., liquidity, currency, and interest rate risks) in the composition of the overall vulnerability index.

The vulnerability index is calculated as follows: (i) develop a set of macroeconomic and financial scenarios, either by judgmental opinion or by simulation techniques, and project some key variables such as gross domestic product (GDP) growth, interest rates, and exchange rates, among others; (ii) simulate over a 12-quarter period of the banking system's balance sheet and income statement under the projected macro-financial scenarios developed in the first step; (iii) trace the evolution of the risk indicators (e.g., liquidity ratios and capital adequacy ratios) over the simulation period under the projected scenarios; (iv) select the appropriate thresholds in order to separate the normal values that each indicator can take from the "problem zone," which is a range of values that indicate some type of vulnerability in the system; and (v) determine the number of risk indicators that would be in the problem zone at any point in time during the simulation period and the size of the distance from their thresholds, and summarize all of this information into a single vulnerability indicator.

In addition, by determining the risk indicators that enter into the problem zone and to what extent, the methodology provides a detailed picture of the eventual behavior of the vulnerability index subcomponents, which helps to identify where banking weaknesses may lie and favors adequate mitigating actions.

Regarding the assessment of an individual entity's soundness, the paper proposes a type of cluster analysis methodology in combination with the previous framework. In this case, the methodology can be summarized as follows: (i) develop a set of macroeconomic and financial scenarios, either by judgmental opinion or by simulation techniques, and project some key variables (e.g., GDP growth, interest rates, exchange rates); (ii) simulate over a 12-quarter period of each bank's balance sheet and income

statement under the projected macro-financial scenarios developed in the first step; (iii) trace the evolution of the risk indicators (e.g., liquidity ratios and capital adequacy ratios) of each bank over the simulation period under the projected scenarios; (iv) measure the distance of each bank's projected risk indicators from those of their group of peers; (v) find those banks that are far enough from their peers in terms of their projected risk indicators to be considered outliers (by selecting a threshold based, for example, on the empirical distribution of distance measures); (vi) assess which of the risk indicators account for most of the calculated distances in order to identify the outlier institutions and the type of risks that makes them more vulnerable than their peers, and provide guidance on the corrective actions that need to be taken.

It is worth noting that our methodology to analyze systemic vulnerabilities and the methodology proposed for the evaluation of individual institutions are both based on forward-looking exercises. Therefore, all of the indicators that result from them can be viewed as early warning indicators. As mentioned above, these early warning indicators are different from typical indicators based on historical data, which have proven to be not as useful or applicable as desired due to data availability constraints, among other problems.

While our methodology has the advantage of not depending on data availability and econometric modeling, it relies on the ability of the supervisor to envision relevant macroeconomic scenarios under a judgmental setting and the supervisor's proficiency in selecting adequate probability distributions and calibrating appropriate parameters under a simulation framework.

An illustrative application was made for the case of Argentine private banks, showing that our vulnerability indicator started to increase steadily beginning in 1999, following 2 years of flat behavior, and peaked in 2001, which was just before the onset of the crisis. At the same time, the counterfactual assessment of the subcomponents shows a good early diagnosis of the vulnerability sources that eventually disrupted the Argentine banking system.

1.   Introduction

The recent banking crisis in the industrialized countries has stirred debate about its causes, consequences, and policy implications. The extent and depth of this crisis took economists and policymakers by surprise. The policy response was decisive and unprecedentedly large, and while the consequences of the crisis are still not totally clear, everything indicates that it has had large fiscal costs and led to the worst worldwide recession since the Great Depression.

Somewhat paradoxically, this crisis took place in spite of increased efforts in recent years by policymakers to strengthen financial stability and at a time when regulators were putting in place the Basel II principles to reduce financial vulnerability and strengthen the banking sector.

Financial crises, by their nature, may be unavoidable and we are likely to experience others in the future that could very well be the consequence of financial innovations, new excesses in financial markets, or some other unforeseen event. The implementation of adequate policies and a better understanding of crises' possible causes and transmission mechanisms can certainly help to limit the detrimental effects when they do occur.

Although policymakers failed to anticipate the recent crisis, the decisive response, which to a large extent was devised from in-depth studies of the policy mistakes that were made during the Great Depression, has so far helped to limit the adverse economic and financial outcomes.

A distinctive feature of this crisis is that by and large it did not spread to banking systems in emerging market countries (EMCs). Although it may still be too early to arrive at a firm conclusion, it seems that there are at least three reasons that can explain this outcome. First, the crisis mainly affected investment banks and institutions that were involved with derivates and complex structured products, which are not as prevalent in EMCs. Second, there has been significant improvement in the quality of the prudential regulation of banks in EMCs in recent years. Furthermore, banks in these countries entered this crisis well-capitalized and were not as vulnerable as they had previously been in terms of currency and interest rate gaps. Third, EMCs had much better macroeconomic fundamentals than during previous crisis episodes, with stronger fiscal and external accounts, a larger stock of international reserves, and more flexible exchange rate systems.

The purpose of this paper is to develop a set of indicators and a vulnerability index to help detect in advance macroeconomic and financial vulnerabilities that can affect the banking system. The paper follows a top–down approach by starting with a review of the macroeconomic variables generally recognized in the economic literature as key to alerting policymakers of potential financial problems and discusses how to include them in our analysis. In section 2 we will discuss the transmission mechanisms of macroeconomic variables that impact the banking sector and identify the main variables needed to be tracked based on their ability to affect the performance of the banking system and impact the banks' balance sheets.

Section 3 concentrates on those issues that could lead to systemic problems in the banking system. Among other aspects, the section evaluates the effectiveness of the financial safety net, which includes issues such as the scope and viability of the deposit insurance system, the existence of a lender of last resort, as well as potential risks deriving from large exposures to the public sector or from the liquidity side. It also analyzes the interactions between banking and macroeconomic shocks.

Section 4 develops a detailed methodology for the construction of a banking vulnerability index based on the main items of the balance sheet and profit and loss statements, which is then used to evaluate the banking system's ability to withstand different types of shocks such as a currency depreciation or a sharp increase in interest rates, among others. The methodology used in this paper combines the more traditional approach of early warning indicators with some element of stress testing that have been used recently to analyze the soundness of banks in the industrialized countries. A distinctive feature of this approach is that it introduces stress testing to construct early warning indicators of banking system problems, which is done by constructing different macroeconomic and financial scenarios and tracing their effects over time on key banking performance indicators.

Section 5 develops an application to show how our methodology would have worked in the case of the 2001 Argentine banking crisis. The application shows that the methodology can potentially be very useful in monitoring the evolution of a banking system and detecting vulnerabilities at an early stage.

At the same time, it is worth noting that the exercise shows that there are important requirements in terms of data and in having a thorough understanding of the main macroeconomic and financial vulnerabilities, and the characteristics of the banking system. The models are country specific and need to incorporate an individual country's macro, financial, and institutional characteristics in some detail.

The main objective of Section 6 is to look at the evolution of risk indicators of individual banks under alternative macro scenarios in order to detect at an early stage whether there are financial institutions potentially at risk. We propose a methodology that is based on peer group analysis that reviews a pre-set number of bank indicators to monitor the performance of individual banks and detect which are the outliers within the system.

In section 7 we present the main findings of the paper and some preliminary conclusions about the usefulness of the methodology and the challenges and data requirements of applying it to different countries.

2.   Macroeconomic Factors and Systemic Banking Risks

The recent international financial crisis, which had its epicenter in the industrialized countries, has generated a new debate about the causes and consequences of financial crises. One critical question that has been raised time and again is why regulators and monitoring institutions did not foresee that a crisis of this type was coming and why they

took no early action to avoid it. How did regulators not perceive the problems with collateralized debt obligations or with credit default swaps?

This financial crisis was the result of a combination of adverse events including (i) a lack of regulation of key financial players such as investment banks and insurance companies; (ii) a lack of coordination among the regulatory agencies within and across countries in monitoring globalized complex financial institutions; and (iii) the inability of credit rating agencies to understand complex structured products, which led them to consistently underestimate risks in awarding generous investment grade rates ratings.

While the causes of the recent international financial crisis, especially in the industrialized countries, are not yet entirely clear, they appear to be more related to excesses and a lack of supervision in the financial markets, and less related to macroeconomic policies and imbalances. One could argue that a relatively long period of low interest rates and large increases in asset prices were important factors, but the main problems appear to be excesses in the financial sector and very lenient lending policies.

In this respect, the recent financial crisis seems different from the typical crisis in EMCs that have mainly been triggered by macroeconomic events, including sudden and large changes in key macroeconomic prices (e.g., a sharp currency depreciation, inflation, and a sudden stop in capital inflows), or significant and unexpected increases in long-term domestic interest rates.

The recent banking crises in EMCs—Mexico in 1994/95, Asia in 1997/98, Russia in 1998, and Argentina and Uruguay in 2001/02—all had their origins in macroeconomic imbalances that directly affected the solvency or liquidity of banking systems. In some cases the problem was a maxi-devaluation that had a large balance sheet effect, as banks were net debtors in dollars (Asia). In other cases, fiscal and debt management problems affected banks that had a large exposure to the public sector (Russia). Finally, in a third group of countries, expectations of a devaluation combined with a government that faced solvency problems and had no access to financing triggered a run on a dollarized banking system that lacked a credible lender of last resort (Uruguay and—to a lesser extent—Argentina).

There is a vast literature that analyzes the links between macroeconomic and banking crises. This relationship can be mutually reinforcing as a banking crisis is bound to have important effects on key macroeconomic variables such as the fiscal deficit, interest rates, and the rate of economic growth. Meanwhile, macroeconomic factors are often the underlying reason behind a banking crisis.

In addition to intrinsic banking problems such as poor management or other structural deficiencies, most banking problems, especially systemic ones, can be explained by adverse macroeconomic fundamentals or shocks, which at a certain moment can trigger sharp movements in a group of key macroeconomic variables that impact banks' balance sheets.

There is wide coverage in the specialized literature of a range of banking crisis episodes showing the huge explanatory power of macroeconomic misalignments.[1] While this is true for both developed and developing countries, the latter face some additional threats and vulnerabilities.

Banking systems in developing countries are often under pressure due to fiscal deficits (Honohan, 1997) that generate financial demands on banks. This can lead to an increase in the banks' exposure to the public sector, which can in turn lead to a large deterioration in their creditworthiness and the disruption of banks' equity and liquidity. The 1997/98 Asian and 2001 Argentine crises are clear examples of such a situation. Thus, the government budget and its sustainability represent an important variable that needs to be taken into account for many developing countries.

However, macroeconomic issues do not explain every single banking stress episode. Sometimes there are other factors that are microeconomic in essence that underlie stress or crises events, such as structural deficiencies or poor management practices. Regulation and the behavior of financial intermediaries could be behind other crises, which can be labeled endogenous in the sense that they are generated because of the incentives or practices within the banking system. Usually, banks fuel much of the boom–bust financial cycles, even when they are the first to suffer the consequences of the boom suddenly ending. The recent subprime crisis is a clear example in this regard.

Additionally, banking stress events are sometimes motivated by exogenous factors in that they are not the result of macroeconomic deterioration or intrinsic banking problems, but instead are driven by external shocks such as a crisis in a neighboring or partner country. The "Tequila effect" in Argentina in 1994/5 and the most recent financial crisis in some countries in Eastern Europe and Iceland are examples of such events, notwithstanding the role of internal financial excesses in the latter two examples. Contagion effects are sometimes motivated by fundamentals, such as cross-border exposures, but it is also common to see contagion between developing countries without objective fundamentals. These are externalities that create sources of vulnerability beyond the control of domestic authorities. The impact of the 1998 Russian crisis on Brazil—and subsequently other countries in Latin America—illustrates the point.

Given the diversity of factors that could stress banks' balance sheets, it is important to consider each carefully in the pursuit of a comprehensive approach.

2.1   Main Macroeconomic Variables Affecting Banking Risks

Macroeconomic factors affect banks' performance both in normal times and in times of stress. A group of key variables—interest rates, exchange rates, economic growth, and unemployment—has a direct impact on banking risks. Even when this group of key variables is the only thing that has a direct impact on banks' balance sheets, in a forward-looking approach it is still important to perform a complete assessment of macroeconomic fundamentals in order to anticipate eventual movements within that group.

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[1]   Reinhart and Rogoff (2008).

For instance, a current account problem has no direct impact on banks' performance indicators, but it will have an indirect impact through interest rate and exchange rate movements and probably through economic activity and unemployment as well.

Thus, we divide the analysis of macroeconomic factors affecting banks into two separate sections: (i) we first consider macroeconomic fundamentals in a broad sense and then (ii) focus on the group of key variables that has a direct impact on banks' indicators. Hereafter, we will refer to those variables as triggers.

2.1.1 Fundamentals

As mentioned above, we need to assess the broad macroeconomic picture in order to foresee risks and anticipate the buildup of banking vulnerabilities.

There is not a unique macroeconomic model to analyze the macro-fundamentals, but each central bank should have its own framework. Proposing a new or specific model to perform macroeconomic monitoring is beyond the scope of this paper and there likely is not a single model that would fit all countries. Instead, tailor-made models used by individual central banks are usually the most appropriate.

Whatever the model in use in an individual country, it should contemplate the country's specificities and be able to deal with the evaluation and anticipation of typical macroeconomic problems that have been historically associated with banking crisis events.

In general terms, these problems can be classified as follows (Kaminsky, 2003):

- current account deficit,
- debt burden and debt structure,
- sudden stops/reversal in capital flows,
- fiscal deficit,
- inflation,
- financial excesses, and
- protracted economic recession.

Current account deficits can generate problems for the banking sector, especially when reaching a certain critical level (e.g., exceeding 4% of GDP), as it implies that the economy relies on foreign financing that may potentially be a source of vulnerability. Large and sustained current account deficits may imply increasing risk of a currency crisis or a major depreciation, which could lead to a sudden movement in interest rates and a sharp slowdown in economic activity following an abrupt stop or reversal of capital flows.

Public debt and large financial requirements can also pose a problem for the banking system, especially if the public sector does not find voluntary financing in the capital markets, as banks could become a tempting source of liquidity. In the process, banks

might take on a large exposure to the public sector and face a high concentration of risk in one borrower. There are different ways to measure debt sustainability, although in many EMCs the key indicator is not only the amount of debt (e.g., measured as a ratio to GDP), but also the debt structure including the currency composition, amount of short-term debt, and concentration of debt amortizations. Unfortunately, there are no set rules of thumb on these issues. In the case of the Maastricht Treaty, European Union member countries are required to maintain their public debt below 60% of GDP. However, this is an arbitrary number and most EMCs should probably have debt levels that are much lower.

Other macroeconomic indicators that could be used as a sign of vulnerability are large levels of foreign borrowing, especially because EMCs are subjected to sudden stops (Calvo and Talvi, 2005) and high rates of inflation, which negatively affect long-term credit markets and can lead to periods of high real interest rates or protracted recessions that affect the ability of firms to remain financially sound.

The literature provides a set of macroprudential indicators to monitor the likelihood of macroeconomic problems (IMF, 2000) as shown in Table 1.

Table 1: Fundamentals and their Indicators

Fundamental Problem	Indicators
Current account	Current account balance/GDP
	Terms of trade
	Composition and maturity of capital flows
	International reserves
	Real exchange rate
	FX volatility
Debt	Currency structure of debt
	Debt/Reserves
	External debt/Exports
	Maturity structure of debt
	Short-term debt/Reserves
	External debt service/current account
	Interest rate volatility
Fiscal problems	Fiscal balance/GDP
Sudden stops	International real interest rate
Inflation	Inflation rate

Fundamental Problem	Indicators
Financial excesses	Volatility in inflation
	Stock prices
	Real estate prices
	Domestic credit/GDP
	M2/Reserves
Economic growth slumps	GDP growth rate
	Output GAP
	Sectoral slumps

Source: Centennial Group
FX = foreign exchange, GDP = gross domestic product.

The indicators included in Table 1 should be measured on a forward-looking basis to be able to foresee eventual problems. As noted above, each central bank will have its own views and models to determine values for these indicators.

2.1.2   Trigger Variables

Once macroeconomic fundamentals have deteriorated enough, or when an exogenous shock hits the domestic economy, sharp movements in the group of key macroeconomic variables known as triggers can be expected. This is what we call a stress event, which eventually leads to crisis.

Table 2 summarizes the triggers and the kind of financial risk through which they impact banks' balance sheets and solvency.

Table 2: Triggers

Variable	Banking Risk
Exchange rates	Market
Interest rates	Market/Liquidity
Government bond prices (Government default)	Market/Liquidity/Credit
Asset prices	Market/Liquidity/Credit
Unemployment rate	Credit

Source: Centennial Group

The triggers are variables that typically can move very quickly and (at some point) respond to imbalances in the fundamentals. Examples include the exchange rate, which can jump in response to a speculative attack on the currency; a sudden stop in capital inflows; and a protracted period of large current account deficits associated with a currency that is clearly overvalued. In other words, a trigger is a variable that directly affects banks' balance sheets. In this respect, the current account is a macroeconomic problem, but its effects on the banking system only appear following a devaluation of the currency. Likewise, when the government has difficulty obtaining financing or rolling over its debt, the effects on the banking system generally take place through increases in domestic interest rates, leading to the crowding-out effect, or through a higher country risk.

Thus, an example of a trigger includes a large depreciation of the currency, which is typically driven by an imbalance in the external accounts (i.e., large currency account deficits) or by efforts of the central bank to defend a clearly overvalued currency.

The basic idea is that macroeconomic fundamentals do not directly affect the banking system, but rather affect it indirectly through different triggers that, in turn, have an impact on the banks´ balance sheets. Thus, both fundamentals and triggers have impacts on banks' balance sheets and profit and loss (P&L) statements, albeit at different stages.

There are cases in which the triggers can move without changes in the fundamentals, which suggests the need to understand triggers' behavior even in cases when there are no apparent imbalances in the fundamentals. One example of these movements relates to financial bubbles, where asset prices or the exchange rate—two variables that have important effects on the banking system—can display large swings even without any significant change in fundamentals. One clear implication of this analysis is that even with a good evaluation of the fundamentals, one cannot rule out the possibility of movements in asset prices (or in the triggers). Hence, any thorough evaluation of vulnerabilities in the banking sector also needs to look at the evolution of the financial variables in order to try to detect whether there are worrying patterns.

2.2   Fundamentals' Deterioration vs. Exogenous Shocks

As noted before, the triggers of a crisis are generally related to problems in the fundamentals or to external shocks hitting the economy. While there are models and analytical frameworks that allow policymakers to judge the status of the fundamentals, it is more difficult to anticipate external shocks such as deterioration in the terms of trade, tightening in foreign financing, sudden stops, or sharp swings in foreign currencies. In general, the models that try to determine the vulnerabilities of the economy basically take the external shocks as exogenous and then evaluate the potential ability of the economy to cope with it. Therefore, the status of the fundamentals plays an important role in this stage as they generally determine the impact of an external shock.

Many crises in EMCs have resulted from a combination of a deterioration in economic fundamentals (e.g., fiscal imbalances and current account problems) that made policies unsustainable, even though the trigger of the crisis was often an external event. The

1997/98 Asian financial crisis, for instance, was affected by a fundamental problem—excessive borrowing of EMCs in foreign currency—which was not a threat to individual economies or banking systems as long as exchange rates remained fixed. Once significant pressure on a currency materialized, due to a sudden stop of capital flows, and the central bank was forced to let the exchange rate float, the weak fundamentals meant that depreciation would have large and negative effects on the economy and banking system.

Something similar occurred in the Russian crisis of 1998, when the main problem was a vulnerability in the fundamentals, namely a large amount of short-term debt issued in domestic currency that the government had to rollover at unsustainably high interest rates. While the money kept flowing in, the government managed to refinance it. However, at one point there was a sudden change in expectations as investors wanted to take money out of the system and this triggered a sharp increase in interest rates and a devaluation of the currency that hit the banking sector hard. Once again, the fundamental problems had been in place for some time, but the triggers of the crisis were large changes in interest rates and the exchange rate.

Finally, the Argentine crisis is another example of an event that was caused by a combination of weaknesses in the macroeconomic fundamentals and in external conditions. The domestic problems were twin deficits, large financial requirements relative to the size of the domestic capital market, and a banking system that was highly dollarized and lacked both a lender of last resort and a credible deposit insurance system. In addition, as the country had a fixed exchange rate, it did not have an easy way to adjust to external problems. While the rest of the world was growing and willing to finance the country, the economy managed to grow and even remain financially sound. However, once external conditions changed—the US dollar strengthened in world markets, US interest rates increased, and commodity prices fell—concerns arose about the sustainability of the fixed exchange rate system and about the ability to obtain financing. Soon, Argentina was facing its worst economic and financial crisis in recent history. Once again, the problem was weak fundamentals, which implied vulnerabilities, and the trigger was the change in the external environment.

3.   Systemic Banking Problems

While macroeconomic fundamentals explain many banking stress events, microeconomic issues within the banking sector are also very important in assessing risks and the ability to withstand shocks. Moreover, many times endogenous vulnerabilities within the banking sector have generated or fueled macroeconomic crises even when the macro fundamentals had previously been in good shape. Usually, the feedback effects between banking problems and macroeconomic performance are not negligible.[2]

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[2] Blejer et al. (1997) developed a model showing how an exogenous shock provokes a run on deposits in an initially solvent banking system, creating a solvency crisis which finally leads to a contraction in economic activity.

As is the case with the economy as a whole, the banking sector faces two types of vulnerabilities: one related to individual weaknesses and another related to systemic problems against which an individual bank cannot insure itself.

3.1　Banking Sector Fundamentals

The typical problems of an individual bank arise as a result of weaknesses that can be detected by looking at variables such as:

- low profitability;
- asset and liability structure: currency mismatches, excessive duration, and interest rate mismatches;
- poor management (strategic and/or financial);
- deficient loan origination process and risk management and monitoring; and
- inadequate structure and low efficiency.

When a bank faces important weaknesses in one or more of these areas, which are also the areas that bank supervision agencies typically monitor, it could either close a bank or require corrective measures to address the problems. The important step at this stage, especially if it is an isolated problem, is to take the right policy measures to avoid turning an individual bank's problem into a systemic one.

3.2　Banking Sector Shocks

A second step in assessing the soundness and vulnerabilities of the banking system as a whole is to evaluate the overall bank safety net and its ability to provide financial stability. The main components of this assessment are the (i) quality of prudential regulation and supervision, which is important to ensure that bank managers and owners do not take excessive risk; (ii) rules of the deposit insurance system, which need to at least cover small depositors as a way to avoid bank panics; (iii) resolution system of bank failures, which is important to avoid fiscal losses; and (v) capacity of the central bank to act as a lender of last resort when a bank (or the banking system as a whole) faces liquidity problems.

The existence of the safety net and its design can have an important effect on the stability of the banking system, especially when there are systemic problems that could lead to deposit runs or generalized solvency problems that could affect its performance and incentives.

The typical triggers of systemic banking problems include (i) liquidity problems that can be caused by a run or a bank panic, (ii) a sharp drop in asset prices or a government default that affects the solvency of banks, (iii) a large increase in nonperforming loans (NPLs) that can be a leading indicator of a systemic crisis, and (iv) contagion from abroad.

In order to assess the vulnerability of the banking system to these type of shocks, an analytical framework is needed that combines the traditional bank fundamentals, which

should be designed to assess the banks' solvency and liquidity, with a separate assessment of the system's safety net.

Table 3: Fundamentals and Shocks within the Banking System

Problems	Indicators
Fundamentals	Capital ratios
	Leverage ratios
	NPLs ratios
	NPLs coverage ratios
	Credit and deposit concentration
	Dollarization of assets and liabilities
	Exposure to the public sector
	Sovereign yield Spreads
	Liquidity ratios and gaps
	Access/liquidity of secondary markets
	Central bank credit to financial entities
	Interest rate/duration gaps
	Currency gaps
	ROA
	ROE
	Efficiency ratios
	Credit growth rate
Shocks	Deposit growth rate
	Asset prices
	Government default
	Exchange rate
	NPLs
	Collateral values
	Cross-border exposures

NPLs = nonperforming loans, ROA = return on assets, ROE = return on equity
Source: Centennial Group

4. A Methodology for the Assessment of Banking Risks

This section presents a methodology similar to Mermelstein (2009) to develop an analytical framework that can be used to identify early warning indicators to detect problems in the banking system. This approach combines a traditional macro-financial analysis that considers different macroeconomic and financial scenarios, including the worst-case ones, with stress-test methods that incorporate those scenarios into the banks' balance sheets and evaluates the dynamic evolution of the banking system over a period of time. While this methodology relies on stress-testing practices, deviating from the typical early warning system approach developed by Kaminsky et al. (1999), it generates a vulnerability indicator—projected over time—that is very useful in detecting potential problems in the banking system at an early stage.

From an analytical point of view, we divide the analysis into five successive steps, which can be summarized as follows:

- In the first step, we develop a set of macroeconomic and financial scenarios that is based on a standard macroeconomic framework and attempts to detect main macro-vulnerabilities and their impact on key financial variables. The analysis then centers on adverse macroeconomic scenarios that might take place under plausible—albeit low probability—conditions. These scenarios are developed (see Section 4.1) using judgment based on widely accepted analytical frameworks, historical data, and experience, or by simulating alternative scenarios using Monte Carlo techniques.[3]

- The second step is to model in some detail the relationship that exists between the macroeconomic scenarios, the variables that are defined as the critical ones (the triggers, such as the exchange rate or the interest rates, among others), and the banks' balance sheets and P&L statements both, on impact and over a 12-quarter simulation period (see Section 4.2).

- In the third step there is an evaluation of the evolution over a 12-quarter period of the various risk indicators that are developed in the model—liquidity, market, credit, solvency—under the different macro-financial scenarios (see Section 4.3, 4.4, and 4.5).

- The fourth step involves the selection of appropriate thresholds for each of the risk indicators that are considered in the model in order to detect when they would enter into a "problem zone," which is a range of values indicating whether the system is facing some type of vulnerability. In simple terms, a problem zone is equivalent to determining whether there is a green, yellow, or red traffic light, which is not a simple task in the evaluation of risks in the banking system (see Section 4.6).

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[3] A Monte Carlo application is described in Mermelstein (2009).

- The final step is to determine the number of risk indicators that enter into the problem zone and to estimate the magnitude of the problem. All of this information is then summarized in a single indicator—the vulnerability index.

When run on a regular basis (e.g., monthly), the analysis of the evolution of the vulnerability index would allow for the detection of vulnerabilities on a forward-looking basis. Therefore, the vulnerability indicator provides an early warning of banking problems, which can alert regulatory authorities to implement contingency or mitigation plans in advance.

Figure 1: Methodological Scheme
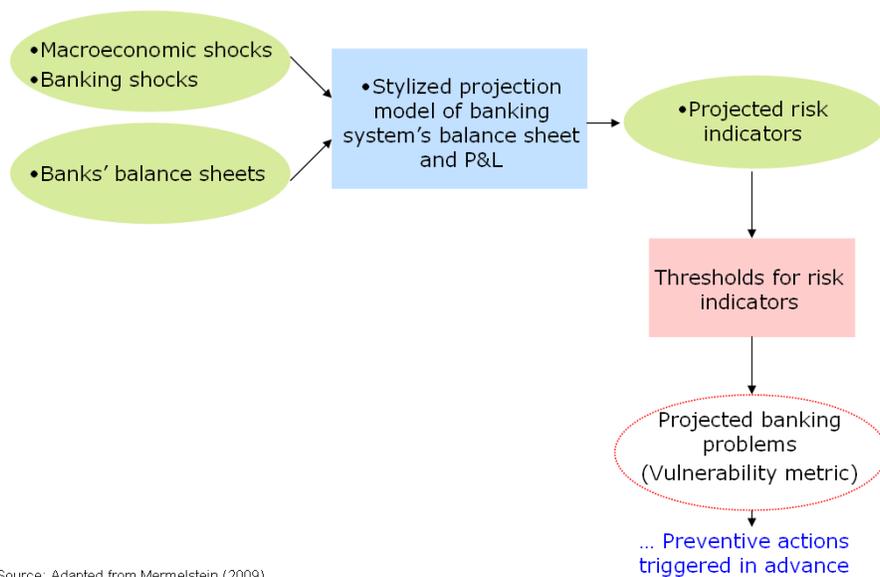
Source: Adapted from Mermelstein (2009)

One of the attractive features of this approach is that it provides a detailed diagnosis of the type of risk that could trigger a stress event by providing a list of the risk indicators that would enter into the problem zone and providing some indication of the extent of the seriousness of the risk.

The effectiveness of this approach depends to a large extent on the ability of the banking supervisor to develop relevant and consistent adverse macroeconomic scenarios, especially when applying judgmental scenarios. As mentioned in section 2, there is a large literature on the subject and policymakers generally have access to models that can provide them with the scenarios needed to run the simulations.

The critical element of our approach is to incorporate into the analytical framework a dynamic and forward-looking stress-testing methodology that will allow the supervisor or regulator to trace the effects of different macroeconomic scenarios on the banking

system over time and detect, in some detail, the type and seriousness of different vulnerabilities.[4]

As in any stress-testing exercise, it is critical to have a good understanding of the type and magnitude of the shocks that the economy might face and how they would impact the banking system. One of the main challenges is the ability to anticipate worst-case scenarios. This view reinforces the need to model macroeconomic and financial shocks, and to identify the relationship that exists between the macro-fundamentals and their effects on the triggers, including some calculation of the quantitative effects (e.g. the magnitude of a currency depreciation in response to capital outflows or a current account deficit).

The following sub-section describes specific details of the proposed methodology.

4.1   Macroeconomic Drivers and Banking Parameters

Macroprudential monitoring requires a thorough examination of macroeconomic and banking events that could potentially affect financial stability, in addition to other issues such as market, compliance, and structural data. Recent crises have demonstrated that while worst-case scenarios are difficult to envision they do take place and their occurrence probabilities have been systematically underestimated. Difficulties in predicting these episodes arise because the evidence is not easy to detect using historical data, while the use of quantitative approaches based on the assumption that the shocks are normally distributed does not give enough weight to the tails of the distribution and, hence, tends to underplay extreme events.

While there has been some progress in the use of quantitative techniques, in an effort to achieve more realism in the scenarios that are considered, including the use of heavy-tailed distributions for macro-financial variables that allow for the inclusion of event risk, there is also a move to consider judgmental scenario building. This could allow enough flexibility in order to incorporate extreme events that might be difficult to include in the quantitative models. In this sense, the methodology presented in this section does not elude the requirement of scenario building as a systematic process.

Regardless of the process through which the different scenarios are built, the inputs that we use are a path of the various drivers that we consider over a 12-quarter period, which are inputs for the model, and a set of parameters that help us to understand some of the main stylized facts of the banking system.

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[4]   Our proposal is based on what is known as "worst-case approach" in stress-testing, which relies on the elaboration of extremely adverse scenarios subject to a minimum plausibility constraint. The alternative approach is that known as the "threshold approach," which tries to estimate the worst scenario that the banking system could withstand before entering into the problems zone (i.e., risk indicators overcoming pre-established thresholds). We keep in line with the former approach and thus still rely on the ability of the macroeconomic committee (supervisor or any other authority) to envision future plausible adverse scenarios. In this sense, our approach does not eliminate human subjectivity, but we do not believe it is possible to do so in any conceivable approach. It is well known that even completely quantitative methods do not eliminate all human subjectivity.

The drivers represent macroeconomic or financial variables such as the rate of growth of GDP or interest rates, while the parameters represent structural or regulatory features of the banking system such as the ratio of administrative expenditures to assets or reserve requirements. Parameters are allowed to change once and for all within the simulation period.

The following table summarizes the drivers and parameters used as inputs by the model.

Table 4: Model Inputs

Driver	Definition
Macroeconomic drivers	
GDP growth	Annual GDP growth rate
Spot exchange rate	Local currency per unit of foreign currency
Expected devaluation	Expected devaluation as implied by forward contracts
Sovereign yield spread	Some measure of country risk (as EMBI or CDS spread)
Var. Public Debt/GDP	Ratio's annual growth rate
Term structure of interest rates:	
Movement size	Change in interest rates (in basic points)
Movement type	Curve movement type: Parallel/Steepening/Flattening
Banking drivers and parameters	
Deposits' growth rate by currency and type	Growth rate of deposits (q-o-q, broken down by currency and demand/term)
Assets' loss given default	Defined as 1—recovery rate in case of default
Administrative expenditures to assets	Ratio
Non-interest income to net interest income	Ratio
Safety net level of the financial system	Intended to reflect public confidence on deposits' convertibility (the ability of banks to refund deposits on request). Ranges between 0 and 1, where 1 reflects full credibility and 0 reflects no credibility.
Reserve requirements by type of deposit	Reserve requirements ratio, broken down by type of deposit.
Weights for risk-weighted assets (RWA) calculation	Used to calculate regulatory capital ratio
Mark-to-market assets	A binary parameter so as to indicate whether assets are marked-to-market or not

CDS = credit default swap, EMBI = Emerging Market Bond Index.
Source: Centennial Group

These drivers and parameters are required as inputs for both the baseline and alternative scenarios. Alternative scenarios are supposed to reflect stress situations to be assessed and contrasted against a baseline. Instead of comparing between only two scenarios, this framework would allow performing simulation analysis to evaluate a continuum of alternative scenarios.

4.2   Stylized Banking System's Balance sheet

The first building block of the stylized model is the balance sheet of the banking system. This balance sheet consists of a set of equations that relate assets and liabilities, as well as income statements and the banking system's capital, with the underlying drivers and parameters depicted in the previous section to determine the balance sheet's value and evolution over time.

This interrelationship between balance sheet components and the set of macroeconomic and banking drivers and parameters is the heart of the approach, and allows for the assessment of impacts of potential macro-financial scenarios on banking stability on a forward-looking basis.

This section seeks to present an intuitive and non-technical description of the model's equations. A complete technical description can be found in Appendix 1.

The starting point to describe the model structure is the stylized balance sheet upon which it is based, as depicted in table 5.

Table 5: Balance Sheet Structure

ASSETS	LIABILITIES
•LIQUID ASSETS	- Deposits
•TRADING BOOK	- Debt
-Private securities	
-Government securities	
•BANKING BOOK	
- Private securities and loans	
-Government securities	BANKS' EQUITY

Source: Centennial Group

Assets are classified by type, maturity, issuer, and denomination currency, according to the given specifications below.

By type:

Assets are divided into three groups. The first group encompasses liquid assets such as cash, deposits at the central bank, and similar assets.

The second group of assets includes those that are held in the trading book. Assets in this book are marked-to-market and thus are subject to capital gains (losses) as market prices change. For instance, public bonds held in the trading book accrue capital losses when interest rates increase.

The third group encompasses assets held in the banking book. These assets are registered at their par (or book) values and do not produce capital gains in response to changes in market prices. These kinds of assets are typically loans and some government bonds that are held within investment accounts.

Liabilities include deposits and debt that are both registered at face values. Thus, no market price changes affect their value.

Finally, banks' equity completes the balance sheet structure and it results as the difference between assets and liabilities. Thus, changes in the value of assets held in the trading book (e.g., due to a movement in interest rates) impact on banks' capital.

By maturity:

Assets and liabilities are broken down according to their maturity in order to model liquidity and interest rate risks. Each asset and liability is assigned to one of the following six maturity buckets:

Maturity buckets (Quarters)					
0	1	2	4	20	40

Each bucket represents a moment in time which, going forward, is expressed in quarters. Thus, if an asset is assigned to bucket #1, it means that the asset matures in 1 quarter. If the asset were assigned to bucket #20, it would mean that the asset would mature in 20 quarters (5 years). Liquid assets and demand deposits are included in bucket zero, meaning immediate liquidity.

The structure of assets and liabilities by maturity bucket is a very important feature of the balance sheet structure in terms of interest rate and liquidity risk. On one hand, a short-term negative impact on interest rates could create a liquidity problem. On the other hand, interest rates on assets and liabilities contracted at fixed interest rates reset only at maturity. This implies that if liabilities have shorter maturities than assets, a parallel increase in the term structure of the interest rate curve will produce a negative impact on

net interest income. This negative impact takes place because higher interest rates will have to be paid on liabilities before a higher interest rate can be earned on assets.

By issuer:

In order to take into account banks' exposure to the public sector, which typically has been a source of vulnerability for the banking systems of emerging market economies, assets are divided between those issued by the private and public sectors.

By denomination currency:

Additionally, assets and liabilities are classified according to their denomination (domestic or foreign currency) so as to consider currency risks.

Table 6 shows a typical dataset of starting values for the model, displaying assets and liabilities broken down according to the full set of classification criteria. Data corresponds to the Argentine banking system (private banks) as of December 2008.

Table 6: Cumulative Balance Sheet of Argentine Private Banks
(December 2008, AR$ Million)

| | Total | Domestic Currency (c=1) | | | | | | | Foreign Currency (c=2) | | | | | | |
| | | Total | Maturity Buckets | | | | | | Total | Maturity Buckets | | | | | |
			0	1	2	4	20	40		0	1	2	4	20	40
Assets	200,607	154,813	48,680	37,562	26,276	26,726	7,267	8,302	45,739	28,269	4,400	5,582	4,682	1,768	1,092
Liquid Assets	34,692	17,869	17,896	---	---	---	---	---	16,822	16,822	---	---	---	---	---
Trading Book	15,366	14,004	---	---	---	---	---	---	1,361	---	---	---	---	---	---
Private Sector	85	44	---	0	0	17	24	3	41	---	0	0	12	25	4
Public Sector	15,281	13,961	---	4,741	5,454	2,487	548	731	1,320	---	0	86	403	489	343
Banking Book	108,292	92,129	---	---	---	---	---	---	---	16,163	---	---	---	---	---
Private Sector	88,220	73,488	---	31,028	17,046	14,441	4,583	6,390	14,731	---	4,400	5,497	4,124	266	444
Public Sector	20,072	18,640	---	1,793	3,776	9,782	2,112	1,177	1,432	---	0	0	143	988	300
Other Assets	42,257	30,811	30,811	---	---	---	---	---	11,447	11,447	---	---	---	---	---
Liabilities	174,192	134,272	84,730	32,365	7,729	8,212	618	618	39,921	22,932	7,555	1,727	1,511	3,098	3,098
Deposits	129,057	107,968	---	---	---	---	---	---	21,089	---	---	---	---	---	---
Demand Deposits	69,959	59,662	59,662	---	---	---	---	---	10,296	10,296	---	---	---	---	---
Term Deposits	59,098	48,306	---	32,365	7,729	8,212	---	---	10,792	---	7,555	1,727	1,511	---	---
Debt	7,432	1,236	---	---	---	---	618	618	6,196	---	---	---	---	3,098	3,098
Other Liabilities	37,704	25,068	25,068	---	---	---	---	---	12,636	12,636	---	---	---	---	---
Capitals	26,415	20,542	---	---	---	---	---	---	5,873	---	---	---	---	---	---

Source: Centennial Group, based on Argentine Central Bank data.

4.3 Dynamics throughout the Simulation Period

Once an initial balance sheet structure is defined and the hypothetical scenarios are built, the model allows for an evaluation of the risks and vulnerabilities associated with them. The interrelationship between macroeconomic and banking drivers/parameters are taken into account by equations (1) to (27) in the model, as detailed in Appendix 1 and depicted in Figure 2.

Figure 2: Model Structure
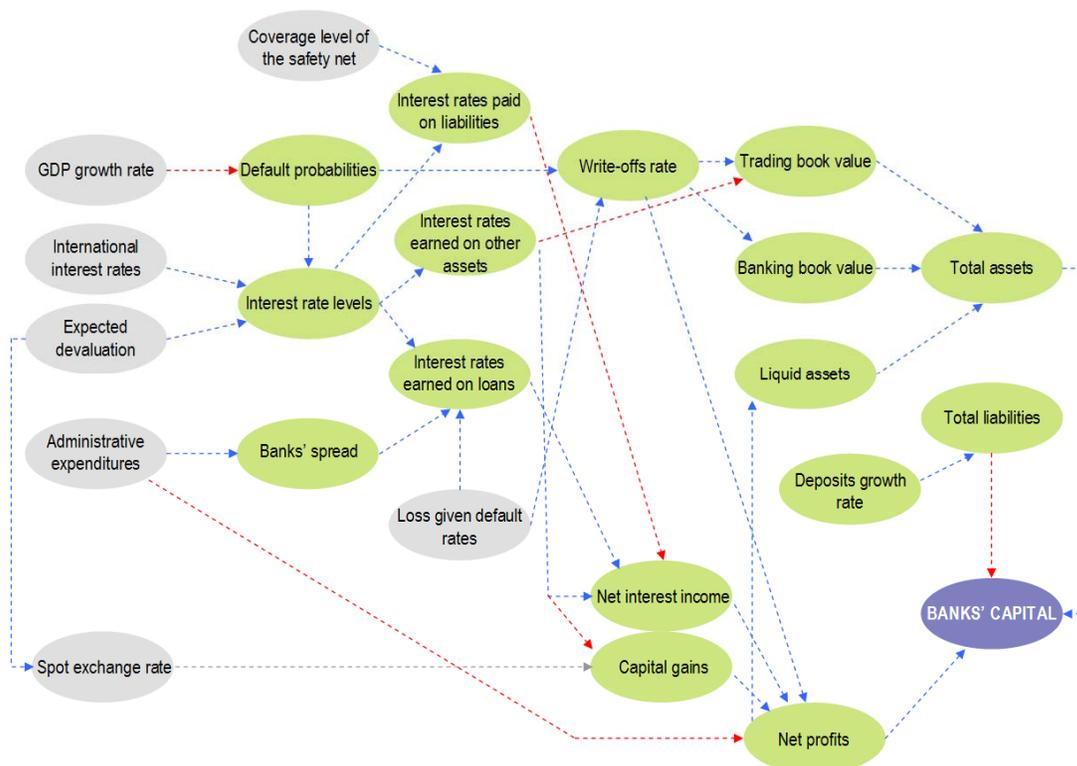
Source: Centennial Group

The rounded grey variables in Figure 2 correspond to drivers or parameters, which are exogenously defined and used as inputs. Each hypothetical scenario produces a different set for these variables.

The variables that are shown in green are the endogenous ones, while the variable representing banks' capital is shown in light purple.

The arrows scheme represented in the figure illustrates the signs of the interrelationships. Blue arrows represent a direct relationship (positive sign), red arrows an inverse relationship (negative sign), and grey arrows an indefinite relationship.

In order to illustrate the model's logic, consider a simple sensitivity analysis where there is a shock that turns GDP growth negative. The red arrow that links the GDP growth rate with default probabilities indicates that when the GDP growth rate drops there will be an increase in default probabilities. This would have two subsequent effects: both interest rates and write-offs would increase. Then, the increase in interest rates would impact both interest rates earned on assets and those paid on liabilities. Following appropriate arrows, it can be seen that there would be (i) a negative impact on the value of assets held in the trading book (capital losses) and (ii) an uncertain impact on net interest income, depending on the duration gap between assets and liabilities. The final step is that the change in the value of assets held in the trading book would reduce the value of assets and net profits would be impacted due to the capital losses and changes in net interest income. All of these effects would have an impact on banks' capital.

The blue arrow connecting net profits and liquid assets shows that the model works adjusting liquid assets so as to balance assets and liabilities period-by-period in response to net profits evolution. That is, if there were net losses, there would be a decrease in liquid assets, while the opposite would hold in the event of net gains.

This simple sensitive analysis is a demonstration of the intricate relationships among variables. In a more realistic exercise (e.g., the case of Argentina given below), the model should be used to analyze complete scenarios, which implies considering consistent changes in the whole set of drivers and parameters.

4.4   Banking Risk Indicators

The impacts of alternative scenarios can be summarized and assessed through the use of typical indicators of banking risk, such as those related with liquidity, interest rate and currency risks. While those indicators are usually based on historical data, the approach in this paper is forward-looking in the pursuit of anticipating the stress scenarios and vulnerabilities that might arise.

While a technical description of these risk indicators is left for Appendix 1, this section discusses the intuition.

Liquidity risk:

We calculate different indicators to assess liquidity problems. On one hand, there are gap indicators, which measure the gap between the amount of assets and liabilities maturing in each of the maturity buckets, while on the other hand we calculate the accumulated gap for the complete simulation period.

The typical banking system shows a negative gap for the shorter maturity buckets. This is usually compensated by long balances for the larger maturity buckets, which results in a positive accumulated gap. This is related to the typical function of the transformation of maturities that banks perform.

There is not a standard way to determine whether or not an accumulated gap is excessive. Banks typically set targets for the accumulated gap at different maturities

according to their own market conditions and the volatility of their funding. For example, a bank could set a -25% percent target as a lower bound for the ratio of the 12-month accumulated gap to total liabilities. This target would constrain asset and liability management (ALM) decisions so as to maintain enough liquidity to ensure that the 1-year accumulated gap is not greater in absolute terms than 25% of total liabilities. Therefore, if total liabilities were USD100, the accumulated gap should not be less than a negative amount of USD25. But for another bank, this target could be too loose if its funding were more volatile since targets and thresholds for the declaration of warnings are not homogeneous when assessing risks. While the model provides the eventual value for the indicator under alternative hypothetical scenarios, deciding whether those values imply vulnerability remains subjective and dependent on the context. This applies not only for liquidity risk indicators, but also for almost every risk indicator.

In addition to gap indicators, it is possible to obtain some additional liquidity ratios from the model. Thus, the usual ratios between liquid assets and liabilities, and between liquid assets and reserve requirements, can be easily calculated. As the lower bounds for the second ratio are fixed by central bank regulations, there is no room for alternative criteria to foresee a liquidity problem. For the former ratio, targets are usually defined according to the market conditions and asset and liability features.

Interest rate risk:

The model provides two usual indicators that help to anticipate eventual vulnerabilities arising from changes in interest rates. The first is known as the "dollar GAP" indicator, which measures the difference between interest rate sensitive assets (RSA) and interest rate sensitive liabilities (RSL). An asset or liability is interest rate sensitive if it is contracted at variable rates or, alternatively, if it matures just after the movement in the term structure. The dollar GAP indicator is useful to anticipate the impacts of parallel movements of the term structure of interest rates on net interest income.

For example, if a bank were to have RSA of USD100 and RSL of USD70, the dollar GAP would be USD30 (i.e., RSA – RSL). This implies that the bank has a long position on interest rates. For that reason, a parallel increase[5] in the term structure of interest rates would benefit the bank by improving its net interest margin.

The second indicator available is known as the "duration GAP," which is the difference between the weighted average duration of assets and liabilities. Consider a bank that has an equal amount of assets and liabilities, with an average duration of assets of 5 years and an average duration of liabilities of 3 years. Thus, the bank shows a duration GAP of 2. That means that the bank would suffer a capital loss in case of a parallel increase in the term structure of interest rates since the duration of its assets is larger

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[5] An increase or decrease in interest rates is considered parallel if the interest rates for different maturities change in the same magnitude and thus the shape of the yield curve does not change. Alternatively, other types of movements are usually known as steepening and flattening. A steepening movement takes place when the rates for long maturities increase and those for short maturities decrease.

than the duration of its liabilities.[6] The magnitude of the loss would be approximately equal to two times (duration gap value) the percentage increase in interest rates multiplied by the value of its assets, according to the following expression:

$$\Delta \text{ Capital} \cong - \text{DurGAP} * [\, \Delta i \, / \, (1+i) \,] * A \tag{1}$$

where i represents the relevant interest rate and A the value of total assets.

Continuing with the example, a 200 basis points (bp) increase in interest rates from an initial value of 10% (assuming A = USD100) would produce a capital loss of:

$$\Delta \text{ Capital} \cong - 2 * [\, 0.02 \, / \, 1.1 \,] * 100 \cong - 3.63 \tag{2}$$

While the two indicators presented in this section are associated with interest rate risk, each allows assessing the risk from a different point of view. While the dollar gap indicator is closely related with the income statement, the duration gap is tied to the balance sheet through capital losses (gains) that could take place due to movements in interest rates.

A neutral position in these gaps would represent a fully hedged position against interest rate risk. Banks usually vary their exposure by taking directional strategies according to their expectations on interest rates prospects. Evaluating whether a certain gap is excessive requires a well-founded outlook on interest rates prospects.

Exchange rate risk:

In order to anticipate the impact of exchange rate movements, the model provides an indicator of currency mismatch. This indicator is calculated as the difference between assets and liabilities denominated in foreign currency as a share of banks' capital. Negative values for this indicator represent a short position in foreign currency, which represents a downside risk in the event of a devaluation of the domestic currency.

For the sake of simplicity, the existence of only one foreign currency is assumed so that there will be only one exchange rate.

Suppose a bank with assets of USD100, of which USD30 are denominated in foreign currency, and with liabilities of USD70, of which USD20 are foreign currency denominated. Thus, the bank shows a 33% currency mismatch (i.e. 10 / 30). The positive sign of the resulting currency mismatch implies a long position in foreign currency, which would benefit banks with capital gains in the event of a domestic currency devaluation.

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[6] Duration approximates a measure of the drop (increase) in an asset price due to an increase (drop) in interest rates. The approximation is valid for small changes in interest rates.

Credit risk:

Among credit risk indicators, the model provides the non-performing loan (NPL) ratio and the write-offs rate (WR). For the sake of simplicity, the former ratio is equaled to default probabilities in this paper. In a more realistic implementation, specific models could be built. As default probabilities depend negatively on the GDP growth rate, so does the NPL ratio (Appendix 3).

The WR also depends on the GDP growth rate, as it is a function of the default probability (PD), but also depends on the loss-given-default rate (LGDR). LGDR measures the share of defaulted debt that will not be recovered. In that sense, it is the effective loss rate in the event of default. Hence, the WR is given as:
WR = PD * LGDR

Exposure to the public sector is another credit risk indicator that can be calculated from the model. This exposure can be an important source of credit risk, especially when public sector finance faces stress periods as still happens cyclically in developing countries. It is measured simply as the ratio of holdings of government issued assets to total assets.

Profitability:

Sustained periods of low or negative profits could end in a solvency problem and even trigger some liquidity pressures when it undermines public confidence.

Several indicators of profitability are derived from the model and provided as outputs. Return on assets (ROA) and return on equity (ROE) are calculated, as well as an indicator of net interest income to total assets. At the same time, the model provides an implicit spread indicator to measure the difference between the implicit interest rate earned on loans and the implicit interest rate paid on deposits.

Additionally, a specific indicator devoted to measure capital gains and losses is provided. Given the volatility usually shown by assets in emerging markets, it is an indicator to monitor closely, especially when an important share of assets is marked-to-market.

Solvency:

In order to foresee eventual problems related to solvency, some indicators are calculated. In addition to the calculation of banks' capital under the baseline and stress scenarios, the ratio of capital to risk weighted assets is provided in order to assess whether it remains above the 8% required by standard regulations. Risk weighted assets is a well known concept within the Basel accord. Instead of a static capital requirement calculated over the value of total assets (e.g., 8% of total assets), the 8% capital requirement is applied on risk weighted assets. Thus, each asset type will be weighted according to its own risk. For instance, a consumer loan would be weighted riskier (e.g., 75%) than a mortgage (e.g., 35%), as the latter would be secured by collateral.

In addition, a measure of leverage is provided by another indicator, which measures the ratio of banks' debt to equity. The lower this indicator is the more capitalized the banking system and the stronger the solvency position of the system.

4.5   Relationship between Inputs and Outputs

Thus far, we have described the macroeconomic and banking drivers and parameters used as inputs by the model, the interrelationships among model variables, and the risk indicators that can be calculated from the model.

The purpose of this section is to describe the qualitative relationships among the inputs of the model (macroeconomic and banking drivers) and the outputs (risk indicators). A more rigorous description is included in Appendixes 1 and 2.

However, the interrelationships do not always have the same sign since they depend on the balance sheet structure. For instance, an increase in the nominal exchange rate could have a positive or negative initial impact on net worth, depending on whether the banking system initially has a net long or short position in foreign currency. Likewise, an increase in interest rates would imply a capital loss if the banking system had a long position in long duration instruments. Nevertheless, the overall impact of a change in interest rates on the income statement will also depend on the effects that the higher interest rates eventually have on net interest income, which to some extent can compensate the capital loss. Thus, the overall effects of changes in the critical macroeconomic and financial variables on the banking system depend on the initial structure of the balance sheet.

For illustrative purposes, the matrices that follow present the signs of the impact that changes in the inputs (e.g., GDP growth, interest rates, and exchange rates) have on the outputs of the model for the particular case of the group of Argentine private banks as of December 2008. As our simulation period encompasses 12 quarters, the first matrix shows the immediate impact on outputs of changes in inputs (short-term impacts), while the second matrix shows the impact at the end of 12 quarters (long-term impacts).

Short-Term Impacts

OUTPUTS		INPUTS								
Risk type	Indicator	Interest rates (parallel change)	GDP growth	Sovereign yield spread	Spot exchange rate	Future exchange rate	Adm. expenditures	Private sector deposits (var. q-o-q)	Public debt / GDP (var. q-o-q)	Safety net coverage
Liquidity risk	Liquidity GAPs	(-)	---	(+)	(+)	(+)	(-)	(-)	(-)	---
	Liquidity ratios	---	---	(+)	(+)	---	(-)	(+)	(-)	---
Interest rate risk	Dollar GAP	---	---	---	---	---	---	(-)	(+)	---

OUTPUTS		INPUTS								
Risk type	Indicator	Interest rates (parallel change)	GDP growth	Sovereign yield spread	Spot exchange rate	Future exchange rate	Adm. expenditures	Private sector deposits (var. q-o-q)	Public debt / GDP (var. q-o-q)	Safety net coverage
Exchange rate risk	Duration GAP	(-)	---	(-)	(-)	(-)	---	(-)	(+)	(-)
	Currency mismatch	---	---	---	(+)	---	---	---	---	---
Credit Risk	NPLs	---	(-)	---	---	---	---	---	---	---
	Write-offs ratio	(+)	(-)	---	(-)	---	---	---	---	---
	Exposure to the public sector	(-)	---	(-)	(-)	(-)	(+)	(-)	(+)	---
Profitability	ROA	(-)	---	(+)	(+)	(-)	(-)	(-)	(-)	(+)
	ROE	(-)	---	(+)	(+)	(-)	(-)	(-)	(-)	(+)
	Net interest income / Assets	---	---	(+)	(-)	---	(+)	(-)	(+)	(+)
	Implicit spread	---	---	(+)	(-)	(+)	(+)	(+)	(-)	(+)
	Net capital gains	(-)	---	(-)	(+)	(-)	---	---	(-)	---
Solvency	Capital	(-)	---	(+)	(+)	---	(-)	---	(-)	---
	Leverage	(+)	---	(-)	---	---	(+)	(+)	(+)	---
	Capital / RWA	(-)	---	(+)	(+)	---	(-)	---	(-)	---

Long-Term Impacts

OUTPUTS		INPUTS								
Risk type	Indicator	Interest rates (parallel change)	GDP growth	Sovereign yield spread	Spot exchange rate	Future exchange rate	Adm. expenditures	Private sector deposits (var. q-o-q)	Public debt / GDP (var. q-o-q)	Safety net coverage
Liquidity risk	Liquidity GAPs	(+)	---	(+)	(+)	(+)	(-)	(-)	(-)	---
	Liquidity ratios	(+)	---	(+)	(-)	(+)	(-)	(+)	(-)	(+)
Interest rate risk	Dollar GAP	---	---	---	---	---	---	(-)	(+)	---

		OUTPUTS			INPUTS					
Risk type	**Indicator**	**Interest rates (parallel change)**	**GDP growth**	**Sovereign yield spread**	**Spot exchange rate**	**Future exchange rate**	**Adm. expenditures**	**Private sector deposits (var. q-o-q)**	**Public debt / GDP (var. q-o-q)**	**Safety net coverage**
	Duration GAP	(-)	---	(-)	(-)	(-)	---	(-)	(+)	(-)
Exchange rate risk	Currency mismatch	(-)	---	(+)	---	(-)	(-)	---	(+)	(+)
Credit Risk	NPLs	---	---	---	---	(+)	---	---	---	---
	Write-offs ratio	(-)	---	(-)	---	---	---	---	---	---
	Exposure to the public sector	(-)	---	(-)	---	(-)	(+)	(-)	(+)	---
Profitability	ROA	(+)	---	(+)	---	(+)	(-)	(-)	(-)	(+)
	ROE	(+)	---	(+)	---	(+)	(-)	(-)	(-)	(+)
	Net interest income / Assets	(+)	(+)	(+)	---	(+)	(+)	(-)	(+)	(+)
	Implicit spread	(+)	(+)	(+)	---	(+)	(+)	(+)	(-)	(+)
	Net capital gains	---	(+)	(-)	---	---	(+)	(-)	(-)	---
Solvency	Capital	(+)	---	(+)	---	(+)	(-)	(-)	(-)	---
	Leverage	(-)	---	(-)	---	(-)	(+)	(+)	(+)	---
	Capital / RWA	(+)	---	(+)	---	(+)	(-)	(-)	(-)	---

GDP = gross domestic product, etc.
Note: (+) indicates a positive dependence, (-) indicates an inverse dependence, and --- represents no direct dependence.
Columns represent inputs and rows represent banking risk indicators that result as outputs from the model.

Source: Centennial Group

It should be noted that these matrices represent what would have happened in the specific case of the balance sheet structure that the group of Argentine private banks displayed as of December 2008. An alternative balance sheet structure would produce significantly different matrices.

To illustrate how to use these matrices, assume a shock on interest rates that shifts the whole yield curve upwards. This shock is represented by the first column of inputs (interest rates – parallel change). The matrices above provide the impact signs that would be observed.

For the case of liquidity risk, the sign is negative in the short-term (for the case of liquidity gaps, but not for the liquidity ratios) and it turns positive as time goes by. This is because the increase in interest rates has an immediate negative impact on net interest income, as the liquidity gaps are negative for short-term maturity buckets. As assets mature and are reinvested, the bank starts to benefit from the higher interest rates that it earns on the new assets. Profits eventually improve and, hence, they present a positive sign in the long-run after having been negative immediately after the interest rate shock.

In addition, the increase in interest rates also produces immediate capital losses due to the interest rate shock as the present value of those assets that are held in the trading book declines. However, those losses are offset once net interest income increases in time. This dynamic is reflected by the negative sign for net capital gains in the matrix for the short-run impacts, and by the null sign in the long-run matrix.

There is a good deal of information that the model provides in giving a complete qualitative description of the impacts that the different drivers and parameters can have on the banking risk indicators.

4.6   Defining Thresholds for Risk Indicators

There is not a unique or best recipe on how to establish thresholds so as to determine admissible values for risk indicators. When the indicator is part of the regulation parameters (e.g., capital adequacy ratio [CAR]), it is easier as the threshold is already established by the central bank or included in the Basel principles. For the case of the CAR, the floor is 8%, so the selected threshold should be 8% or above.

But when we look at risk indicators that are not subject to direct regulation, establishing an appropriate threshold becomes a more subtle task. The final purpose is to define a cut-off that best discriminates between crises or problem times from tranquil times. The examination of historical information is usually an appropriate way, which can be done by simple inspection or by more sophisticated analysis. The literature provides some options in this sense based on the minimization of the noise-to-signal ratio (Kaminsky and Reinhart, 1999) or some other variants (Demirgüç-Kunt and Detragiache, 1997; and Borio and Drehmann, 2009).

Alternatively, in cases where historical information is lacking, one could preset the thresholds based on judgmental analysis.

4.7 Accounting for Projected Vulnerabilities as an Early Warning Indicator

As in Mermelstein (2009), the last step to complete our methodology involves summarizing the projected vulnerabilities in one metric so as to use it as an early warning indicator.

There are several different ways to add up the projected values for the risk indicators, most of which are straightforward. We suggest one of them, summarized in the following steps:

   (i) detect risk indicators entering into the problem zone under the projected scenario;
   (ii) for those indicators, calculate the (squared) distance between their projected values from their respective thresholds; and
   (iii) add up all those distances.

The sum can be understood as the value for our vulnerability indicator, which is a pure number without a meaning in itself. Its usefulness derives from its use as a metric for chronological comparisons. This requires establishing a baseline period and then calculating it on a regular basis in order to measure its variation.

As shown in the application for Argentina in section 5, during the years 2000 and 2001, before the crisis that took place at the end of 2001, our indicator showed a significantly higher mark than was observed for 1997 or 1998, which were 2 years of tranquil times. Therefore, the indicator could have been used to help to foresee that some vulnerabilities were building up within the banking system.

An increase in the indicator, however, does not necessarily anticipate a crisis. What the increase means is that the system is losing soundness and its ability to tackle shocks. Of course, there are some feedback effects and a huge increase in the indicator might signal an impending crisis episode in the form of a banking crisis.

4.8 Scope and Limitations of this Exercise

This section has presented a conceptual illustration of a methodological approach that seeks to anticipate banking vulnerabilities. By its nature, it is very general and it requires a number of refinements in order to be applied to specific banking systems or to asses the vulnerability of individual banks. For example, the number of maturity buckets that are considered in a specific case need to be adapted to the actual structure of assets and liabilities of the system to be analyzed. There is a need to estimate or calibrate alternative specific models for default probabilities based on historical data from the economy and of the banking system under study. Instead of assuming two scenarios (base and alternative), stochastic simulation could be used to provide a continuum of alternative scenarios and cross-credit exposures among entities, while second-round and other effects related with a bottom–up approach could complement this top–down methodology.

This approach was followed because the purpose of this paper is mainly to provide a conceptual framework to develop early warning indicators of financial vulnerability, as opposed to providing a detailed model of the financial system for a specific country that quantifies these measures in a more precise way. Nevertheless, the analysis that we provide here should also be helpful in designing and implementing specific models as needed.

5. The Model in Action: The Case of Argentina

This section develops an illustrative example of the proposed methodology for the case of the group of Argentine private banks. The first part is devoted to simulate alternative scenarios, starting with the banks' balance sheet as of December 2008 to gain familiarity with the projection model.

In the second part, a specific scenario is applied chronologically to the successive banks' balance sheets, starting in 1997 and ending in late 2001 just before the onset of the crisis. The objective is to show how well a vulnerability indicator built with our methodology would have performed in anticipating the crisis as an early warning indicator.

5.1 Scenario Simulations

The starting point is the balance sheet for the group of Argentine banks as of December 2008.

Starting values

As described in Section 4, assets and liabilities in the balance sheet are broken down according to several criteria:

- Currency: indicates whether assets and liabilities are denominated in domestic or foreign currency.
- Maturity buckets: each asset and liability is assigned to the corresponding bucket, according to its maturity.
- Assets are broken down (i) according to their type, (ii) between liquid assets, (iii) assets held in the trading book, (iv) assets held in the banking book, and (v) other assets. Additionally, assets are divided into those issued by the private sector and those issued by the public sector whenever applicable. Other assets are those that are not of first importance in performing risk assessment exercises, such as fixed assets.
- Liabilities are split between deposits, debt, and other liabilities. Deposits are divided into demand and time deposits. Other liabilities include all liabilities that are not part of the previous categories.

Table 7: Cumulative Balance Sheet of Argentine Private Banks
(December 2008, AR$ million)

	Total	Domestic Currency (c=1)							Foreign Currency (c=2)						
		Total	Maturity Buckets						Total	Maturity Buckets					
			0	1	2	4	20	40		0	1	2	4	20	40
Assets	200,607	154,813	48,680	37,562	26,276	26,726	7,267	8,302	45,739	28,269	4,400	5,582	4,682	1,768	1,092
Liquid Assets	34,692	17,869	17,896	---	---	---	---	---	16,822	16,822	---	---	---	---	---
Trading Book	15,366	14,004	---	---	---	---	---	---	1,361	---	---	---	---	---	---
Private Sector	85	44	---	0	0	17	24	3	41	---	0	0	12	25	4
Public Sector	15,281	13,961	---	4,741	5,454	2,487	548	731	1,320	---	0	86	403	489	343
Banking Book	108,292	92,129	---	---	---	---	---	---	---	16,163	---	---	---	---	---
Private Sector	88,220	73,488	---	31,028	17,046	14,441	4,583	6,390	14,731	---	4,400	5,497	4,124	266	444
Public Sector	20,072	18,640	---	1,793	3,776	9,782	2,112	1,177	1,432	---	0	0	143	988	300
Other Assets	42,257	30,811	30,811	---	---	---	---	---	11,447	11,447	---	---	---	---	---
Liabilities	174,192	134,272	84,730	32,365	7,729	8,212	618	618	39,921	22,932	7,555	1,727	1,511	3,098	3,098
Deposits	129,057	107,968	---	---	---	---	---	---	21,089	---	---	---	---	---	---
Demand Deposits	69,959	59,662	59,662	---	---	---	---	---	10,296	10,296	---	---	---	---	---
Term Deposits	59,098	48,306	---	32,365	7,729	8,212	---	---	10,792	---	7,555	1,727	1,511	---	---
Debt	7,432	1,236	---	---	---	---	618	618	6,196	---	---	---	---	3,098	3,098
Other Liabilities	37,704	25,068	25,068	---	---	---	---	---	12,636	12,636	---	---	---	---	---
Capitals	26,415	20,542	---	---	---	---	---	---	5,873	---	---	---	---	---	---

Source: Centennial Group, based on Argentine Central Bank data.

The table shows that the system had total assets of AR$200.6 billion, of which AR$154.8 billion was denominated in domestic currency and AR$45.8 billion in foreign currency. Total liabilities amounted AR$174.2 billion, of which AR$129 billion was deposits, and net worth amounted AR$26.4 billion.

In addition to balance sheet values, there is a set of parameters and market values required as starting values. It consists of:

- International zero coupon rates corresponding to the maturity buckets of the model.
- Default probabilities corresponding to the average probability of default in the economy, being valid in the initial period and broken down by currency. This is a simplification that could be avoided by entering different default probabilities according to asset type and maturity.

For simulations, the following values were entered:

Spot Interest Rates—US (Annual Rates, %)	
Quarters	**%**
1	0.322%
2	0.383%
4	0.607%
8	1.259%
12	1.897%
20	2.753%
40	3.738%

Domestic Probabilities	
Domestic currency	6%
Foreign currency	9%

Macroeconomic and banking drivers

In addition to the starting values, a set of macroeconomic and banking drivers defining a baseline and an alternative (e.g., stress case) scenario is required.[7] The simulation period encompasses 12 quarters, as well as the time length for drivers' projections. While in this paper a set of values are judgmentally defined, the dynamic process underlying the evolution of drivers could be treated with usual stochastic models describing the evolution of financial variables (e.g, Vasicek,[8] Cox–Ingersoll–Ross,[9] or other models[10] for interest rates).

Macroeconomic drivers include the evolution over 12 quarters for the following variables:

- spot exchange rate, defined as units of local currency per unit of foreign currency;
- expected devaluation, as implied in futures markets;
- sovereign yield spread, as implied in credit default swaps or, alternatively, as measured by emerging market bond indices (EMBI);
- annual percentage change in the ratio of public debt to GDP; and,
- GDP growth rate, measured as an annual percentage change.

The following table shows the baseline assumptions for the case of Argentina:

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[7]   If a stochastic simulation approach were followed, at this point the parameters describing the probability distributions of drivers and the correlations among them should be introduced.

[8]   Vasicek, O. 1977. An Equilibrium Characterization of the Term Structure. Journal of Financial Economics. Vol. 5. pp. 177–188.

[9]   Cox, J.C.; J.E. Ingersoll; and S.A. Ross. 1985. A Theory of the Term Structure of Interest Rates. Econometrica. Vol. 53. pp. 385–407.

[10] Svoboda, S. 2004. Interest Rate Modeling (Finance and Capital Markets). Palgrave Macmillan.

Table 8: Baseline Macroeconomic Assumptions

Quarter	Current Exchange Rate	Expected Devaluation	Sovereign Yield Spread	Public Debt / GDP	GDP Growth
		var. q-o-q %	%	var. y-o-y %	var. y-o-y %
0	3.85	3.0%	10.0%	0.0%	2.0%
1	3.97	3.0%	10.0%	0.0%	-2.5%
2	4.08	3.0%	10.0%	0.0%	-2.5%
3	4.21	3.0%	10.0%	0.0%	-2.5%
4	4.33	3.0%	10.0%	0.0%	-2.5%
5	4.46	3.0%	10.0%	0.0%	1.5%
6	4.60	3.0%	10.0%	0.0%	1.5%
7	4.74	3.0%	10.0%	0.0%	1.5%
8	4.88	3.0%	10.0%	0.0%	1.5%
9	5.02	3.0%	10.0%	0.0%	3.0%
10	5.17	3.0%	10.0%	0.0%	3.0%
11	5.33	3.0%	10.0%	0.0%	3.0%
12	5.49	3.0%	10.0%	0.0%	3.0%

Source: Centennial Group

On the banking side, assumptions have to be made about the evolution of deposits. The quarter-over-quarter growth rate of deposits is required, divided by the type of deposit (demand or term) and currency (domestic or foreign). As for other drivers, specific models can be implemented to forecast the evolution of deposits.

In this case, deposits are assumed stable for the baseline scenario.

Structural parameters

Finally, the following parameters are required for each scenario:

- administrative expenditures to assets;
- LGDR: a measure ranging between 0 and 1 of the effective loss in case of default, after considering the percentage of the exposure at default that is recovered;
- non-interest income to net-interest income: a measure indicating the percentage of net revenue that comes from fees and concepts other than interests;
- safety net in the financial system: a quantitative representation of public confidence in the convertibility of deposits, ranging between 0 and 1, where 1 represents full confidence and 0 signals no confidence;
- Weights for RWA calculation; and,
- Reserve requirements, measured as ratios of demand and time deposits.

For simulations, the following parameters are assumed:

Parameter	
Loss Given Default	35.0%
Administrative Expenditures to Assets	7.0%
Non Interest Income to Net Interest Income	66.7%
Safety Net Level	85.0%
Reserve requirements	
Current & Savings Accounts	19.0%
Term Deposits	15.0%

Weights for RWA Calculation	Maturity Buckets				
	1	2	4	20	40
Claims on Private Sector	85%	85%	85%	85%	50%
Claims on Public Sector	100%	100%	100%	100%	100%

Source: Centennial Group

Having defined required parameters and baseline dynamics of macroeconomic and banking variables, the next step is to define alternative scenarios. Three alternative scenarios were assessed, with each scenario progressively gaining in realism. Each of these scenarios are presented and discussed below.

Alternative Scenario 1

Assumptions:

- Devaluation of domestic currency represented by a 40% increase in the spot exchange rate during the first simulation year, increasing by 12.5% per year in subsequent years.
- One-time 500 bp parallel increase of interest rates in quarter 1.
- Contraction of GDP by 5% over the first two simulation years, followed by GDP growth of 0% from the third year on.

Results:

Argentine private banks entered the assessment showing a positive mismatch in foreign currency. A devaluation of the domestic currency increases the long position in foreign currency during some quarters (until about the fifth quarter), when it starts to decrease again as the net position in domestic currency recovers weight progressively due to the fact that net revenues are in the domestic currency.

Currency Mismatch (% of Net Worth)

Net Capital Gains (% of Assets)
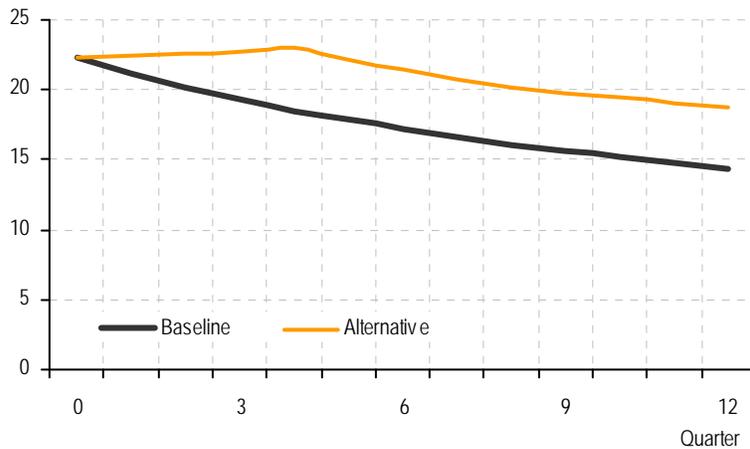
On the stocks side, the devaluation impacts banks balance sheets positively due to their starting long position in foreign currency. It represents a capital gain that takes effect immediately after the exchange rate increase.
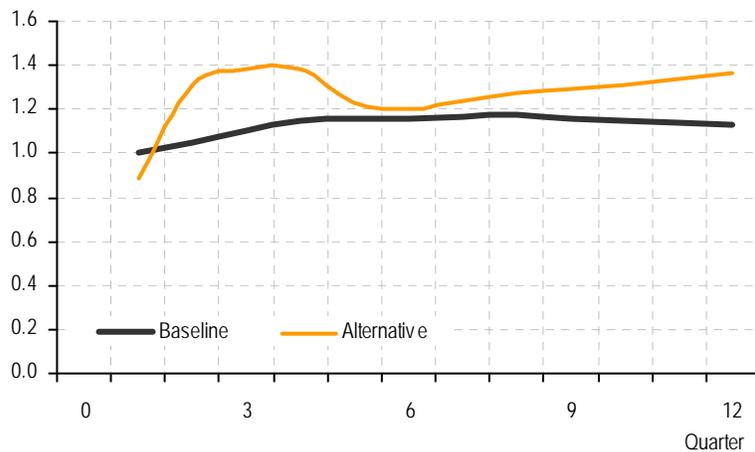
However, the increase in interest rates impacts negatively on banks' capital in small amounts as the bulk of assets is held in the banking books—54% of total assets compared to 8% in the case of assets held in the trading book—so that they are not marked-to-market on a regular basis. This result would be different if more assets were held in the trading books (e.g., alternative scenario 3).

Once assets mature and interest rates reset over time, the assumed rise in interest rates generates an increasing implicit spread. This effect produces additional profits over time

so that the net interest income, as well as the ROA, is always greater than in the baseline scenario. In addition, as net profits are not distributed and accumulated as liquidity (as a simplifying assumption), every indicator measured as a ratio to assets (e.g., ROA) tends to decline over time.
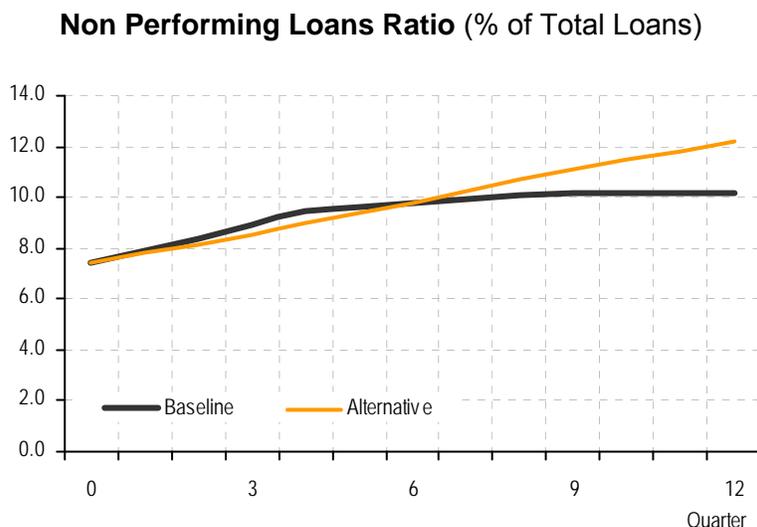
Implicit Spread (%)
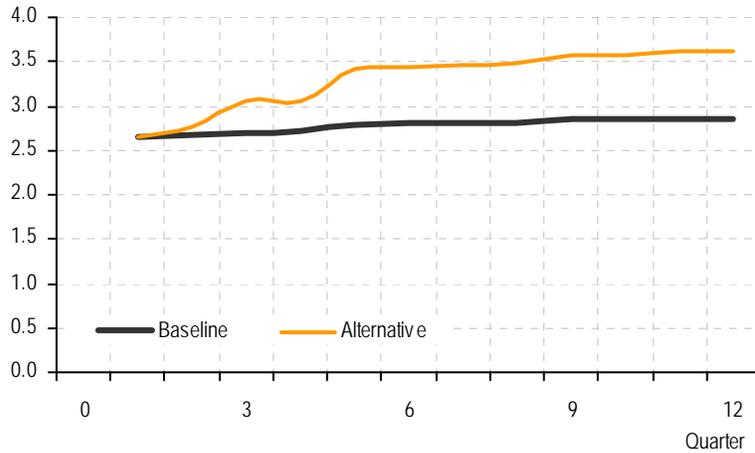
Return on Assets (% of Assets)
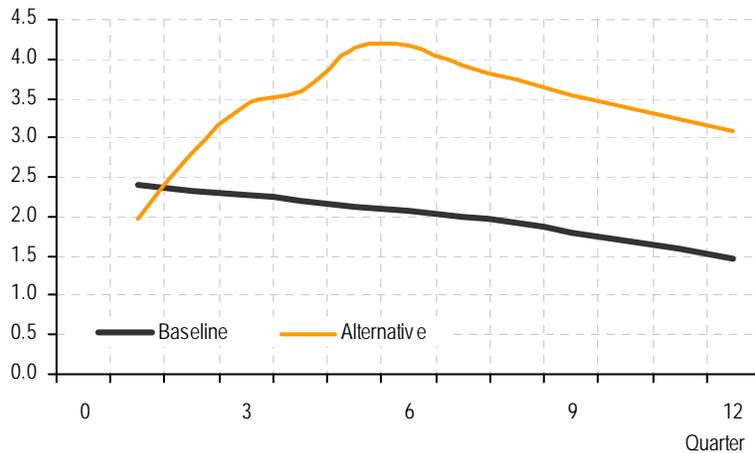
A contraction in GDP does not produce an impact as significant as those described previously. Nevertheless, it generates an increase in credit problems, as reflected by a growing rate of NPLs and write-offs.

Non Performing Loans Ratio (% of Total Loans)

Under this scenario, there are no problems with capitalization. Conversely, banks' capital increases as profits do.

On the liquidity side, there are no negative effects under this scenario, as deposits are not assumed to change at this stage. This probably does not seem realistic enough though given that a currency devaluation with increasing interest rates and a GDP contraction should trigger a drop on deposits. For this reason, the following alternative scenario incorporates a drop in deposits.

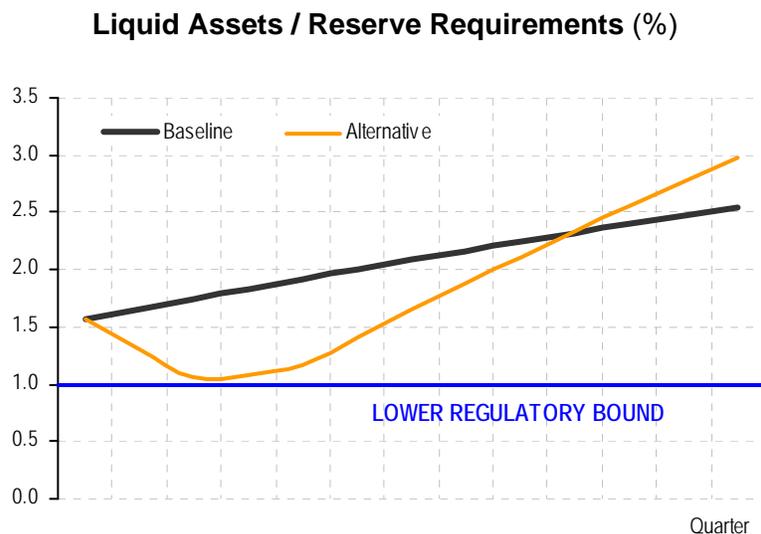**Alternative Scenario 2:**

Assumptions:

- Devaluation of domestic currency represented by a 40% increase in the spot exchange rate during the first simulation year, increasing by 12.5% per year in subsequent years.
- One-time 500 bp parallel increase of interest rates in quarter 1.
- Contraction of GDP by 5% over the first two simulation years, followed by GDP growth of 0% from the third year on.
- Decline of 25% in all types of deposits over the first simulation year, followed by 0% growth from the second year on.

This scenario incorporates the previous the assumption of a 25% drop in deposits during the first year. Specifically, it assumes a 9.5% drop during the first two quarters, 5% drop in the third quarter, and 3.5% drop in the fourth quarter.

For the sake of simplicity, no distinction is made between foreign- and local-currency-denominated deposits, or between demand and time deposits. Nevertheless, 68% of

time deposits mature during the first simulation quarter (maturity bucket 1), hence, for simulation purposes, they do not perform very differently from demand deposits.

What is seen under this new scenario is that the liquidity position reaches the lower admissible bound, at least from a regulatory point of view, as the ratio of liquid assets to reserve requirements displays a minimum near 1 during quarters 3 and 4 of the first simulation year. This could indicate a situation in which some liquidity assistance is needed, at least in small amounts. If properly managed and further negative effects are avoided, the situation would tend to improve from going forward as the balance sheet structure, in combination with the increased interest rates, would help to increase profits and rebuild liquidity.

Liquid Assets / Reserve Requirements (%)

**Alternative Scenario 3:**

Assumptions:

- Devaluation of domestic currency represented by a 40% increase in the spot exchange rate during the first simulation year, increasing by 12.5% per year in subsequent years.
- One-time 1000 bp parallel increase of interest rates in quarter 1.
- Contraction of GDP by 5% over the first two simulation years, followed by GDP growth of 0%.
- Decline of 25% in all types of deposits over the first simulation year, followed by 0% growth.
- Marked-to-market public bond holdings.

Under this scenario, adding the assumption of mark-to-market government bonds, which are otherwise held in investment accounts, allows for a gain in realism and an

assessment of the actual economic condition of the system independent of accounting practices. To stress the effect, interest rates are assumed to jump 1000 bp.

While the initial impact of changing from marking-to-book to marking-to-market with respect to public bonds could be either positive or negative depending on current market values, the assumption is that those holdings were always accounted at market prices so as to assess the eventual impact of interest rate movements over the simulation period. Therefore, by moving the holdings from the banking to the trading book at the beginning of the exercise, the impact of the 1000 bp parallel increase in interest rates is evaluated.

The increase in interest rates once public bonds are marked-to-market generates a much more important negative impact in terms of capital losses as the holdings decrease in value.

Net Capital Gains (% of Assets)
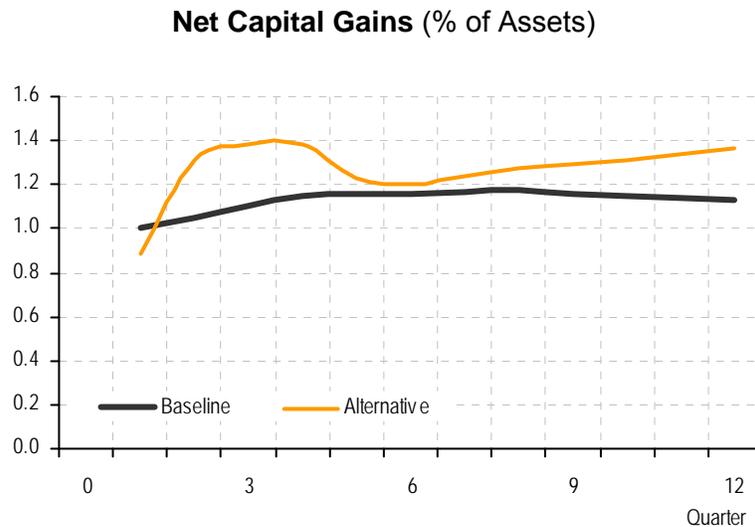
After the initial capital loss, a subsequent devaluation of the local currency produces new capital gains that are even greater than in the base case scenario since the devaluation is larger.

Additionally, increased interest rates contribute to a larger net interest rate margin and, thus, to profitability and capital increases over time.

Return on Assets (% of Assets)
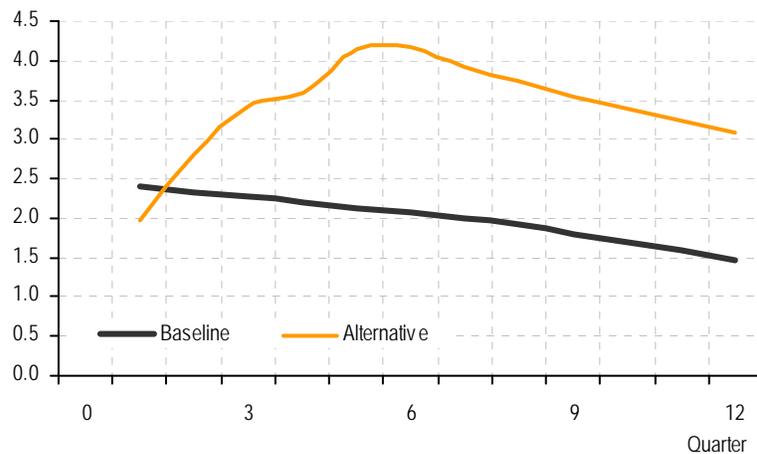
Banks' Capital (AR$ million)
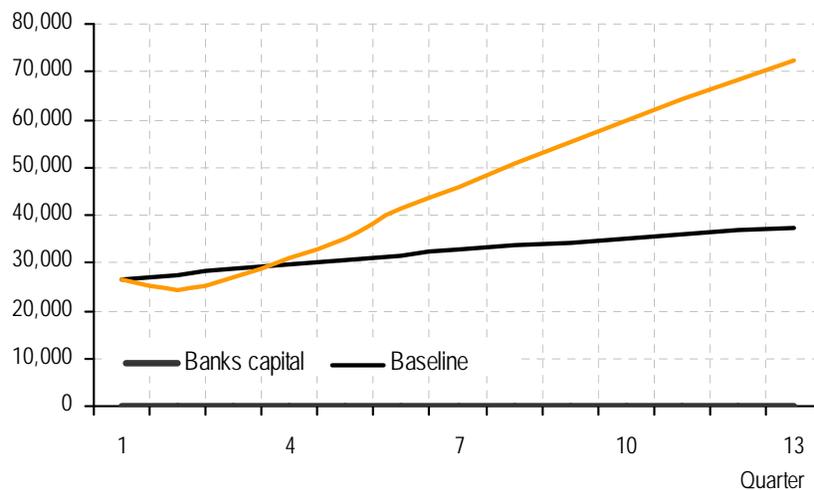
Regarding liquidity, the situation would remain the same as in scenario 2 since marking–to-market assets does not generate cash flow changes. That is, the assumed deposit outflows would produce a very tight liquidity situation and temporary assistance from the central bank would likely be needed.

The results show a somewhat paradoxical situation in which an extremely adverse scenario that generates an initial negative impact would eventually produce a significant improvement.

These results need to be interpreted with caution. They show a banking system that would become extremely vulnerable during the first simulation year as liquidity problems arise in combination with a strong decline in profits. The subsequent improvement would

only take place if the period of huge vulnerability were successfully overcome and it would mostly likely require sound policies on the part of the central bank.

The model shows that this adverse scenario would only have transitory effects if the right policy actions are taken to overcome it. In such a scenario, the adverse impacts would fade out relatively quickly (2 years), suggesting that the balance sheet structure would essentially remain healthy in the long run under current assumptions. However, at the same time, the model is showing that any lack of policy responses slip during the first year could lead to a disruptive situation.

5.2   The Methodology and Early Warnings of the 2001 Crisis in Argentina

The proposed methodology was applied to the case of Argentina in an exercise that evaluated the evolution of the banking system from 1997 to mid-2001, which is just before the peak of the banking crisis. The purpose of the exercise is to show the evolution of the vulnerability indicator starting in a relatively tranquil year and ending in the immediacy of the 2001 crisis. As will be seen, the indicator remained relatively flat during the first 2 years, except for a short period in 1998 during the Russian debt crisis. Beginning in early 1999, the indicator showed a significant upward trend, suggesting that financial vulnerabilities were starting to build up. In addition, we will show that an analysis of the evolution of the indicator's subcomponents would be very useful to understand the different sources of vulnerability that were taking place prior to the crisis.

The methodology that was used for the Argentine experience can be summarized as follows:

- We collected monthly data from January 1997 to May 2001[11] for the group of private banks, as in the previous section.
- For each month, we simulate the trajectories for the risk indicators over a 12-quarters period under the same assumptions applied in alternative scenario 3. The scenario was held constant to make the projections and the risk indicators comparable along time.
- In line with the methodology developed in section 4, in the case of Argentina we consider that the five critical risk indicators to measure the vulnerability of the banking system during this period were:

    o   currency mismatch,
    o   profitability,
    o   liquidity,
    o   capital adequacy, and
    o   exposure to the public sector.

We then defined a threshold for each indicator in order to separate the tranquil from the problem zone. The threshold for the liquidity risk indicator—liquid assets to reserve

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[11] We shortened the period by ending in May 2001 instead of December 2001 due to data availability.

requirements—was defined based on whether the banks were complying with the regulatory requirements, while the remaining thresholds were chosen in a judgmental way by looking at their historical behavior and analyzing how they had performed during periods of financial turmoil. The following table summarizes the selected thresholds.

Table 9: Thresholds for the critical risk indicators

Indicator	Definition	Threshold value	Threshold type
Exposure to the public sector	Claims on the public sector / Total assets	15%	Cap
Capital adequacy (Leverage)	Total assets / Net worth	x 10	Cap
Currency risk	(Assets – 1.4 * Liabilities) / Net worth[12]	- 200%	Floor
Profitability	Return on assets	0%	Floor
Liquidity risk	Liquid assets / Reserve requirements	x 1	Floor

Once the projected values were calculated for each indicator, we determined which ones entered into their respective problem zones. For the indicators in the problem zones, we calculated their squared values in order to neutralize the effect of their signs[13] and added them over the 12-quarters simulation period. Finally, we normalized them as an index number by defining the average value for the year 2000 as a base period.

As a final step, the index numbers for each indicator were added up into a single measure, which we defined as the vulnerability index. In this case, we weighted equally all the index numbers. Alternatively, different weights could be assigned to each. This single index of banks' vulnerability summarizes our assessment of the banking system. By comparing it along the time series, we can observe the behavior of the indicator and its ability to function as an early warning indicator.

In what follows, we present a short illustrative example of how we made the calculations. Assuming a simulation span of 4 periods, the next table shows a hypothetical projection for the selected risk indicators.

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[12] By multiplying liabilities by 1.4, we provide a more restrictive measure of currency risk so as to reflect the particular situation of Argentina during the final years of the convertibility period in which borrowers' income was denominated in domestic currency while banks' deposits were denominated in foreign currency. Even when typical mismatch indicators would have showed a comfortable figure for the banks, the mismatch was located in borrowers' balance sheets.

[13] By this transformation, we ensure that for every indicator a higher value implies a higher vulnerability measure. Even for the case of the liquidity risk indicator, as we compute it as the squared value of the liquidity ratio (a number between 0 and 1) minus 1.

Table 10: Hypothetical Projection for the Selected Risk Indicators

	Date #1	Date #2	Date #3	Date #4
Exposure to the public sector	18%	16%	7%	9%
Capital adequacy	12,0	11,2	11,0	10,9
Currency risk	-236%	-259%	-118%	63%
Profitability	-9%	-8%	2%	3%
Liquidity risk	0,63	0,51	1,10	1,52

For these projected indicators, we filter the values that enter in the problem or tranquil zones, depending on each indicator's threshold. For those indicators in the problem zone, we calculate their squared value. As regards the liquidity indicator, we first subtract it by 1 and then elevate it, so as to make the squared values of the indicators nearer 0 greater than those closer to 1. For those indicators in the tranquil zone, we compute a zero value. The table that follows shows these calculations:

Table 11: Intermediate Calculations

	Date #1	Date #2	Date #3	Date #4
Exposure to the public sector	0.03	0.03	0	0
Capital adequacy	144.00	125.44	121.00	118.81
Currency risk	5.57	6.71	0	0
Profitability	0.01	0.01	0	0
Liquidity risk	0.14	0.24	0	0

Finally, we take the first period as the base for the index numbers, establishing them as 100. Then, the vertical sum of the squared values defines the vulnerability index for each period as follows.
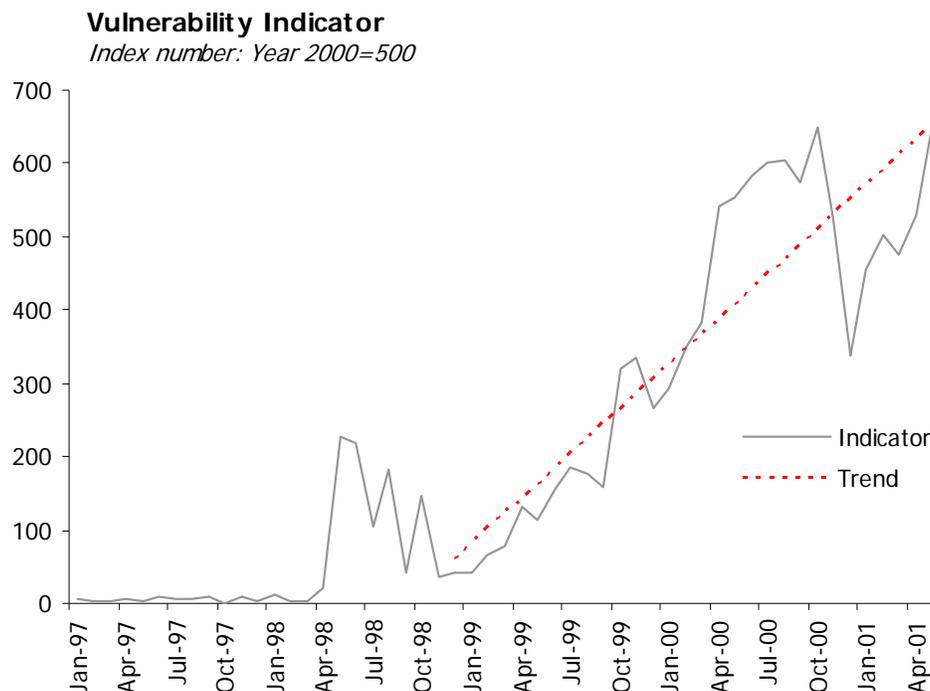
Table 12: Vulnerability Index

	Date #1	Date #2	Date #3	Date #4
Exposure to the public sector	100	79,01	0	0
Capital adequacy	100	87,11	84,03	82,51
Currency risk	100	120,44	0	0
Profitability	100	79,01	0	0
Liquidity risk	100	175,38	0	0
Vulnerability Index	**500**	**540,96**	**84,03**	**82,51**

5.3   Results

The evolution of the early warning indicator (Figure 3) shows clearly how the vulnerability of the banking system was increasing prior to the crisis as well as the deterioration that can be observed in the various risk indicators. Following an initial period between 1997 and early 1999 when the index remained relatively flat and at low

levels, indicating that the banking system was by and large stable, the index started to increase steadily.

Figure 3: Early Warning Indicator

Vulnerability Indicator
*Index number: Year 2000=500*

The index shows that in 1997 and 1998 the Argentine banking system was stable and that the only source of vulnerability during this period was the liquidity risk to a very small degree. Although the aggregate index shows some increase in vulnerability in mid-1998, probably in response to the Russian crisis, it quickly returned to its previous levels. The upward trend starts in early 1999 and appears to coincide with the Brazilian devaluation.

Looking at the components of the index (Figure 4), it seems that liquidity was already an issue in 1999 and that exposure to the public sector started to represent an increasing source of eventual weakness for Argentine banks.[14] The other components—currency risk, lack of profits, and capital adequacy—were deteriorating in a marginal way.

The values of the vulnerability index for the years 2000 and 2001 were significantly higher than during previous years, with the index reaching its maximum value just before the beginning of the 2001 crisis. By that time, it was clear that all of the individual risk indicators had increased and the banking system was facing a significant degree of vulnerability.

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[14] For banks in some developing countries like Argentina, exposure to the public sector is usually seen as a source of vulnerability due to Argentina's long history of fiscal imbalances. For other countries, this would not necessarily be the case.

Figure 4: Vulnerability Sources

Vulnerability Sources
Index number: Year 2000=500
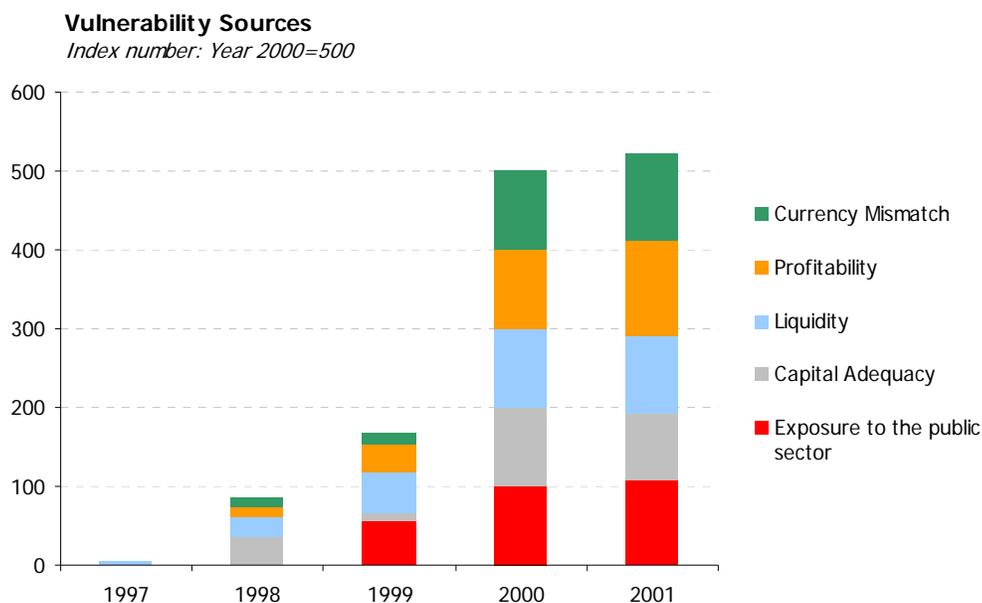
This example illustrates the usefulness of the approach that has been used in this paper and its potential to serve as an early warning indicator of a banking crisis. Nevertheless, there are a number of caveats. First, the model requires a thorough understanding of macroeconomic and financial vulnerabilities in order to understand the worst case scenarios. In the case of Argentina, the main risks during that period for the banking system were a maxi-depreciation of the currency, a large increase in the spreads on sovereign bonds (country risk), and a large recession. In addition, the liquidity risks were critical at the time because the banking system was highly dollarized and the central bank was limited in its ability to act as lender of last resort. In contrast, the current macroeconomic risks are different and some of the vulnerabilities of the banking system have also changed (e.g. because the banking system now operates in pesos). Therefore, we would need to adjust the worst-case scenarios and the model that captures the impact on banks to account for these differences.

Second, the models are country specific and need to capture the interactions of the macroeconomic variables and the banking system. For instance, we argue in the case of Argentina that it is risky for banks to hold public sector bonds. This is true so far as the country has a low credit rating, but it would probably not be the case in EMCs that have investment grade ratings. In contrast, in other countries the problem could be the holding of long-term mortgages at fixed interest rates or a large concentration of loans in a specific sector (e.g., agriculture). As there is no one model that fits all banking systems, the modeling exercises proposed in this paper need to be tailored to specific situations.

Finally, the models are data intensive and require detailed information of the banks' balance sheet and some critical indicators such as the interest rate and liquidity gaps, which are not always readily available from public information.

6. Peer Group Analysis for the Early Detection of Problematic Entities

Problems in individual institutions, if not properly anticipated and managed, can trigger systemic problems. The general methodology suggested in the previous section provides a framework that can be adapted to analyze and evaluate banking systems as a whole or alternatively individual banks, even when each type of application would need its own refinements.

When applied to individual banks, the general methodological idea remains the same. The process starts with projections of alternative macroeconomic or systemic scenarios, which are used to perform a stress test of the individual bank using its balance sheet, and then the model will provide the risk indicators as outputs on a forward-looking basis.

This section seeks to provide a methodology using a number of risk indicators that can be used to evaluate when an individual bank distances itself from its peer group. The approach applies the same shocks to the balance sheet of each bank to assess whether specific banks would behave differently from their peers and to detect potential problems and vulnerabilities.

Figure 5: Peer Group Analysis
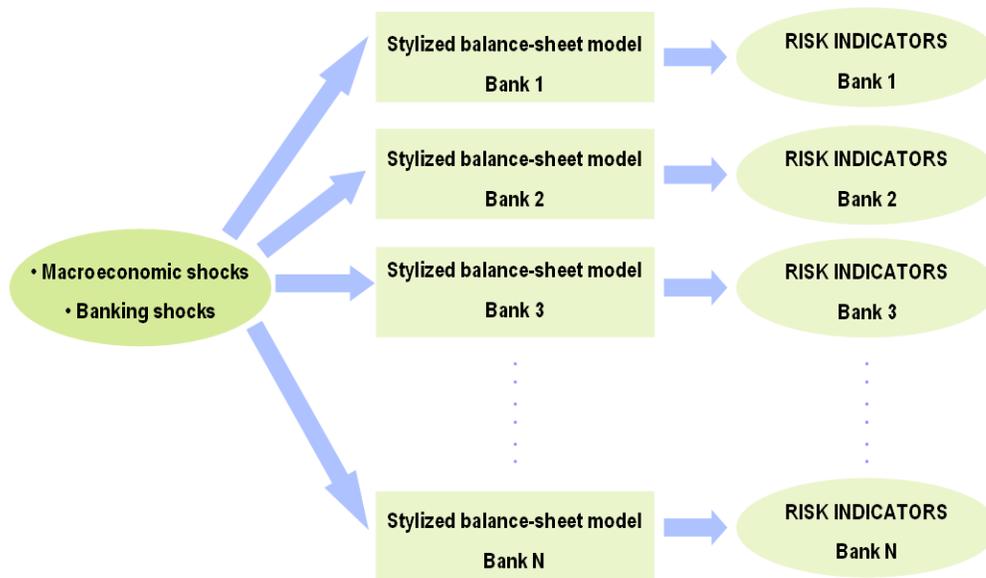
Suppose that there are N banks in an economy and that a set of risk indicators is calculated for each of them for a given scenario. The set of risk indicators is the same as the ones calculated as outputs in the previous section.

In order to compare the risk indicator set for each bank, we first calculate the average value for each indicator or variable for the overall system, or for the peer group of banks that we select, and then measure the distance for a given variable between the value of the individual bank and the systemic value. The model generates a vector (or multidimensional set) of *k* risk indicators, where *k* is the total number of indicators that are considered.

The most natural distance measure would be that known as Euclidean distance.[15] To illustrate it, assume that the relevant set of risk indicators would have only two items— ROA and a liquidity ratio (LIQ). If the peer group average for these two indicators were meanROA and meanLIQ, the Euclidean distance between bank *i* and its peer group would be calculated as:

$$d_i = \sqrt{\left(ROA_i - meanROA\right)^2 + \left(LIQ_i - meanROA\right)^2} \tag{1}$$

This calculation should help to detect the outlier banks in terms of risk indicators by comparing each bank's indicators against the peer group averages. In real applications, the whole set of risk indicators would be used for the distance calculation.

Graphing only the two indicators (LIQ and ROA) of the example, banks would be situated in the plane as in **Figure 6**. As can be seen, there are two banks (circled) that show huge negative profits in contrast to their peers and there is one bank showing a relatively low liquidity ratio compared with others in its peer group.

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[15] In this case, the distance between a bank and its peer group in terms of risk indicators would be calculated as the square root of the sum of the squares of the arithmetical differences between the value of its own risk indicators and the average value of the group's risk indicators.

Figure 6: Two Indicators Example

Two risk indicators example
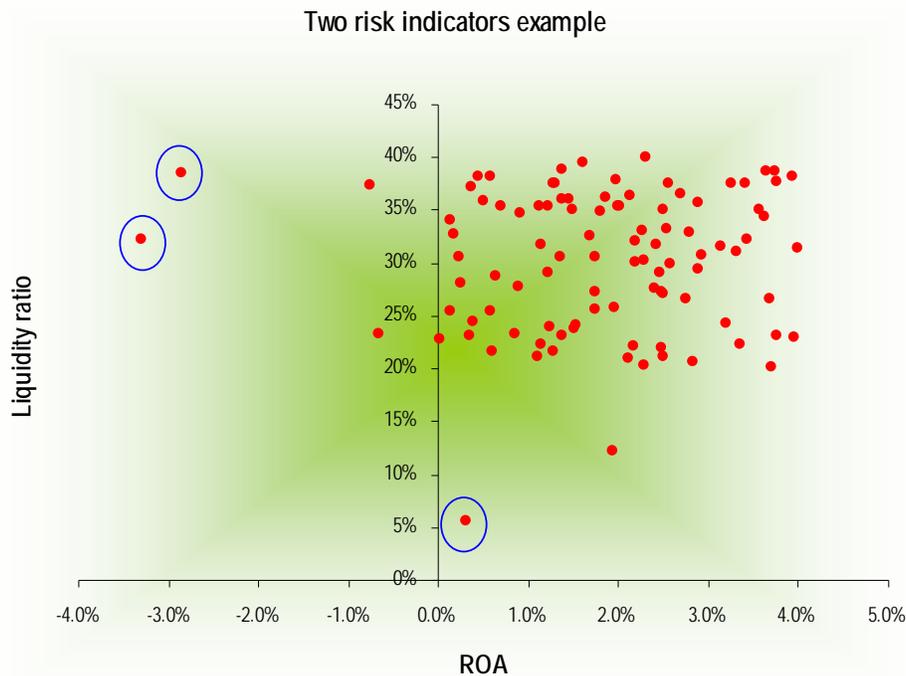
Alternatively, a more appropriate distance measure would be a Mahalanobis distance.[16] It differs from Euclidean distance in that it takes into account the correlations between the risk indicators and is scale-invariant. Thus, it is not dependent on the scale of measurements. Another improvement from Euclidean distance is that it weights each risk indicator inversely to their variance so that the noisier an indicator is the less important it will be for the determination of final location of the bank in terms of its peers.

When this approach is applied, the full set of risk indicators would be used so the dimension of the distance measure would be equal to the quantity of them. Additionally, some other methodological issues should be considered. In particular, indicators should be normalized in order to ensure that there is a positive relationship between the variable and the level of risk. For example, the larger the ROA, the lower the risk. Alternatively, the larger the leverage, the larger the risk. Therefore, leverage indicators should be measured by their respective complement (capitalization indicators) so as to guarantee that all of the indicators maintain the same relationship sign with risk.

Once the distance is calculated for each individual bank, it is possible to assess the frequency distribution of the calculated distances. The upper tail of the distribution will contain those banks that show greater distance from their peers and, therefore, these should be analyzed.

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[16] Mahalanobis, P. C. 1936). On the generalized distance in statistics. Proceedings of the National Institute of Sciences of India. Vol. 2 (1). pp. 49–55. Available at http://ir.isical.ac.in/ dspace/handle/1/1268.

There is another methodological issue to help in detecting the vulnerabilities facing those banks that show significant distance from their peers. The manner in which distances are calculated should allow for reverse engineering to enable detection of those risk factors that accounted for most of the distance.

Coming back to the example using two risk indicators, it is a straightforward process to determine whether ROA or LIQ accounts for most of the total distance value. Generally, the same procedure can be done to produce a ranking of importance among risk factors to account for each bank distance indicator.

While this methodology is well known in some fields, including marketing applications and anomaly detection for anti-money laundering practices, the interesting result in this application is the combination of this analysis with scenario-building and stress-testing methods to provide a forward-looking comparison among peer banks. Once again, a forward-looking approach can help in anticipating eventual problems and vulnerabilities within a macroprudential framework.

7.   Final Reflections

This paper has presented a methodology that attempts to construct a risk indicator for the early detection of vulnerabilities in the banking system. The first step is to identify the macroeconomic and systemic shocks that could affect the banking system or individual banks, especially their impact on solvency and liquidity.

The methodology tries to capture the dynamic interactions between key macroeconomic variables and a set of parameters that affect the overall banking system, on one side, and the evolution of key risk indicators of the banking system, such as solvency and liquidity, on the other. The framework relies on a set of equations that summarizes the main elements of the balance sheet, the income statement of the banking system, and critical indicators such as the interest rate and currency and liquidity gaps.

One distinctive feature of the methodology is that the scenarios are essentially forward-looking in the sense that the shocks under consideration are not only based on historical data, but they also take into account the tail of the distribution. In other words, we consider events that have a low statistical probability of taking place based on historical data, yet these events could occur when the economy faces large macroeconomic imbalances or there is a systemic banking problem. In this sense, the methodology tries to capture episodes that are particularly traumatic for the banking system which could lead to systemic solvency or liquidity problems.

The different scenarios that are considered in the paper can be built either by using expert judgment or through mathematical simulation regarding the evolution of the exogenous variables. These assumptions are then used to perform a dynamic simulation of the banking system and are summarized in a vulnerability index that can be used as an early warning indicator.

One of the distinctive features of our vulnerability index is that it combines traditional early-warning macroeconomic indicators with forward-looking, stress-testing techniques. The index integrates macroeconomic and bank performance indicators in a way that should help regulators to better understand the effects of macroeconomic shocks on a banking system.

The model was calibrated for the Argentine banking system for the period 1997–2001, which covers an initial period of financial stability when the country's banking system was in good shape and a second period that ended in a major banking crisis. The model performed well during this period and the vulnerability index was a useful early warning indicator of an impending Argentine banking crisis. In this regard, the Argentine application of the model shows the usefulness of the overall approach. At the same time, as we argued in section 5, the modeling exercise requires a thorough understanding of the macroeconomic vulnerabilities of the country under review as well as the specific characteristics of the banking system.

This exercise illustrates the potential use of combining traditional early warning indicators with stress-testing techniques. While it is only a first step in this direction, we believe that this approach can be successfully used in other countries if significant efforts were made in each case to collect detailed banking sector data and understand the main institutional features and macroeconomic risks.

Among the issues that need to be incorporated into the analytical framework are the overall safety net—especially the strength of the deposit insurance system and its ability to establish the confidence of small depositors—and the ability of the central bank to act as lender of last resort. In future exercises, we will try to incorporate the possible effects that these aspects have on the dynamic simulations.

The dynamic framework that we use can help to evaluate the ability of a banking system to withstand an adverse shock. For instance, banks would have little ability to recover if there were a deterioration in the quality of their portfolios resulting from a large number of NPLs impairing their capital base. In contrast, the adverse effects of an increase in short- and long-term interest rates, which typically lead to a reduction in the value of long-duration assets and negatively affect banks' net worth in the short-run, can be compensated for in the medium- to long-term as assets mature and the bank lends at higher rates of interest. In this respect, it is an advantage to use a multi-period model to track the evolution of profits, assets, and net worth to assess the ability of the banks to recover from certain shocks.

The paper also develops an early warning indicator that is based on the performance of individual banks. This analytical framework uses cluster analysis and compares peer group financial institutions to detect those financial institutions, which based on a number of parameters, show risks or vulnerabilities that are different from the system as whole. As a result, this can serve as an early warning system for individual banks and help regulators to differentiate between individual and systemic problems.

The dynamic simulations that were performed clearly illustrate that a well-designed regulatory framework aimed at reducing financial vulnerabilities needs to integrate

macroeconomic and microeconomic elements. While a banking system needs to have adequate capital and liquidity requirements to address potential credit problems and avoid a run on deposits, it is also necessary to incorporate into risk management practices an informed view about the evolution of key variables such as economic growth, interest rates, and the exchange rate.

8.   Appendix

APPENDIX 1: Model Equations

This appendix shows the equations behind the stylized banking system's model. The approach here is similar to those of Drehman et. al. (2006), Kida (2008), and Mermelstein (2009).

The starting point is the initial picture of assets and liabilities of the banking system under study, and we then proceed to assess its eventual performance over a 12 quarters time-window, when some changes or shocks in the scenario are made to happen.

The model encompasses:

$t = 0 \dots T$ periods

with *t=0* being the starting period, and *t=1...T* the simulation horizon.

Additionally, the banking system's balance-sheet model has:

$j = 0 \dots \lambda$ maturity buckets

which means that every assets or liability contemplated in the model matures in some period *j*, and where *j*=0 means immediate liquidity. Finally, assets and liabilities are denominated either in domestic or in foreign currency so that there are

$c = 1, 2$ currencies (1: domestic currency; 2: foreign currency)

1.   Assets

Total assets of the banking system are defined as follows:

$$A_t = M_t + TB_t + BB_t \qquad (1)$$

where:

A_t : Total assets in *t*

M_t : Liquid non-interest earning assets in *t*

TB_t : Assets held in the trading book in *t*

BB_t : Assets held in the banking book in *t*

Interest earning assets, held either in the trading or in the banking book can be claims on private sector such as loans or on public sector such as public bonds. So that, there are two kinds of debtors:

$k = 1, 2$ debtors (1: private sector; 2: public sector)

Assets held in the trading book are those that are marked-to-market period by period, so that they are registered at their present values, while those assets held in the banking book are registered by their face values.

In the following paragraphs the valuation process of each asset type is detailed.

1.1   Valuation of Assets Held in the Trading Book:

Trading assets are registered by their current present values period by period as follows:

$$TB_t = \sum_{k=1}^{2}\sum_{c=1}^{2}\sum_{j=0}^{\lambda} E_t^{c-1} PV_t(FV_t^{c,j,k})$$ (2)

where:

E_t : Exchange rate in *t*

$PV_t(FV_t^{c,j})$: Present value in *t* of assets maturing in *j*, denominated in currency *c*, against debtor *k*.

Equation (2) shows how assets held in the trading book are marked to market. It indicates that *TB* is the sum across two debtor types (*k*), two currencies (*c*), and λ maturity buckets, of the properly discounted face value of assets, converted to domestic currency by multiplying by E where appropriate.

The discounting process opens the possibility of capital gains (losses), as discounting factors vary period by period as market interest rates do, but coupon rates do not change until the assets mature. This shows the importance of the maturity structure of assets in terms of interest rate risk.

Discount factors, interest and coupon rates, and default probabilities:

Discount factors are defined as follows:

$$D_t^{i,c} = \left(\prod_{q=1}^{i} d_{q-1,q}^{c}\right)_t$$ (3)

with

$$\left(d_{q-1,q}^{c}\right)_t = \left(\frac{1}{1+R_{q-1,q}^{c}}\right)_t$$ (4)

where $R_{q-1,q}^{c}$ represents the equilibrium forward rate between *q-1* and *q*, for risky assets denominated in currency *c*, implicit in the spot curve in *t*.

At the same time, arbitrage should ensure that for every period and maturity bucket the following equality holds:

$$1 + r_f^{\ c} = (1 + R^c)[(1 - PD^c) + (1 - LGD^c PD^c)]$$

so that

$$R^c = \frac{r_f^{\ c} + LGD^c PD^c}{1 - LGD^c PD^c} \qquad (5)$$

where

$r_f^{\ c}$: Risk-free rate for assets denominated in currency c

PD^c : Probability of default for assets denominated in currency c

LGD^c : Loss-given-default rate for assets denominated in currency c

Expression (5) shows that the return on any asset depends positively on the risk free interest rate and negatively on the probability of default and the loss given default. At this stage, LGD^c is considered a fixed parameter, while default probabilities are determined by:

$$PD_t^c = PD_t^c(X_t \beta) \qquad (6)$$

where $X_t \beta$ is a linear combination of a set of macroeconomic variables X and a vector of coefficients β.

Additionally, assuming perfect capital mobility and the accomplishment of international interest rates parities, "domestic" risk free rates should be determined by:

$$(r_f^{\ 1})_t = (r_f^{\ *})_t + \frac{E^e - E_t}{E_t} + \rho_t \qquad (7)$$

$$(r_f^{\ 2})_t = (r_f^{\ *})_t + \rho_t \qquad (8)$$

being $r_f^{\ 1}$ the risk-free rate for domestic currency denominated assets, which depends positively on the international risk-free rate for foreign currency denominated assets $r_f^{\ *}$ of the same maturity, on the expected devaluation $ED_t = \dfrac{E^e - E_t}{E_t}$ of the domestic currency, and on the sovereign yield spread ρ.

On the other hand, foreign currency denominated assets earn $r_f{}^2 = r_f{}^1 - ED_t$

Replacing equations (6) to (8) in (5) we have:

$$R^1 = R^1(r_f^*, ED, \rho, PD(X\beta), LGD) \; ; \text{Domestic currency denominated assets} \qquad (9)$$

$$R^2 = R^2(r_f^*, \rho, PD(X\beta), LGD) ; \text{Foreign currency denominated assets} \qquad (10)$$

with all the derivatives > 0.

Additionally, interest rates charged on loans include a spread (α) that reflects administrative expenses. So that, for those assets held either in the trading book or in the banking book against private debtors, the final interest rate becomes:

$$R^c_{LOANS} = \frac{r_f{}^c + LGD^c PD^c}{1 - LGD^c PD^c}(1+\alpha) \qquad (11)$$

In numerical simulations, it is assumed that α is equal to the ratio of administrative expenditures to assets.

Now that we have introduced interest rates and discount factors, we can return to the valuation of the assets held in the trading book by calculating their present values.

Present value of assets held for trading:

To show how to compute the sum in equation (2), we need to provide the formulae for the computation of present values of each asset type $PV_t(FV_t^{c,j})$:

The next table illustrates the procedure, for bonds that coupon rate C_0 does not change:

Maturity bucket	Present value
j=1	$PV_t = D_t^1 C_0 FV_t + D_t^1 FV_t$
j=2	$PV_t = D_t^1 C_0 FV_t + D_t^2 C_0 FV_t + D_t^2 FV_t$
j=3	$PV_t = D_t^1 C_0 FV_t + D_t^2 C_0 FV_t + D_t^3 C_0 FV + D_t^3 FV_t$
...	...
j=λ	$PV_t = D_t^1 C_0 FV_t + D_t^2 C_0 FV_t + ... + D_t^\lambda C_0 FV + D_t^\lambda FV_t$

Present values result from the sum of present values of interest payments $C_0 FV_t$ discounted by the appropriate discount factors D_t^i defined as in equation (4).

For the assets maturing in the bucket j we have:

$$PV_t = \sum_{i=1}^{j} D_t^i C_0 FV_t + D_t^j FV_t \tag{12}$$

Summing all maturity buckets we have:

$$PV_t = \sum_{j=1}^{\lambda} \sum_{i=1}^{j} D_t^i C_0 FV_t + D_t^j FV_t \tag{13}$$

It is worth noting that in equation (13) we are keeping coupon rates constant at C_0 but in fact it is not the case for assets maturing before t. Thus, the last step we need to complete in order to calculate TB_t is to consider that coupon rates reset when assets mature in some period $l < t$. Taking this into account (and omitting the summation across k for simplicity), we can express the value of the trading book in period t as:

$$TB_t = \sum_{c=1}^{2} E_t^{c-1} \left\{ \sum_{j=1}^{t-1} \sum_{i=1}^{j} \left(D_t^{i,c} FV_t^{c,j} \left[C_0 (1-I_l) + C_l I_l \right] + D_t^j FV_t^{c,j} \right) + \sum_{j=t}^{\lambda} \sum_{i=1}^{j} \left(D_t^{i,c} FV_t^{c,j} C_0 + D_t^j FV_t^{c,j} \right) \right\}$$

$$\tag{14}$$

with

$I_t = 1$ in period l when assets in bucket j repriced the last time prior to t.
$I_t = 0$ otherwise

The first double summation in (14) sums present values of those assets of which coupon rates have changed in some period l before t, while the second sums present values of those that keep paying C_0 at t.

Additionally, coupon rates are determined in each period according to the prevailing term structure so as, for any par security maturing T periods ahead, we have:

$$C_l = \frac{1 - D_{l+T}}{\sum_{i=1}^{T} D_{l+i}}$$

so that C_l is the coupon rate that makes 100 the present value of a security, given the current term structure of interest rates.

1.2   Valuation of Assets Held in the Banking Book:

As opposite to trading assets, assets held in the banking book are registered by their face values according to:

$$BB_t = \sum_{k=1}^{2} \sum_{c=1}^{2} \sum_{j=0}^{\lambda} E_t^{c-1} FV_t^{c,j,k} \tag{15}$$

with

$FV_t^{c,j}$: Face value in *t* of assets maturing in *j*, denominated in currency *c*, against debtor *k*.

In this case, there is no discounting process involved. Assets are registered only at their face values, regardless of market interest rates movements.

1.3   TB and BB Dynamics:

Face values of those assets that are claims on the private sector (held either in the TB or in BB) evolve according to:

$$FV_t^{c,j} = FV_{t-1}^{c,j}\left(1 - PD_t^{c,j}LGD^{c,j}\right)\left(\frac{E_t - E_{t-1}}{E_{t-1}}\right)^{c-1} \qquad ; \text{when } k=1 \tag{16}$$

this means that assets are rolled over constantly, and their stocks only decrease due to write-offs and exchange rate movements for those denominated in foreign currency. Moreover, write-offs evolve according to equation (23).

However, for those assets that represent claims on the public sector, an exogenous growth rate is assumed, so as to incorporate the possibility of compulsory bond issuances. It is quite usual that governments in developing countries rely excessively on banks when running fiscal imbalances. In that cases governments tend to crowd-out private assets within banks' balance-sheets and the exposure to the public sector increases accordingly. Thus, for the case of claims on the public sector equation (16) becomes:

$$FV_t^{c,j} = FV_{t-1}^{c,j}\left(1 - PD_t^{c,j}LGD^{c,j}\right)\left(\frac{E_t - E_{t-1}}{E_{t-1}}\right)^{c-1}(1 + g_t) \qquad ; \text{when } k=2 \tag{16'}$$

where *g* is the exogenous growth rate of government bonds held by banks. For simulation purposes it is quite useful to link *g* to the growth rate of the public debt to GDP ratio as done in the numerical illustrations in section III.

1.4 Total Assets' Value:

The value of total assets in each period of time t can be obtained by replacing equation (3) and (14) in equation (1). The resulting expression and its partial derivatives are included in Appendix 2. The following table presents the signs of those derivatives.

Variable	Derivative sign
Nominal exchange rate	+ (for foreign denominated holdings)
Coupon rate	+
Return rate	-
Expected devaluation	-
Country yield spread	-
Default probability	-
Loss given default rate	-

As expected, increases in interest rates, expected devaluation, country risk, default probabilities and loss given default rates erodes asset values, while increases in coupon rates and nominal exchange rates increases registered asset values.

2. Liabilities

Liabilities evolve according to exchange rate movements and to an exogenous growth rate γ_t. This growth rate is included in the model in order to allow simulation of stress episodes that could impact deposits' dynamics, such as bank runs as an extreme case. Thus, the following equation represents the dynamics of face values:

$$FVL_t^{c,j} = \sum_{c=1}^{2} FVL_{t-1}^{c,j}\left(\frac{E_t - E_{t-1}}{E_{t-1}}\right)^{c-1}(1+\gamma_t) \tag{17}$$

As liabilities are all registered at their face values, there are not capital gains due to shifts in interest rates. Interest rates movements only impact on interest income flows, but they do not produce stock impacts.

It is assumed that banks do not pay interests on current account or savings deposits. Contrarily, time deposits accrue interests, but they are lower than those earned by assets of similar maturity. Specifically, it is supposed that time deposits accrue the international risk-free rate plus the expected devaluation for the case of those deposits denominated in domestic currency. However, it is assumed that deposit rates do not include any country risk premium. This is in line with what is observed in real markets and the stylized facts described by Maes (2005).

3.   Income Statements

Net profit before taxes and dividends for period t is given as:

$$\Pi_t = NIY_t - WR_t + OI_t - Cost_t + NKG_t \tag{18}$$

where:

Π_t : Net profit before taxes and dividends

NIY_t : Net interest income

WR_t : Write-offs

OI_t : Non-interest net income

$Cost_t$: Administrative expenditures

NKG_t : Net capital gains

Each component of the benefit equation is defined as follows:

3.1   Net Interest Income:

NYI is the difference between interest earnings on assets (CFA) and interest expenses on liabilities (CFL):

$$NIY_t = CFA_t - CFL_t \tag{19}$$

where

$$CFA_t = \sum_{c=1}^{2} E_t^{c-1} \left\{ \sum_{j=1}^{t-1} \left[C_0^{c,j}(1-I_l) + C_l^{c,j}I_l \right]\left(1 - PD_t^{c,j}LGD^{c,j}\right)FV_{t-1}^{c,j} + \sum_{j=t}^{T} C_0^{c,j}\left(1 - PD_t^{c,j}LGD^{c,j}\right)FV_{t-1}^{c,j} \right\}$$

$$\tag{20}$$

$$CFL_t = \sum_{c=1}^{2} E_t^{c-1} \left\{ \sum_{j=1}^{t-1} \left[C_0^{c,j}(1-I_l) + C_l^{c,j}I_l \right]FVL_{t-1}^{c,j} + \sum_{j=t}^{T} C_0^{c,j}FVL_{t-1}^{c,j} \right\} \tag{21:}$$

with

$I_t = 1$ in period l when assets in bucket j repriced the last time prior to t.
$I_t = 0$ otherwise

where *FVL* stands for "face value of liabilities". Equations of CFA and CFL are just the summation of coupon earnings on assets and coupon expenses on liabilities, respectively. The presence of the indicator variable *I* is just to consider that coupon rates are fixed at their initial values for those assets (liabilities) that do not reprice in the current period, while the new coupon rates applies for those that repriced in some period *I* after *t=0*.

3.2   Non-interest Income:

Non-interest margin is just assumed as a fixed share of interest margins according to:

$$OI_t = \omega \; NYI_t \tag{22}$$

3.3   Write-offs:

Write-offs on assets are given by the share of assets defaulting each period by the loss given default rate:

$$WR_t = FV_{t-1} PD_t LGD_t \tag{23}$$

3.4   Administrative Expenditures:

Administrative expenditures are assumed as a constant share of total assets:

$$Cost_t = \eta \; A_{t-1} \tag{24}$$

3.5   Net Capital Gains:

Net capital gains are produced by changes in interest rates that impacts on present values of those assets market-to-market, and by exchange rate movements affecting both assets and liabilities denominated in foreign currency.

$$NKG_t = TB_t^{k=1} + TB_t^{k=2} + BB_t^{k=1} + BB_t^{k=2} - (TB_{t-1}^{k=1} + TB_{t-1}^{k=2} + BB_{t-1}^{k=1} + BB_{t-1}^{k=2}) + WR_t -$$
$$- (TB_{t-1}^{k=2} + BB_{t-1}^{k=2}) g_t - FVL_{t-1}^{c=2} \left(\frac{E_t - E_{t-1}}{E_{t-1}} \right) + M_{t-1}^{c=2} \left(\frac{E_t - E_{t-1}}{E_{t-1}} \right) \tag{25}$$

As equation (25) shows, net capital gains can be calculated as computing the total increase in trading and banking book values, then subtracting the exogenous increase in public bonds $(TB_{t-1}^{k=2} + BB_{t-1}^{k=2}) g_t$, the change in liabilities due to exchange rate

movements $FVL_{t-1}^{c=2}\left(\dfrac{E_t - E_{t-1}}{E_{t-1}}\right)$, and finally adding the impact of movements in the

exchange rate on holdings of foreign denominated liquid assets $M_{t-1}^{c=2}\left(\dfrac{E_t - E_{t-1}}{E_{t-1}}\right)$.

4.   Banks' Capital

$$K_t = K_{t-1} + \Pi_t \qquad (26)$$

We assume no taxes and no dividend payouts.

5.   Closing the Model

Assets held in the trading and banking books have their own dynamics, as they evolve according to default and recovery rates, according to market value changes in the case of those held for trading, and because of exchange rate movements in the case of foreign denominated assets. Liabilities and capital have also their own dynamics.

We close the model with ΔM_t, that is, cash and other similarly non-interest earning liquid assets. So that we have

$$\Delta M_t = \Delta L_t - \Delta TB_t - \Delta BB_t + \Pi_t \qquad (27)$$

6.   Risk Indicators for Prudential Monitoring

The model developed in this section represents a comprehensive framework for financial risk simulation within a banking sector or an individual bank. In order to assess those risks, it is necessary to build some macroeconomic scenarios first so as to provide the model with the necessary inputs. The model is also useful to perform sensitivity analysis, which means the variation of individual parameters so as to measure its impact in terms of risk indicators.

6.1   Inputs

Once forward-looking scenarios are built, we should have a vector of inputs for each scenario.

As described through its equations, our model works with the following inputs as stress forces:

- Maturity structure of assets
- Maturity structure of liabilities
- Term structure of interest rates

- Default probabilities (based on macroeconomic assumptions $PD_t^c = PD_t^c(X_t, \beta)$)
- Sovereign yield spread
- Spot exchange rate
- Future exchange rate (Expected devaluation)
- Bank efficiency parameters (Administrative expenses / Assets)

6.2 Outputs

6.2.1 Liquidity Risk:

a) *Liquidity Gaps*

Liquidity gap in the bucket *j* (incremental gap):
$$LG_t^j = A_t^j - L_t^j$$
Cumulative liquidity gap in the bucket *j*:
$$CLG_t : \sum_{j=1}^{T} A_t^j - L_t^j$$

b) *Liquidity Ratios*

Liquid assets as percentage of liquid liabilities:
$$LRatio^1{}_t = \frac{\sum_{j=1}^{L} A_t^j}{\sum_{j=1}^{L} L_t^j}$$, where liquid assets (liabilities) those maturing not after

t=L.
Liquid assets as percentage of total assets:
$$LRatio^2{}_t = \frac{\sum_{j=1}^{L} A_t^j}{\sum_{j=1}^{\lambda} A_t^j}$$, where liquid assets (liabilities) those maturing not after

t=L.
Liquid assets as percentage of reserve requirements:
$$LRatio^3{}_t = \frac{\sum_{j=1}^{L} A_t^j}{\sum_{j=1}^{\lambda} \phi^j L_t^j}$$, where liquid assets (liabilities) those maturing not after

t=L, and ϕ^j represents the requirement ratio on liabilities according to their maturity.

6.2.2 Interest Rate Risk:

a) *Dollar Gap Indicator*

$$DGap_t = \sum_{j=1}^{\lambda} RSA_t^j - \sum_{j=1}^{\lambda} RSL_t^j$$

This indicator is the difference between the dollar amount of interest-rate-sensitive assets (RSA) and the dollar amount of interest-rate-sensitive liabilities (RSL). A positive (negative) dollar gap implies a long (short) position on interest rates, which means that a parallel increase on interest rates increases (reduces) net interest income where *DGap* is positive (negative).

b) Duration Gap Indicator

$$DurGap_t = \sum_{j=1}^{\lambda} DurA_t^j - W \sum_{j=1}^{\lambda} DurL_t^j$$

where W represents the ratio of total assets to total liabilities $W = \dfrac{\sum_{j=1}^{\lambda} L_t^j}{\sum_{j=1}^{\lambda} A_t^j}$

A positive (negative) DurGap indicates that parallel increases in interest rates would imply a decrease (increase) in the market value of the equity relative to total assets as follows:

$$\frac{\Delta NetWorth_t}{TotalAssets_t} \cong -DurGap_t \frac{\Delta i_t}{1 + i_t}$$

While dollar gap is a measure of interest flows sensitivity, duration gap is a measure of net worth sensitivity to movements in interest rates.

6.2.3 Exchange Rate Risk:

An indicator of currency mismatch in each period can be calculated as the ratio of foreign currency (c=2) denominated equity to total banks' capital, as follows:

$$CM_t = \frac{\sum_{j=0}^{\lambda} A_t^{j,c=2} - \sum_{j=0}^{\lambda} L_t^{j,c=2}}{K_t}$$

6.2.4 Credit Risk:

a) NPLs Ratio

The ratio of non-performing loans (NPLs) to total assets is the most typical indicator of quality of credit portfolios. In this context, it depends on macroeconomic variables ($X_t\beta$) through the probabilities of default, and it is roughly approximated by the ratio of the share of defaulted assets to total assets, as follows:

$$NPL_t = \frac{\sum_{j=1}^{\lambda} PD_t^j (X_t \beta) A_t^j}{\sum_{j=1}^{\lambda} A_t^j}$$

b) *Write-offs Ratio*

This indicator is calculated as the ratio of effective write-offs to total assets.

$$WRR_t = \frac{\sum_{j=1}^{\lambda} A_{t-1}^j PD_t^j LGD_t}{\sum_{j=1}^{\lambda} A_t^j}$$

c) *Exposure to the Public Sector*

This indicator is calculated as the ratio of claims on the public sector to total assets. As indicated, claims on the public sector are assumed to growth in tandem with the ratio of public debt to GDP.

$$EPS_t = \frac{\sum_{j=1}^{\lambda} A_{t-1}^{j,k=2}}{\sum_{j=1}^{\lambda} A_t^j}$$

6.2.5 Profitability:

a) *Return on Assets (ROA)*

Calculated as $ROA_t = \dfrac{\Pi_t}{A_t}$

b) *Return on Equity (ROE)*

Calculated as $ROE_t = \dfrac{\Pi_t}{K_t}$

c) *Net Interest Income to Total Assets*

Calculated as $NIYratio_t = \dfrac{NIY_t}{A_t}$

d) Implicit Spread

Calculated as the difference between the implicit interest rate earned on assets, and the implicit interest rate paid on liabilities.

$$SPREAD_t = i_t^a - i_t^l = \frac{CFA_t}{A_t} - \frac{CFL_t}{L_t}$$

e) Net Capital Gains

Calculated as $NKGratio_t = \dfrac{NKG_t}{A_t}$

6.2.6 Solvency:

a) Capital
It summarizes the evolution of assets and liabilities over time, and it is calculated as

$$K_t = K_{t-1} + \Pi_t$$

b) Leverage

Calculated as $Leverage_t = \dfrac{A_t}{K_t}$

c) Capital to Risk-weighted Assets

Calculated as $CRWA_t = \dfrac{K_t}{\displaystyle\sum_{k=1}^{2}\sum_{c=1}^{2}\sum_{j=0}^{\lambda} \varpi^{c,j,k}(A_t^{c,j,k})}$

where the denominator are the risk-weighted assets, calculated according to the appropriate risk weights $\varpi^{c,j,k}$.

APPENDIX 2

Total assets value is given by:

$$A_t = \sum_{k=1}^{2}\sum_{c=1}^{2} E_t^{c-1}\left\{ M_t^c + \sum_{j=0}^{\lambda} FV_t^{c,j,k} + \sum_{j=1}^{t-1}\sum_{i=1}^{j}\left(D_t^{i,c,k} FV_t^{c,j,k}\left[C_0\left(1-I_l\right)+C_l I_l\right] + D_t^{j,k} FV_t^{c,j,k}\right) + \sum_{j=t}^{\lambda}\sum_{i=1}^{j}\left(D_t^{i,c,k} FV_t^{c,j,k} C_0 + D_t^{j,k} FV_t^{c,j,k}\right)\right\}$$

(A.1):

$$A_t = A_t\left(E_t, D_t^1\left(r_f^*, ED_t = \frac{E^e - E_t}{E_t}, \rho_t, PD_t^1(X_t\beta^1), LGD^1\right), D_t^2\left(r_f^*, \rho_t, PD_t^2(X_t\beta^2), LGD^2\right)\right)$$

(A.2):

where the following are its partial derivatives showing the risk factors affecting asset values:

$$\frac{\partial A_t}{\partial E_t} > 0$$

$$\frac{\partial A_t}{\partial r_f^*} = \frac{\partial A_t}{\partial D_t^1}\frac{\partial D_t^1}{\partial r_f^*} + \frac{\partial A_t}{\partial D_t^2}\frac{\partial D_t^2}{\partial r_f^*} < 0$$

$$\frac{\partial A_t}{\partial ED_t} = \frac{\partial A_t}{\partial D_t^1}\frac{\partial D_t^1}{\partial ED_t} < 0$$

$$\frac{\partial A_t}{\partial \rho_t} = \frac{\partial A_t}{\partial D_t^1}\frac{\partial D_t^1}{\partial \rho_t} + \frac{\partial A_t}{\partial D_t^2}\frac{\partial D_t^2}{\partial \rho_t} < 0$$

$$\frac{\partial A_t}{\partial PD_t^c} = \frac{\partial A_t}{\partial D_t^c}\frac{\partial D_t^c}{\partial PD_t^c} + \frac{\partial FV_t}{\partial PD_t^c} < 0$$

$$\frac{\partial A_t}{\partial LGD_t^c} = \frac{\partial A_t}{\partial D_t^c}\frac{\partial D_t^c}{\partial LGD_t^c} + \frac{\partial FV_t}{\partial LGD_t^c} < 0$$

APPENDIX 3

1.   Implementation Issues:

As this application tends to be just illustrative, some implementation issues were treated simplistically.

In this regard, default probabilities were related negatively with GDP growth rates period by period by the following econometric equation estimated from Argentine banks' data:

$$PD_t = \frac{1}{1 + \exp(-(0,03477286 - 1,17057625 * \text{GDPgrowth}_t + \ln(PD_{t-1})))}$$

Default probabilities were also increasingly escalated according to maturities, by a rate of 0.025 per quarter.

Interest rates on deposits were inversely related with the ratio liquid assets to liquid liabilities, with the ratio of capital to RWA and with the parameter that reflect the perceived level of safety net within the banking system, and were related with the currency mismatch ratio and the exposure of banks to the public sector in a direct way.

All this issues would need a more detailed and specific treatment, according to each real application and its particularities.

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