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**MASTER**
ECONOMICS

# A TOP-DOWN STRESS TEST OF PORTUGUESE BANKS DURING THE SOVEREIGN DEBT CRISIS

Maria de Ferraz e Brás Oliveira

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**2026**






# A TOP-DOWN STRESS TEST OF PORTUGUESE BANKS DURING THE SOVEREIGN DEBT CRISIS

**Maria de Ferraz e Brás Oliveira**

Dissertation

Master in Economics

Supervised by

**Ana Isabel Morais de Sá**

**&**

**Manuel Mota Freitas Martins**

2026

## Acknowledgements

To Professor Manuel, for agreeing to guide me through this challenge from the very beginning, and especially for that first call, when I was unsure how to keep going and was quickly encouraged to push through.

To Professor Ana, for joining us without hesitation, for her patience in going over the same thing with me three times, and for all the help with the endless lines of code and technical details.

And to both, for their remarkable availability and commitment throughout this process, for making time beyond what could reasonably be expected, and for revisiting every section with exceptional care and attention to detail. Their dedication and willingness to support me made an enormous difference, and I am deeply grateful for the time and energy they invested in helping me.

To my housemates in Hamburg, for keeping me company in the kitchen when this journey was just beginning.

To my Supervision Unit, for the advice and understanding during the final stretch of this journey. A special thank you to Tiago – forever my first boss – for always recognising my effort.

To my friends, for the co-working sessions, the feedback, the venting, and the humour that could only come from those who were in the same boat.

And lastly, of course, to my parents, for teaching me to stay curious, for supporting all my madness, and for their unwavering presence in every way.

**Abstract:** Prior to the sovereign debt crisis, assessments of the Portuguese banking sector generally pointed to its resilience, yet the subsequent crisis exposed important vulnerabilities in banks' funding structures, profitability, credit risk, and capital positions. This raises the question of whether a simplified top-down solvency stress-testing framework, if applied retrospectively using information available at the time, could have provided earlier signals of such vulnerabilities. To address this question, a simplified top-down solvency stress test, inspired mainly by the Global Bank Stress Test (GST) and the Capital and Loss Assessment under Stress Scenarios (CLASS) framework, is implemented using research-accessible bank-level accounting and prudential data together with publicly available macro-financial information. Historical relationships are estimated over 2000-2010 using pooled Ordinary Least Squares (OLS) and used to project banks' Tier 1 capital ratios recursively for 2011-2012 under baseline and adverse macroeconomic scenarios. The results confirm that the stress scenario generates a materially weaker capital trajectory. By the second year, the main effect of stress is to prevent part of the capital improvement projected under the baseline, particularly among banks in the lower and intermediate Tier 1 ranges, rather than to generate broad-based capital deterioration. Combined with patterns already visible in the 2000-2010 bank data – including a declining share of deposit funding, heterogeneous capital buffers, and rising provisions and impairments – the findings suggest that relevant banking-sector vulnerabilities were detectable before the start of the projection period. Overall, a simplified top-down stress test applied at the start of the 2011-2012 horizon could have provided a useful indication of broad vulnerabilities in the Portuguese banking sector, although it would not have anticipated the full scale or specific form of the subsequent distress.

**JEL codes**: C53, E44, E58, G01, G21

**Keywords**: Financial Regulation, Financial Stability, Macroprudential Stress Testing, Portuguese Banking Sector, Public Data, Supervisory Activities, Top-Down Stress Tests

**Resumo:** Antes da crise da dívida soberana, as avaliações do setor bancário português apontavam, em geral, para a sua resiliência. Contudo, a crise subsequente revelou vulnerabilidades importantes nas estruturas de financiamento, rentabilidade, risco de crédito e posições de capital dos bancos. Isto levanta a questão de saber se um quadro simplificado de testes de esforço de solvência *top-down*, aplicado retrospetivamente com a informação então disponível, poderia ter sinalizado essas vulnerabilidades mais cedo. Para responder a esta questão, implementa-se um teste de esforço de solvência *top-down* simplificado, inspirado sobretudo no *Global Bank Stress Test* (GST) e no *Capital and Loss Assessment under Stress Scenarios* (CLASS), recorrendo a dados contabilísticos e prudenciais por banco acessíveis para investigação, bem como a informação macrofinanceira pública. As relações históricas são estimadas para 2000-2010 através de Mínimos Quadrados Ordinários agrupados e utilizadas para projetar recursivamente os rácios de capital Tier 1 dos bancos em 2011-2012, sob cenários macroeconómicos de base e adverso. Os resultados confirmam que o cenário de stress gera uma trajetória de capital substancialmente mais fraca. No segundo ano, o seu principal efeito é impedir parte da melhoria de capital projetada no cenário de base, sobretudo nos bancos com rácios Tier 1 baixos e intermédios, em vez de provocar uma deterioração generalizada. Em conjunto com padrões já visíveis em 2000-2010 – menor peso dos depósitos no financiamento, reservas de capital heterogéneas e aumento de provisões e imparidades –, os resultados sugerem que vulnerabilidades relevantes já eram detetáveis antes do período de projeção. Assim, um teste simplificado aplicado no início de 2011-2012 poderia ter sinalizado vulnerabilidades gerais, embora não a dimensão total nem a forma específica das dificuldades posteriores.

**Códigos JEL**: C53, E44, E58, G01, G21

**Palavras-chave**: Regulação Financeira, Estabilidade Financeira, Testes de Esforço Macroprudenciais, Setor Bancário Português, Dados Públicos, Atividades de Supervisão, Testes de Esforço Top-Down

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## List of Acronyms

| | |
|---|---|
| Banif | Banco Internacional do Funchal |
| BCP | Banco Comercial Português |
| BdP | Banco de Portugal |
| BEAST | Banking Euro Area Stress Test |
| BES | Banco Espírito Santo |
| BIS | Bank for International Settlements |
| BPI | Banco Português de Investimento |
| BPLIM | Banco de Portugal Microdata Research Laboratory |
| BPN | Banco Português de Negócios |
| BPP | Banco Privado Português |
| CET1 | Common Equity Tier 1 |
| CGD | Caixa Geral de Depósitos |
| CLASS | Capital and Loss Assessment under Stress Scenarios |
| CT1 | Core Tier 1 |
| EA | Euro Area |
| EAD | Exposure at Default |
| ECB | European Central Bank |
| EFAP | Economic and Financial Adjustment Programme |
| EU | European Union |
| EURIBOR | Euro Interbank Offered Rate |
| FI | Financial Institution |
| FSAP | Financial Sector Assessment Program |
| FSB | Financial Stability Board |
| FSR | Financial Stability Report |

| | |
|---|---|
| GDP | Gross Domestic Product |
| GFC | Great Financial Crisis |
| GST | Global Bank Stress Test |
| HICP | Harmonized Index of Consumer Prices |
| IMF | International Monetary Fund |
| IRB | Internal Ratings-Based |
| LGD | Loss Given Default |
| NFCI | Net Fee and Commission Income |
| NII | Net Interest Income |
| NPL | Non-Performing Loans |
| NTI | Net Trading Income |
| OECD | Organisation for Economic Co-operation and Development |
| OI | Other Income |
| OLS | Ordinary Least Squares |
| P&I | Provisions and Impairments |
| P&L | Profit and Loss |
| p.p. | Percentage points |
| PD | Probability of Default |
| RWA | Risk-weighted Assets |
| SIP | Special Inspections Programme |
| SSM | Single Supervisory Mechanism |
| STAMP€ | Stress-Test Analytics for Macroprudential Purposes in the euro area |
| US | United States |
| WEO | World Economic Outlook |

## 1. Introduction

The Great Financial Crisis (GFC) exposed important weaknesses in macroprudential policy and stress testing, particularly their limited ability to anticipate vulnerabilities related to leverage, capital, and liquidity buffers, and fragile funding structures (Bank for International Settlements, 2018). Portugal provides a relevant case study of these limitations. Despite limited exposure to complex high-risk assets, the euro-area (EA) sovereign debt crisis revealed deeper macro-financial weaknesses, including high indebtedness, low savings, weak growth prospects, and a deteriorated external position. By 2011, rising sovereign risk had increased borrowing costs, restricted banks' access to wholesale funding, and intensified their reliance on Eurosystem financing, culminating in Portugal's request for international financial assistance. These developments raise the question of whether stress testing frameworks could have identified the vulnerabilities that materialised during the crisis (Alfaro & Drehmann, 2009; Anderson et al., 2018; Banco de Portugal, 2011b, 2012a).

Stress testing was adapted from engineering to finance as a tool for assessing the resilience of financial institutions (FIs) and systems under adverse conditions (Borio et al., 2014). Over time, it evolved from "micro stress tests", focused on individual portfolios, towards "macro stress tests" designed to assess system-wide vulnerabilities (Quagliariello, 2009a). Since 1996, stress testing has also become part of regulatory risk management, with FIs required to use it in internal models for market-risk capital requirements (Basel Committee on Banking Supervision, 2006). Its role expanded considerably during the GFC, when stress tests became crisis-management tools supporting bank recapitalisation and market confidence, before becoming a standard component of modern supervisory frameworks for assessing capital adequacy and banking-sector resilience (Henry et al., 2018; Henry et al., 2013; Llorent-Jurado et al., 2024; Oura & Schumacher, 2012).

In Portugal, stress tests conducted between 2004 and 2006 generally concluded that the banking system was resilient to adverse shocks, with equity exposure through pension funds identified as a more relevant vulnerability rather than credit solvency risk (Banco de Portugal, 2004, 2005, 2006). However, the GFC exposed important weaknesses, particularly banks' dependence on wholesale funding, liquidity pressures, and declining profitability; additionally, the distress of Banco Português de Negócios (BPN) in 2008 and Banco Privado Português (BPP) in 2010 highlighted a gap between earlier resilience assessments and the vulnerabilities that subsequently materialised (Banco de Portugal, 2007, 2008b; Ferguson et

al., 2007; Haldane, 2009; Kapinos et al., 2018; O'sullivan & Kinsella, 2013; Ong & Pazarbasioglu, 2014).

Similar limitations were apparent during the sovereign debt crisis: although the 2011 EU-wide stress test concluded that Portuguese banks would remain above the minimum capital threshold under the adverse scenario, subsequent FSRs continued to identify weak profitability, rising credit risk, deleveraging pressures and constrained market access (Banco de Portugal, 2011a, 2012a, 2012b, 2013b, 2013c, 2014). This motivates a retrospective assessment of whether an alternative top-down stress-testing framework, applied using information available at the time, could have provided complementary signals of banking-sector vulnerability.

Against this background, this dissertation asks whether a simplified top-down solvency stress test, inspired by the later-developed Global Bank Stress Test (GST) and Capital and Loss Assessment under Stress Scenarios (CLASS) frameworks and applied retrospectively, could have identified broad vulnerabilities in the Portuguese banking sector during the sovereign debt crisis and the Economic and Financial Assistance Programme (EFAP). Using research-accessible bank-level and contemporaneous macro-financial data, reduced-form relationships are estimated over 2000-2010 and used to project profitability, capital, and Tier 1 ratios for 2011-2012 under baseline and adverse scenarios. The projections are then compared with actual outcomes to assess the vulnerability signals generated by the framework and the usefulness of research-accessible bank data for evaluating banking-sector resilience.

The remainder of the dissertation is organised as follows. Section 2 presents the conceptual foundations and main methodological dimensions of stress testing. Section 3 reviews the evolution of major stress-testing initiatives before and after the GFC and discusses relevant bank-data initiatives. Section 4 examines the Portuguese banking sector and the evolution of its vulnerabilities and stress-testing outcomes before and during the crisis. Section 5 describes the research design, data, sample construction, methodology and statistical evaluation framework. Section 6 presents the empirical results, while Section 7 discusses their implications and the limitations of this simplified stress-testing framework. Finally, Section 8 summarises the main findings, limitations, and directions for future research.

## 2. The Foundations and Methods of Stress Testing

To understand the role of stress testing in banking, it is useful to first consider its purpose. In simple terms, a stress test is a "what if?" exercise. It examines how a bank or the banking system as a whole might perform under stress conditions such as a major economic downturn, a sharp decline in house prices, a substantial increase in loan defaults, or a combination of these events (Quagliariello, 2009b).

From a microeconomic perspective, the objective of stress tests is to measure the sensitivity of a FI to extreme yet plausible portfolio shocks (Hilbers et al., 2004). Therefore, microprudential stress tests are, by nature, forward-looking tools: they aim to assess a bank's capital or liquidity adequacy against portfolio risks, and to enable regulators to enforce measures if the bank fails (Adrian et al., 2020; Llorent-Jurado et al., 2024).

From a system-wide perspective, macroprudential stress tests safeguard financial stability by identifying vulnerabilities and assessing the banking sector's resilience to shocks. They evaluate whether FIs have sufficient capital and liquidity to absorb losses without disrupting essential functions (Adrian et al., 2020; Quagliariello, 2009b; Schinasi, 2003).

These vulnerabilities may include excessive leverage, asset mispricing, risk concentration, and inadequate liquidity management, all of which can amplify the effects of financial disturbances (Adrian et al., 2020). The possibility that such vulnerabilities may undermine the stability of the financial system constitutes systemic risk. International Monetary Fund et al. (2009) define systemic risk as "a risk of disruption to financial services caused by impairment of all or parts of the financial system, with potential serious negative consequences for the real economy". If systemic risk materialises, it may develop into a systemic crisis through the interaction of an initial shock and contagion effects. The initial shock may be idiosyncratic, affecting a single asset or FI, or systemic, affecting the financial system more broadly. Contagion channels may then transmit and amplify its effects across institutions and markets (Quagliariello, 2009a). Accordingly, the analytical scope of a macroprudential stress test depends on whether it assesses only the direct impact of the initial shock or also captures its propagation through contagion channels.

Macroprudential stress-test design involves a trade-off between analytical completeness and practical feasibility. Excluding feedback loops narrows the analysis, while incorporating them is often constrained by data limitations and uncertainty over behavioural responses under stress (Quagliariello, 2009b). Despite these constraints, authorities use

macroprudential stress tests to calibrate policy instruments and strengthen early identification of systemic vulnerabilities and crisis severity (Llorent-Jurado et al., 2024). Their robustness therefore depends on a clear understanding of underlying vulnerabilities, potential triggers, and propagation channels (Quagliariello, 2009a).

In terms of shock specification, stress tests may be conducted through sensitivity or scenario analysis. Sensitivity tests examine how outcomes change when one risk factor is altered while the others are kept unchanged. This makes them simple and transparent, but less suitable for capturing interactions between risks or wider systemic effects. Scenario tests, by contrast, apply multiple simultaneous shocks – such as a stock market crash, an emerging market crisis, an interest rate shock, or a widening of credit spreads – to assess the resilience of FIs under adverse conditions (Committee on the Global Financial System, 2001; Quagliariello, 2009b).

Scenario analyses may be further classified by origin, structure, and severity. In terms of origin, historical scenarios reproduce shocks observed during past crises, whereas hypothetical scenarios are based on plausible events that have not previously occurred (Committee on the Global Financial System, 2001). In terms of structure, risk factors may be applied as a set of combined shocks or linked coherently through a macroeconomic model (Oura & Schumacher, 2012). In terms of severity, scenarios usually include a baseline projection, which reflects expected economic conditions and provides a benchmark, and, at least, one adverse scenario designed to assess resilience under aggravated stress (Llorent-Jurado et al., 2024).

Regarding the dimension of financial resilience assessed, stress tests may focus on either solvency or liquidity. Solvency refers to a bank's ability to maintain sufficient capital relative to its liabilities over different time horizons (de Bandt et al., 2020; Oura & Schumacher, 2012), whereas liquidity concerns its ability to meet immediate obligations without incurring unacceptable losses (Bank for International Settlements, 2010b; de Bandt et al., 2020). Although conceptually distinct, the two are closely interconnected: persistent liquidity shortages may force banks to obtain costly funding or sell assets at depressed prices, thereby eroding equity and ultimately giving rise to solvency problems (de Bandt et al., 2020). Although liquidity and solvency risks are interconnected, this dissertation focuses exclusively on solvency stress testing because the available data do not allow a sufficiently robust modelling of liquidity channels.

Regarding the level of analysis and data used, stress tests may follow a bottom-up or top-down approach. In bottom-up stress tests, individual FIs assess the impact of a common macroeconomic scenario on their own balance sheets, typically using internal models and institution-specific data. The resulting losses and capital impacts may then be aggregated to evaluate the resilience of the financial system as a whole (Hilbers et al., 2004; Tressel et al., 2022).

The main advantage of the bottom-up approach is its high granularity, as FIs can draw on detailed portfolio data and institution-specific models. However, it is resource-intensive, may require additional analysis of second-round effects to capture interbank interdependencies, is less suited to highly complex scenarios, and can produce results that are difficult to compare due to differences in modelling assumptions across institutions (International Monetary Fund and the World Bank, 2005).

Top-down stress tests are typically conducted by supervisory authorities or researchers using common models and supervisory data, providing a broad, "bird's eye view" of the banking sector (Tressel et al., 2022). Uniform macroeconomic shocks are applied across FIs, with systemic risk primarily attributed to common economic factors (Chan-Lau, 2013; Hilbers et al., 2004).

Although top-down approaches generally offer greater comparability and a broader systemic perspective, their reliance on aggregated data provides less institution-specific detail than bottom-up testing (Čihák, 2005). In practice, however, the distinction is not always clear-cut, as many stress testing exercises combine elements of both top-down and bottom-up approaches, as discussed below in Section 3.

Stress tests can also be classified by the type of data used. Balance-sheet stress tests rely on accounting information, including financial soundness indicators, to estimate the impact of shocks on variables such as non-performing loans (NPL), provisions, and capital ratios (Aikman, 2023; Moretti et al., 2008). Their main advantage is the use of detailed information on banks' financial positions. However, their reliance on historical data makes them backward-looking and may limit their ability to capture changes in asset composition and quality over time (Aikman, 2023).

Market-based stress tests use financial market data, such as equity prices, volatility measures, and credit spreads, to incorporate forward-looking investor expectations and capture the risk of self-fulfilling crises (Moretti et al., 2008). Their main advantage is the

ability to provide early-warning signals based on current market perceptions. However, market indicators may misprice risk, be distorted by illiquidity, and be unavailable for privately held institutions (Chan-Lau, 2013).

Within balance-sheet stress testing, a further distinction concerns how FIs are assumed to respond over the projected horizon. Dynamic stress tests allow adjustments to portfolios, lending, funding, and risk exposures, whereas static tests assume that the size and composition of balance sheets remain unchanged (Llorent-Jurado et al., 2024). The static approach is simple and transparent but may become unrealistic under severe or prolonged shocks, when FIs adjust lending, portfolios, or funding and public authorities intervene. Dynamic approaches capture these behavioural and policy responses, including procyclical effects through which financial and real-economy distress reinforce one another (Quagliariello, 2009b).

A final dimension concerns the types of risk incorporated into the analysis, most commonly credit, market, and liquidity risks, as well as contagion effects. Table 1 summarises their balance-sheet impacts and treatment within stress testing frameworks.

| Risk Type | Origin and Balance-Sheet Impact | Stress Test Inputs | Projected Outcomes |
|---|---|---|---|
| Credit Risk | • A borrower's or counterparty's failure to meet its contractual obligations.<br>• Increase in NPL, impairments, and provisions; reduction of interest income and capital; increase of Risk-weighted Assets (RWA) and capital requirements. | • Macroeconomic shocks translated through satellite models into probability of default (PD), loss given default (LGD), and exposure at default (EAD).<br>• NPL and provisioning ratios may be used when granular data are unavailable. | • Credit losses.<br>• RWAs.<br>• Capital requirements and capital ratios. |
| Market Risk | • Adverse movements in interest rates, credit spreads, exchange rates, equity prices, or commodity prices.<br>• Lower asset values and net interest income (NII), higher trading losses, and reduced capital. | • Shocks to interest rates, spreads, exchange rates, and asset prices.<br>• Applied to banks' trading and banking-book positions. | • Valuation and trading losses.<br>• Changes in NII.<br>• Impact on capital. |

| Risk Type | Origin and Balance-Sheet Impact | Stress Test Inputs | Projected Outcomes |
|---|---|---|---|
| Liquidity Risk | • Inability to meet payment and funding obligations when due without costly funding or asset sales at depressed prices.<br><br>• Depletion of liquidity buffers, asset sales, balance-sheet contraction, and potential capital erosion. | • Stressed cash inflows and outflows.<br><br>• Funding run-off and rollover rates.<br><br>• Haircuts on liquid assets. | • Liquidity shortfalls.<br><br>• Survival horizons. |
| Contagion Effects | • Transmission of distress across institutions or markets through counterparty exposures, funding relationships, or common asset holdings.<br><br>• Counterparty losses, funding withdrawals, higher funding costs, fire-sale losses, and reduced liquidity and capital. | • Initial defaults.<br><br>• Funding withdrawals.<br><br>• Fire-sale shocks.<br><br>• Interbank exposures, funding networks, and common asset holdings. | • Second-round losses.<br><br>• Liquidity and capital effects.<br><br>• Amplification of the initial shock. |

**Source:** Author's elaboration based on Bank for International Settlements (2010b), Moretti et al. (2008), Oura and Schumacher (2012).

**Table 1 - Financial Risk Types: Balance-Sheet Impacts and Stress Testing Approaches**

The methodological alternatives discussed above represent design choices that depend on the purpose of the exercise, the risks assessed, data availability, and the institutional context. Framework design therefore requires balancing transparency and realism, as greater comprehensiveness typically demands more data and modelling capacity. These choices, together with the underlying assumptions and expert judgment, shape the framework's ability to identify vulnerabilities, assess institutional and system-wide resilience, and inform financial-stability policy (Hilbers et al., 2004; Quagliariello, 2009a, 2009b). Stress-test outcomes should not be interpreted as precise forecasts or crisis predictions (Quagliariello, 2009b), but as approximate assessments of how portfolios may evolve under a specified set of assumptions (Hilbers et al., 2004).

## 3. Stress Testing Initiatives

In this section, we describe the main initiatives on stress testing and the data relevant for stress testing, in a historical context. We first describe approaches employed before the GFC, and then focus particularly on the evolution of stress testing practices thereafter.

### 3.1. Pre-Great Financial Crisis Stress Testing

Before the GFC, the evolution of stress testing was closely linked to the broader development of international capital regulation. The 1982 international debt crisis, involving countries such as Mexico, Argentina, and Brazil, exposed significant capital shortages in major international banks and contributed to the regulatory concerns that eventually led to Basel I. Issued in 1988, Basel I introduced a minimum capital requirement of 8% of RWA, with the objective of strengthening the stability of the international banking system and harmonising regulatory standards across countries (Basel Committee on Banking Supervision, 1988; Goodhart, 2011). The framework was subsequently refined in 1991, 1995, and 1996, when a more noteworthy development occurred: the Market Risk Amendment, which introduced the first formal reference to stress testing by allowing banks to use internal models, including Value-at-Risk, to determine capital charges for market risk (Goodhart, 2011; Schuermann, 2014).

Following the Asian financial crisis, the IMF and World Bank launched the Financial Sector Assessment Program (FSAP) in the late 1990s. The 1982 crisis showed that distress could spread across institutions and countries, exposing the limits of institution-level assessments. The FSAP therefore adopted a system-wide approach to identifying macrofinancial vulnerabilities, assessing resilience to shocks and contagion, evaluating regulatory and crisis-management frameworks, and recommending measures to strengthen financial stability. It also encouraged national authorities to develop their own system-wide stress-testing methodologies (Anderson et al., 2018; International Monetary Fund, 2006).

Despite these regulatory advances, pre-GFC stress testing remained fragmented and institution-specific, with differences in shock magnitudes, time horizons, and modelling assumptions limiting comparability across banks and jurisdictions. Tests also focused mainly on specific downside risks rather than broader systemic scenarios. Moreover, the use of results was largely discretionary, with identified vulnerabilities typically addressed through further investigation, hedging, or gradual exposure reductions rather than automatic corrective measures (Committee on the Global Financial System, 2001).

Basel II, introduced in 2004, sought to improve the risk sensitivity of capital regulation by aligning capital requirements more closely with banks' actual risk profiles. The framework was organised around three pillars: minimum capital requirements based on more sophisticated RWA calculations under Pillar 1, supervisory review of internal capital adequacy under Pillar 2, and market discipline through greater transparency under Pillar 3 (Banco de Portugal, 2004, 2008b; Bank for International Settlements, 2006).

It is now recognised that pre-GFC stress testing frameworks failed to reveal key systemic vulnerabilities. One important limitation was the lack of comparability across jurisdictions, as European banks increasingly relied on Basel II risk weights while US banks continued to operate largely under Basel I rules (Schuermann, 2014). Other limitations were that these models underestimated liquidity risk, funding fragility, and implicit guarantees, including step-in risk, thereby failing to capture banks' exposure to funding and market shocks (Bank for International Settlements, 2010b).

### 3.2. Post-Great Financial Crisis Stress Testing

The GFC showed that traditional stress tests, often focused on firm-specific risks and isolated shocks, were poorly suited to capturing simultaneous cross-market disruptions, systemic interactions, and behavioural responses by other institutions (Bank for International Settlements, 2010b). These limitations highlighted the need for more comprehensive, forward-looking, and system-wide stress testing frameworks.

In Europe, this shift materialised in 2009 when the Committee of European Banking Supervisors (2009) required FIs to run stress tests under three scenarios: an idiosyncratic scenario specific to each institution, a market-wide scenario affecting the broader economy, and a combined scenario incorporating both types of shocks. These macroprudential stress tests were important for assessing bank resilience, but also for supporting the calibration of policy tools such as debt caps, counter-cyclical margins, and liquidity thresholds, ensuring that interventions remain proportionate to systemic risks (Constâncio, 2017).

Some of the main post-GFC stress testing initiatives conducted by supervisory authorities, international institutions and researchers were the following.

#### EU-wide stress test

The first EU-wide stress test, conducted in 2011, was carried out under Basel II using a constrained bottom-up approach, whereby FIs applied internal models within a common

methodology and set of assumptions to ensure consistency (European Banking Authority, 2011b). The ECB provided the adverse scenario, while the European Commission supplied the baseline based on its 2010 forecasts. The exercise assumed static balance sheets, with zero growth and no management actions during the projection period. Since 2023, the static balance-sheet assumption has been retained, but maturing assets and liabilities are replaced by similar instruments, while scenario-driven changes in risk parameters, income, losses, risk-weighted exposures, and capital are allowed (European Banking Authority, 2023, 2025).

The 2011 test assessed resilience using a 5% Core Tier 1 (CT1) capital ratio benchmark. CT1 focused on high-quality capital, mainly ordinary shares, excluding hybrid instruments, which reduced reported Tier 1 capital by 17% in Portuguese banks (Banco de Portugal, 2011b). Government-supported hybrids were temporarily accepted, making CT1 a transitional measure before Basel III's Common Equity Tier 1 (CET1) standard, with a 4.5% minimum phased in between 2013 and 2015 (Bank for International Settlements, 2010a). CET1 quality was further strengthened through deductions for goodwill, intangible assets, participations in other FIs, securitisation positions, and Internal Ratings-Based (IRB) provision shortfalls, ensuring that it reflected genuinely loss-absorbing capital (Banco de Portugal, 2011a; European Banking Authority, 2011a).

By 2014, the EU-wide stress testing framework had fully adopted CET1 definitions. Government support measures were phased out, while hybrid instruments counted as contingent capital only if convertible into CET1 under predefined triggers. Banks were assessed against thresholds of 8% in the baseline scenario and 5.5% in the adverse scenario, with shortfalls prompting supervisory measures such as capital plans, dividend restrictions, or deleveraging (European Banking Authority, 2014).

In the following exercises, from 2016 to 2025, EU-wide stress testing shifted from fixed CET1 pass-or-fail thresholds toward a more risk-sensitive supervisory tool. Supervisors increasingly assessed results considering macroeconomic conditions, institution-specific risk profiles, and bank-specific capital buffers (European Banking Authority, 2016, 2017, 2023, 2025).

**Stress-Test Analytics for Macroprudential Purposes in the Euro area (STAMP€)**

To overcome the limitations of traditional static micro stress tests, the ECB introduced STAMP€ in 2017, a top-down framework combining bank-level resilience assessment with

system-wide macroprudential analysis. It enables the ECB to assess both individual bank solvency and the broader financial-stability implications of stress (Dees et al., 2017).

STAMP€ starts from a baseline or adverse macro-financial scenario, which satellite models translate into bank-level effects on credit and market risk, NII, loan losses, fees, and operational risk. These estimates feed into balance-sheet and profit-and-loss (P&L) projections to derive profitability, capital, RWA, and solvency measures, including the CET1 ratio (Dees et al., 2017).

A key contribution of STAMP€ is its ability to move beyond static balance sheets by incorporating dynamic bank responses, second-round macroeconomic feedback, and contagion channels. This allows it to capture how deleveraging affects credit supply and the real economy, and how distress spreads through interbank and cross-sector linkages (Dees et al., 2017).

Unlike EU-wide stress tests, which are large periodic supervisory exercises, STAMP€ is used internally by ECB staff as a modular infrastructure for ongoing macroprudential monitoring. Its top-down structure provides a more continuous view of financial stability and can be extended to areas such as solvency-liquidity interactions, shadow banking, central clearing counterparties, and borrower solvency (Dees et al., 2017).

Although its modular structure allows each risk channel to be modelled using appropriate tools, the STAMP€ modules are often linked sequentially rather than being fully integrated (Budnik et al., 2020; Dees et al., 2017). As a result, feedback loops may require repeated iterations across models, potentially creating inconsistencies and limiting the framework's ability to fully capture amplification mechanisms.

**Banking Euro Area Stress Test (BEAST)**

Building on the limitations of modular frameworks such as STAMP€, the ECB introduced BEAST in 2020 to jointly model feedback loops between the real economy and the financial system. BEAST is a large-scale, semi-structural, top-down framework that uses granular bank-level data and a common methodology to assess euro-area banking-sector resilience from a macroprudential perspective (Budnik et al., 2020).

BEAST includes a macroeconomic module based on Structural Panel Vector Autoregression models for 19 EA economies. Each country model comprises key real, financial, and banking variables, including output, unemployment, inflation, property prices,

interest rates, equity prices, trade variables, lending rates, and loan volumes. These country models are linked through trade spillovers, allowing shocks in one economy to affect others through changes in foreign demand and prices (Budnik et al., 2020).

The main contribution of BEAST lies in its modelling of potential credit tightening. Bank lending changes are decomposed into normal demand-driven effects and non-linear supply-driven effects resulting from banks' own financial constraints. When banks face capital shortfalls, rising NPL, or pressure to reduce exposures, they may restrict credit more aggressively. BEAST aggregates this bank-level deleveraging into a country-level credit supply shock, which feeds back into the macroeconomic block by tightening credit conditions, reducing lending, increasing borrowing costs, and weakening economic activity. This deterioration, in turn, further affects bank asset quality and capital, generating a feedback loop between banks and the real economy (Budnik et al., 2020).

When applied to the 2018 EU-wide stress test, BEAST showed that incorporating dynamic feedback effects produces higher system-wide capital depletion than the standard constant balance-sheet approach. This result highlights how banking-sector stress can amplify an initial downturn and contribute to a deeper systemic crisis (Budnik et al., 2020).

**Global Bank Stress Test (GST)**

The GST framework, introduced by the IMF in 2020, is a top-down solvency stress testing methodology based on publicly available data (International Monetary Fund, 2020). It was initially developed to assess the impact of the COVID-19 pandemic on 29 major banking systems and to support cross-country surveillance of banking-sector vulnerabilities (Tressel et al., 2022).

GST differs from traditional supervisory stress tests because it does not rely on granular, non-public portfolio data. Instead, it uses aggregated bank-level information to capture broad balance-sheet dynamics across countries. This design facilitates international comparisons and enables the framework to cover banking systems for which detailed supervisory data may not be available. The reliance on public data limits its ability to capture institution-specific exposures, borrower characteristics, and national policy measures with the same precision as domestic supervisory exercises. For this reason, GST should be viewed as a complement to the FSAP and national supervisory stress testing exercises –, which provide more in-depth country assessments –, rather than as a substitute for them. (Tressel et al., 2022).

The framework projects banks' CET1 capital ratios over a three-year horizon by translating macro-financial scenarios into changes in profitability, credit losses, capital, and RWA. The baseline scenario is generally based on IMF World Economic Outlook (WEO) forecasts, while the adverse scenario reflects a severe deterioration in economic activity. Bank-level outcomes are estimated using econometric models linking income and loss components to macro-financial variables, allowing the framework to assess how economic stress affects banks' capital positions (Tressel et al., 2022).

The main contribution of GST lies in its ability to combine broad international coverage with a consistent and relatively simple methodology. Although it provides a less detailed assessment than a national supervisory stress test, it can identify vulnerable banks and banking systems that may not be evident from domestic analyses alone. GST therefore provides a useful global benchmark and illustrates the value of combining complementary stress testing frameworks, as no single model or dataset can fully capture the transmission and amplification of systemic risk (Anderson et al., 2018; Tressel et al., 2022).

**Capital and Loss Assessment under Stress Scenarios (CLASS) model**

The CLASS model is another top-down stress testing framework based on publicly available regulatory data. Developed primarily by researchers at the Federal Reserve Bank of New York, it was designed as a research and macroprudential tool rather than as an official supervisory stress test. Its purpose is to assess how adverse macroeconomic conditions may affect the profitability, credit losses, capital ratios, and potential capital shortfalls of US commercial banks and bank holding companies (Hirtle et al., 2016).

As in GST, the macroeconomic scenario is treated as an external input. CLASS does not generate macroeconomic dynamics internally; instead, it takes assumed paths for variables such as GDP growth, unemployment, house prices, equity prices, interest rates, and credit spreads. The consistency between these variables must therefore come from the scenario design itself (Hirtle et al., 2016).

A notable feature of CLASS is its ability to distinguish between different sources of bank income and credit risk. Rather than treating banks' activities as a single aggregate exposure, the model accounts for differences across major lending categories and securities holdings. It can therefore capture, for example, how falling property prices may affect real estate lending or how rising unemployment may increase losses on consumer credit. These

effects are combined to project banks' net income, regulatory capital, capital ratios, and any shortfall relative to a selected capital threshold (Hirtle et al., 2016).

The main contribution of CLASS lies in the transparency with which it connects macroeconomic stress to bank-level capital outcomes using public data. This makes the framework useful for research, policy analysis, and the independent assessment of banking-sector resilience. However, its reliance on simplified behavioural and balance-sheet assumptions limits its ability to reflect institution-specific strategies and adjustments under stress. CLASS therefore illustrates the trade-off between transparency and broad applicability, on the one hand, and the greater precision offered by granular supervisory models, on the other (Hirtle et al., 2016).

**Recent Developments in IMF Top-Down Solvency Stress Testing**

A recent contribution by Santos (2026) develops a top-down solvency stress test for 91 systemically important EA banks. The framework follows the broad architecture of top-down stress testing models, such as GST and CLASS, in which macroeconomic shocks affect bank solvency through profitability, retained earnings, credit risk, RWA, and regulatory capital ratios.

The model operates through two main channels. The first is the profitability channel, which affects the numerator of the capital ratio through projected income-statement components and retained earnings. Santos (2026) estimates profitability using dynamic panel-data methods, allowing bank performance to depend on past profitability and macroeconomic variables such as output growth, unemployment, interest rates, and inflation.

The second is the credit-risk channel, which affects the denominator of the capital ratio through changes in RWA. Using detailed Pillar 3 information on EAD, PD, LGD, and expected losses, Santos (2026) models how deteriorating credit conditions raise risk weights and capital requirements, similarly to the GST framework.

The main methodological contribution of Santos (2026) lies in extending the Basel asymptotic single-risk-factor credit-risk framework by relaxing the normality assumption for idiosyncratic risk. By introducing Skew-Normal and Transmuted-Normal distributions, the model improves the alignment between theoretical Basel risk weights and disclosed IRB RWA. This is particularly relevant when regulatory adjustments, such as Single Supervisory Mechanism (SSM) supporting factors, infrastructure supporting factors, and credit

guarantees, affect reported exposures. The framework can therefore capture deviations in risk weights without mechanically changing PD, LGD, or EAD.

### 3.3. Bank Data Initiatives

Empirical research on stress testing depends on the availability, quality, and comparability of bank data. This subsection reviews the public, commercial, and research-accessible datasets available to researchers, rather than the confidential regulatory and supervisory information used by authorities in official stress-testing exercises.

Since the GFC, several initiatives aimed to improve access to granular information on banks' exposures, interconnections, and risk transmission channels. In the EU, trade repository data collected under the European Market Infrastructure Regulation have improved access to information on over-the-counter derivatives, helping researchers identify how derivative exposures connect FIs. Some countries have also made credit registers available for research, providing granular supervisory data that may be used to detect early signs of financial stress. At the international level, the Bank for International Settlements (BIS) provides statistics on cross-border banking activities, although these data remain relatively aggregated and may not fully capture detailed asset and liability structures (Anderson et al., 2018).

The IMF/FSB/G20 Data Gaps Initiative has also contributed to improving the availability of crisis-relevant data after the GFC. Nevertheless, building databases capable of fully capturing contagion and systemic interconnections remains difficult, as financial linkages are complex, dynamic, and often only partially observable. Consequently, researchers may need to combine several data sources to examine how stress can spread across institutions and financial sectors (Anderson et al., 2018).

Commercial databases provide an additional source of information for empirical research. Databases such as Bankscope contain bank-level financial statements, ratings, and other institutional information, while services such as TOTEM can support the assessment of derivatives valuations. These sources may facilitate cross-country comparisons and analyses of market interactions, particularly when access to supervisory data is restricted. However, they are not substitutes for confidential supervisory information and may be limited in terms of granularity, geographic coverage, and data quality (Anderson et al., 2018).

For Portugal, a particularly relevant source is the Historical Series of the Portuguese Banking Sector[1] by Banco de Portugal (BdP), available for academic research through the Banco de Portugal Microdata Research Laboratory (BPLIM). This dataset provides accounting and prudential information that is valuable for empirical analysis, including stress testing applications. However, access is subject to confidentiality restrictions. Since the data are anonymised and protected by statistical and banking secrecy, results must be reported without revealing institution-level information (Banco de Portugal Microdata Research Laboratory, 2026).

[1] Banco de Portugal, Historical Series of the Portuguese Banking Sector (SLB), https://doi.org/10.17900/SLB.Sep2025.V1

## 4. Historical Context of Portuguese Banking

In the years preceding the GFC, the Portuguese banking system was generally considered resilient, despite the presence of some vulnerabilities (Banco de Portugal, 2004, 2005, 2006; International Monetary Fund, 2006). The Banco de Portugal (BdP) repeatedly highlighted high private-sector indebtedness and concentrated credit exposures, as well as banks' dependence on wholesale funding (Banco de Portugal, 2004, 2008b; International Monetary Fund, 2010). These risks were nevertheless considered manageable given the banks' existing capital buffers, the predominance of mortgage lending in household credit and the collateral associated with these exposures, and the historically low default rates of important borrower groups (Banco de Portugal, 2004, 2005, 2008b; International Monetary Fund, 2006). Thus, the pre-crisis assessments did not overlook the main sources of vulnerability but instead understood them as contained within an otherwise resilient banking system.

The gradual introduction of stress testing was consistent with the view that the Portuguese banking sector was overall resilient. In 2004, BdP relied primarily on solvency, liquidity, and historical performance indicators rather than bank-specific stress tests, concluding that the banking system remained resilient despite high household and corporate indebtedness (Banco de Portugal, 2004). In 2005, BdP introduced a credit-risk stress test based on a severe international recession scenario. Although the exercise projected a marked increase in corporate default probabilities, particularly among large firms, the resulting losses were deemed manageable given historically low default rates (Banco de Portugal, 2005). Later, a more comprehensive exercise was conducted in 2006 under the IMF FSAP, combining bottom-up and top-down stress tests across adverse macroeconomic scenarios. Its results indicated that Portuguese banks could withstand severe shocks without breaching regulatory capital requirements. Non-financial corporations were identified as the main source of credit risk, while mortgage collateral recovery rates were expected to contain losses on household lending. The IMF consequently assessed the Portuguese financial system as sound, well managed, and competitive (Banco de Portugal, 2006; International Monetary Fund, 2006).

The onset of the GFC initially appeared to validate these favourable assessments. In 2007, BdP described the international financial turmoil as a "real-life" stress test and argued that Portuguese banks had demonstrated a significant capacity to adapt to the emerging

liquidity and subprime crises (Banco de Portugal, 2007). However, the operating environment had deteriorated markedly. Corporate credit risk increased, profitability weakened, and access to wholesale funding tightened. Banks partly offset these pressures by attracting customer deposits, but reliance on ECB financing and State-guaranteed debt rose. Aggregate pre-tax profits fell by about 40%, while the Tier 1 ratio stood at 7.5% at year-end, prompting BdP to recommend further capital strengthening (Banco de Portugal, 2008a, 2008b). The early stages of the crisis therefore showed that resilience to the initial external shock did not eliminate the funding, profitability and capital vulnerabilities that had already been identified in earlier assessments.

At the same time, difficulties at some individual FIs exposed an important limitation of relying primarily on favourable system-wide indicators. BPN was nationalised in late 2008 and its management replaced, while BPP was placed under provisional administration and received a €450 million loan from six Portuguese banks backed by a state guarantee. More broadly, the government made up to €20 billion available for guarantees on bank debt and capital support, with approximately €5 billion of the guarantee facility in use by November 2009 (Banco de Portugal, 2008b; International Monetary Fund, 2010). BPP's banking licence was subsequently withdrawn in April 2010, and the institution entered liquidation (European Commission, 2010). These interventions demonstrated that relatively favourable aggregate indicators could coexist with severe institution-specific weaknesses requiring direct public intervention.

At the height of the GFC, Portugal was initially less affected than several other banking systems. The IMF attributed this relative resilience to banks' limited exposure to complex financial products, retail-oriented business models, and the absence of a major domestic property-price bubble. However, it also highlighted rising leverage, heavy reliance on wholesale funding, relatively low capital ratios, and increasing credit risk, particularly among non-financial corporations (International Monetary Fund, 2010). The ECB similarly noted that Portuguese residential property prices had remained comparatively stable, in contrast to the sharp corrections experienced in countries such as Ireland and Spain (European Central Bank, 2009). Portugal, therefore, entered the next phase of the crisis without major property-related losses, but with vulnerabilities concentrated in bank funding, private-sector indebtedness, and relatively weak capital positions.

These vulnerabilities became increasingly important as the GFC evolved into the sovereign debt crisis. From early 2010, the repricing of Portuguese sovereign risk raised banks' funding costs and increasingly constrained access to international debt markets. The subsequent fiscal consolidation and private-sector adjustment simultaneously weakened the domestic economy, heightening credit and market risks. BdP therefore placed greater emphasis on the interaction between sovereign risk, bank funding conditions, and macroeconomic deterioration (Banco de Portugal, 2010). However, the extent of these vulnerabilities was not immediately reflected in market perceptions. Antunes and Silva (2010) applied a Merton model to the three largest listed Portuguese banks and found that market-implied PD remained low during most of the period, suggesting that investors continued to perceive Portuguese banks as relatively resilient.

In April 2011, amid mounting sovereign-market tensions and increasingly restricted access to market financing, Portugal requested international financial assistance, which led to the establishment of the Economic and Financial Assistance Programme (EFAP). For the banking sector, the programme required gradual deleveraging, stronger liquidity and capital positions and more intensive supervision. Minimum CT1 ratios were raised to 9% by the end of 2011 and 10% by the end of 2012, at a time when access to international wholesale funding had become severely constrained (Banco de Portugal, 2011b).

Yet the 2011 EU-wide stress test continued to produce relatively reassuring results concerning solvency. Portuguese banks were subjected to a severe adverse scenario that included a cumulative GDP contraction of 5.5% over 2011–2012, unemployment of around 13%, falling residential and commercial property prices and a sovereign-spread shock affecting the value of government bonds held by banks. The exercise concluded that the participating Portuguese banks could absorb these shocks, partly given capital-strengthening measures already undertaken. Yet, the broader assessment surrounding the exercise was considerably less reassuring: credit and market risks were at historically high levels, profitability was at historical lows, and further capital reinforcement and deleveraging remained necessary (Banco de Portugal, 2011c). The Portuguese experience thus illustrates how favourable stress-test solvency results could coexist with substantial vulnerabilities and an increasingly intervention-dependent banking system.

The crisis also reshaped the assessment of banking resilience. From 2011 onward, stress testing became more frequent and was integrated with higher capital requirements,

deleveraging targets, portfolio inspections, and external validation (Banco de Portugal, 2011b, 2011c, 2012a). Under the EFAP, BdP conducted regular stress tests to monitor the solvency and deleveraging of major Portuguese banking groups. The framework therefore moved beyond assessing capital ratios under hypothetical shocks towards a broader evaluation of banks' balance-sheet vulnerabilities, including credit exposures, asset quality, and funding conditions (Banco de Portugal, 2006, 2011c, 2012a).

Supervision under the EFAP moved beyond periodic solvency exercises towards a more intrusive assessment of banking-sector resilience. Stress tests were conducted regularly and complemented by the Special Inspections Programme (SIP), which independently reviewed credit portfolios, capital calculations, data, and methodologies within the eight largest domestic banking groups (Banco de Portugal, 2012a). These supervisory measures, combined with recapitalisation, deleveraging targets, and Eurosystem liquidity support, contributed to a visible improvement in conventional indicators of resilience. The average CT1 ratio increased to 9.6% at the end of 2011 and to 11.3% by June 2012. Structural liquidity also improved as banks attracted deposits, reduced leverage, and became less reliant on short-term market funding, while some institutions regained access to international debt markets during late 2012 (Banco de Portugal, 2012a, 2012b).

This adjustment, however, required substantial public support. Gross State recapitalisation during the 2011–2014 programme amounted to approximately €7.3 billion[2]. In 2012, support was provided to Caixa Geral de Depósitos (CGD), Banco Comercial Português (BCP) and Banco Português de Investimento (BPI), while Banco Internacional do Funchal (Banif) received additional support in early 2013. Specifically, CGD received approximately €1.7 billion, BCP €3.0 billion and BPI €1.5 billion, while Banif subsequently received €1.1 billion. Some of these instruments were later repaid by the beneficiary banks. Importantly, these recapitalisation needs should not be interpreted exclusively as losses that earlier assessments had failed to identify, since they also reflected the introduction of more demanding regulatory capital requirements during the adjustment programme (European Commission, 2016).

[2] After the end of the EFAP, further interventions were required. In particular, the €4.9 billion capitalisation of Novo Banco following the resolution of BES in 2014 was largely financed through borrowing by the Resolution Fund from the State. Similarly, the 2015 resolution of Banif involved a €2.25 billion public support package, including a €1.77 billion capital injection by the State and a €489 million loan to the Resolution Fund. See more in https://economy-finance.ec.europa.eu/system/files/2022-08/ip040_en.pdf.

By 2013, the Portuguese banking system had improved solvency and liquidity and reduced leverage, while easing market tensions restored some access to debt funding. However, profitability and asset quality remained weak, with NPLs rising particularly among non-financial corporations. More intrusive supervision also uncovered vulnerabilities not fully reflected in headline capital ratios, including €861 million in additional impairment needs related to construction, real-estate development, and tourism exposures. Meanwhile, the emerging Banking Union began shifting responsibility for assessing major banks' resilience towards the ECB (Banco de Portugal, 2013b).

Overall, the Portuguese experience highlights the difference between identifying vulnerabilities and assessing their systemic consequences. Before the GFC, BdP and the IMF had already flagged high private-sector indebtedness, concentrated credit exposures, wholesale funding dependence, and corporate credit risk (Banco de Portugal, 2004, 2005, 2006, 2008b; International Monetary Fund, 2006). Stress-testing exercises also explicitly considered severe macroeconomic shocks and recognised non-financial corporations as an important source of credit risk (Banco de Portugal, 2005, 2006; International Monetary Fund, 2006). There was no failure in detecting these vulnerabilities, but in repeatedly stating that they remained manageable within a resilient system. The crisis later showed how such vulnerabilities could interact with external shocks, sovereign stress, weak economic activity, and restricted funding access (Banco de Portugal, 2007, 2008b, 2010, 2011b).

The post-2011 framework strengthened supervisory scrutiny (Banco de Portugal, 2012a, 2013a), but important limitations remained. The European Commission's *ex-post* evaluation subsequently concluded that the initial programme stress tests omitted relevant market and liquidity risks and underestimated loan-portfolio deterioration under a more severe downturn (European Commission, 2016). This is notable because the 2011 EU-wide stress test had already applied a highly adverse scenario while concluding that Portuguese banks could absorb the shocks (Banco de Portugal, 2011c). Its favourable solvency results therefore did not fully capture broader fragilities that later became apparent and required recapitalisation, Eurosystem support, deleveraging, and intensive supervision (Banco de Portugal, 2012a, 2012b, 2013b; European Commission, 2016). The Portuguese experience therefore motivates examining whether a simplified top-down stress-testing framework, applied retrospectively using information available at the time, could have revealed banking-sector vulnerabilities before they materialised.

## 5. Method and Data

This dissertation assesses whether a simplified top-down solvency stress test could have identified vulnerabilities in the Portuguese banking sector during the sovereign debt crisis and the Economic and Financial Adjustment Programme (EFAP). It applies a simplified top-down solvency stress test combining bank-level accounting and prudential data with historical and scenario-based macro-financial information. The approach draws on the GST and CLASS frameworks, adapting their core principles to the frequency, scope, and granularity of the available Portuguese data.

### 5.1. Research Design and Projection Horizon

The stress test estimates historical relationships over 2000-2010, with 2010 as the final observed balance-sheet position and projection starting point. Bank outcomes are then projected recursively for 2011–2012 under exogenously specified baseline and adverse macroeconomic scenarios. Observed macroeconomic and bank data for 2011–2012 are excluded from estimation and used only for descriptive comparison and *ex-post* benchmarking. Pre-2000 observations are excluded because the transition to the euro arguably represents a structural break in the banking environment and macro-financial relationships.

Given the limited data available, this exercise focuses on the transmission of macroeconomic conditions to bank solvency through their effects on profitability and retained earnings, which affect the numerator of the Tier 1 capital ratio. RWA, by contrast, are projected under a common exogenous growth assumption across scenarios and therefore do not provide a scenario-specific transmission channel. Relative to more comprehensive stress-testing frameworks discussed in Section 3, such as BEAST or Santos (2026), this exercise does not explicitly model liquidity risk, market-price feedback effects, cross-border spillovers, PD or LGD dynamics, endogenous management responses, or scenario-dependent changes in RWA density (RWA-to-total-assets ratio).

### 5.2. Data

The stress testing exercise requires two categories of data: macro-financial variables and individual bank data. For the macro-financial variables, we use historical data (2000-2010) and scenario projections (2011-2012) for real GDP growth, the unemployment rate, Harmonized Index of Consumer Prices (HICP) inflation, and the 3-month EURIBOR. Tables 2 and 3 report the corresponding data sources.

| Variable | Data Source |
|---|---|
| Real GDP growth | OECD |
| Unemployment rate | IMF WEO database |
| HICP Inflation rate | Banco de Portugal (BPstat) |
| 3-month EURIBOR | Bloomberg |

**Source:** Organisation for Economic Co-operation and Development (OECD, 2023), OECD Economic Outlook No. 114 (Edition 2023/2), OECD Data Explorer, https://data-explorer.oecd.org/; International Monetary Fund (IMF, 2025), World Economic Outlook (WEO), IMF Data Explorer,https://data.imf.org/en/Data-Explorer?datasetUrn=IMF.RES:WEO(9.0.0)&INDICATOR=LUR&COUNTRY=PRT; Banco de Portugal (2026), Annual average inflation rate (HICP), BPstat, https://bpstat.bportugal.pt/serie/5739196; Bloomberg L.P., Euribor 3 Month ACT/360 (EUR003M Index), Bloomberg Terminal.

**Table 2 - Macroeconomic estimation data**

| Variable | Data Source | |
|---|---|---|
| | Baseline Scenario | Stress Scenario |
| Real GDP growth | WEO April 2011 | EU-wide stress test: main results for the Portuguese banks by BdP |
| Unemployment rate | WEO April 2011 | EU-wide stress test: main results for the Portuguese banks by BdP |
| HICP Inflation rate | WEO April 2011 | Macroeconomic adverse scenario for the 2011 EU-wide stress by ECB |
| 3-month EURIBOR | Banco de Portugal May 2011 FSR | EU-wide stress test: main results for the Portuguese banks by BdP |

**Source:** International Monetary Fund, *World Economic Outlook, April 2011*, https://doi.org/10.5089/9781616350598.081; Banco de Portugal, *Financial Stability Report, May 2011*, https://www.bportugal.pt/sites/default/files/anexos/pdf-boletim/ref_maio10_e.pdf; Banco de Portugal, *EU-wide Stress Test: Main Results for the Portuguese Banks*, 2011, https://www.bportugal.pt/sites/default/files/anexos/documentos-relacionados/combp20110715_en.pdf; European Banking Authority, *Macroeconomic Adverse Scenario for the 2011 EU-Wide Stress-Test: Specification and Results*, Annex 2, 2011, https://www.mfsa.mt/wp-content/uploads/2019/08/20110318-Macroeconomic-Adverse-Scenario-for-The-2011-EU-Wide-Stress-Test-.pdf.

**Table 3 - Macroeconomic baseline and stress scenario data**

For the individual bank data, given the limited availability of market data for Portuguese banks, many of which are not publicly listed, this dissertation adopts a balance-sheet-based approach to stress testing. Bank-level data, including balance sheet variables, income statement variables, and solvency indicators, are obtained from the Historical Series of the Portuguese Banking Sector provided by BPLIM[3]. This dissertation uses Tier 1 ratios because of the historical period analysed and the data available from BPLIM. As the original dataset includes institutions beyond the scope of this study, the sample was refined through a selection process designed to retain only commercial banks. Further details on the sample selection strategy are provided in Annex A.

### 5.2.1. Variable Definition and Construction

Bank data are expressed in ratios rather than euro amounts, which reduces size effects across institutions and allows projected ratios to be converted back into monetary flows using simple balance-sheet assumptions. The implementation constructs five P&L ratios: the provisions and impairments (P&I) ratio (as a proxy for the loan loss reserves), the net interest income (NII) ratio, the net fee and commission income (NFCI) ratio, the net trading income (NTI) ratio, and the other income (OI) ratio.

$$P\&I\ ratio_{b,t} = \frac{P\&I_{b,t}}{Assets_{b,t}} \quad (5.1)$$

$$NII\ ratio_{b,t} = \frac{NII_{b,t}}{Earning\ Assets_{b,t}} \quad (5.2)$$

$$NFCI\ ratio_{b,t} = \frac{NFCI_{b,t}}{Assets_{b,t}} \quad (5.3)$$

$$NTI\ ratio_{b,t} = \frac{NTI_{b,t}}{Assets_{b,t}} \quad (5.4)$$

$$OI\ ratio_{b,t} = \frac{OI_{b,t}}{Assets_{b,t}} \quad (5.5)$$

Where the subscript $b$ identifies the bank, and the subscript $t$ denotes the year to which the observation refers. This notation is used throughout the dissertation.

[3] Banco de Portugal, Historical Series of the Portuguese Banking Sector (SLB), https://doi.org/10.17900/SLB.Sep2025.V1

[4] Accumulated Provisions and Impairments from the balance sheet are measured as a positive value to facilitate interpretation and ensure consistency with the remaining variables.

To compute these ratios, a number of assumptions were required. First, although a credit loss ratio based directly on impairment expenses would be preferable, data limitations demanded the use of a proxy measure. Specifically, P&I is defined as the sum of the accumulated impairments and value adjustment on loans to other credit institutions, loans to customers, and debt securities[5]. Given that this measure extends beyond the loan portfolio and includes impairments on other asset classes, the ratio is calculated relative to total assets rather than total loans. Therefore, P&I should be interpreted as a broader credit-risk-related impairment measure rather than a pure loan-loss ratio. Second, earning assets are constructed as the sum of the following interest-earning asset categories: cash and cash balances/loans to central banks, demand deposits in other credit institutions, loans to other credit institutions, loans to customers, and debt securities. Finally, the other income (OI) item is computed as a residual designed to close the pre-tax profit identity after the core income and provision components have been identified.

$$OI_{b,t} = Profit\ or\ loss\ before\ tax\ _{b,t} + P\&I_{b,t} - NII_{b,t} - NFCI_{b,t} - NTI_{b,t} \qquad (5.6)$$

### 5.2.2. Training Set and Data Projections Characterization

#### Macroeconomic-financial data

The macroeconomic variables display substantial variation over the training period and clear differences across the baseline, stress, and observed paths for 2011-2012.

| Variable | Training Period (2000-2010) | | | Projection Period (2011-2012) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Observed | | | Baseline | | | Stress | | |
| | N | Mean | SD | N | Mean | SD | N | Mean | SD | N | Mean | SD |
| Growth | 11 | 1.02 | 1.84 | 2 | -2.88 | 1.67 | 2 | -0.10 | 1.27 | 2 | -2.80 | 0.28 |
| Inflation | 11 | 2.47 | 1.37 | 2 | 3.20 | 0.57 | 2 | 1.25 | 0.07 | 2 | 1.00 | 1.84 |
| Interest rate | 11 | 2.80 | 1.32 | 2 | 0.77 | 0.83 | 2 | 1.65 | 0.21 | 2 | 2.95 | 0.21 |
| Unemployment | 11 | 7.75 | 2.11 | 2 | 15.11 | 2.16 | 2 | 11.15 | 0.07 | 2 | 12.25 | 0.92 |

**Table 4 - Macroeconomic descriptive statistics**

[5] Impairment-adjustment items are sign-reversed so that provisions and impairments bookings are expressed as positive loss amounts.

GDP growth was volatile during the training period, with contractions of around 2% in 2003 and 5% in 2009, followed by recoveries in the subsequent years, as shown in Figure 1. For 2011-2012, the baseline scenario assumed a moderate contraction followed by a return to growth, while the stress scenario assumed a deeper and more persistent downturn. Actual GDP growth was approximately -1.7% in 2011 and -4% in 2012, with the 2012 contraction exceeding that assumed under both scenarios.

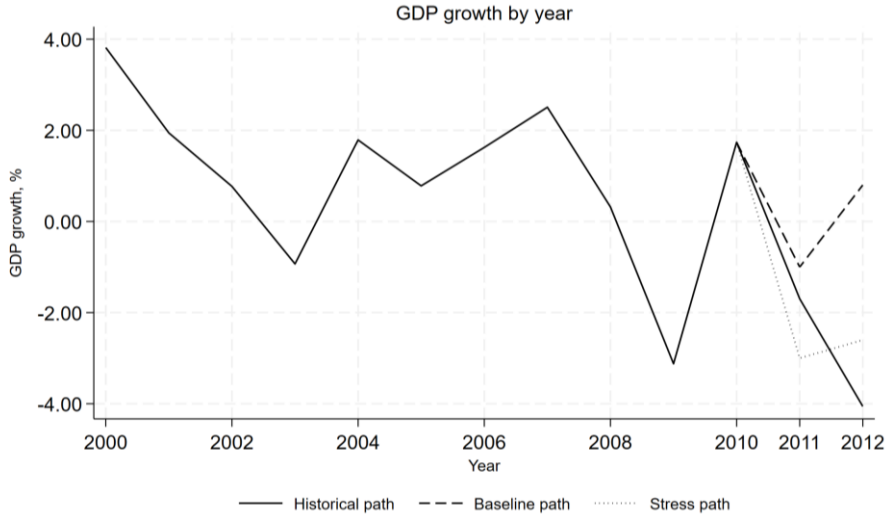



**Figure 1 - GDP annual growth: Historical values, baseline and stress scenario projections**

Inflation was generally contained within the 2-3% range during most of the training period. However, inflation rates were higher in the initial years and fell substantially in the later years, even reaching negative values (Figure 2).

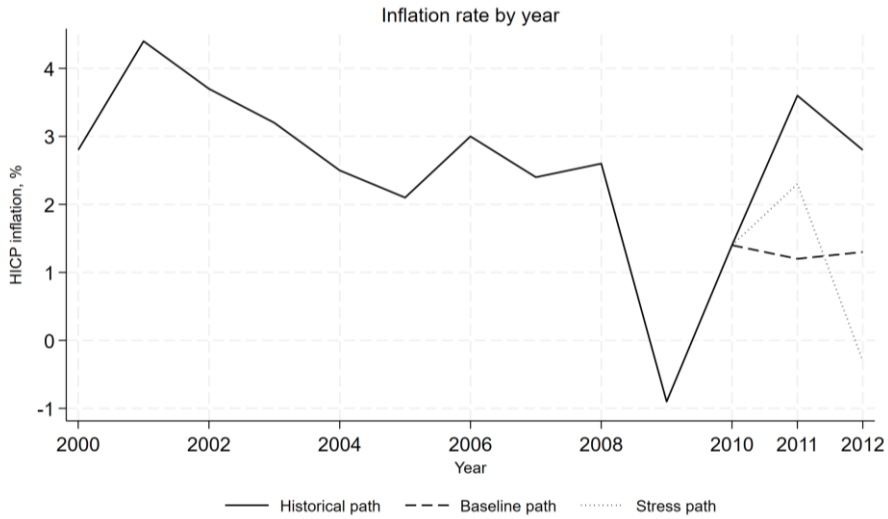



**Figure 2 - HICP inflation: Historical values, baseline and stress scenario projections**

The baseline scenario projects relatively stable inflation of around 1.5% over 2011-2012, while the stress scenario assumes a temporary rise in inflation to 2.1% in 2011 followed by deflation in 2012. Actual inflation increased much more strongly in 2011, reaching approximately 3.6%, before declining to around 2.8% in 2012, remaining well above both scenario projections.

As for the unemployment rate, there is a clear upward trend over the training period (Figure 3), rising from 4.7% in 2000 to around 11.5% in 2010. The baseline scenario projects unemployment to remain broadly stable at around 11% over 2011–2012, while the stress scenario assumes a further increase to 11.6% in 2011 and to 13% in 2012. Actual unemployment increased much more sharply, reaching 13.5% in 2011 and 16.6% in 2012, exceeding both scenario projections in both years.

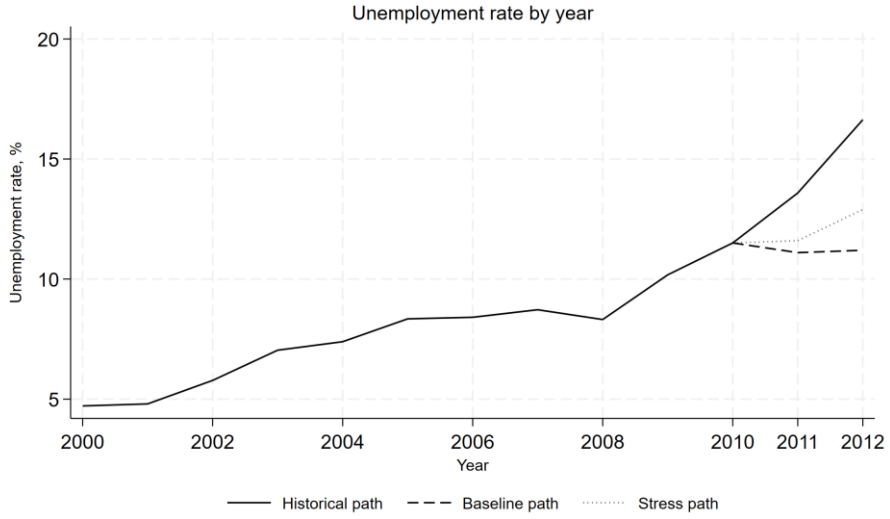



**Figure 3 - Unemployment rate: Historical Values and Baseline and Stress Scenario Projections**

Short-term interest rates were more cyclical (Figure 4). The 3-month EURIBOR declined from approximately 4.8% in 2000 to 2.1% in 2003, rose to around 4.7% in 2007, and subsequently fell below 1% in 2009. From 2010 onwards, the baseline scenario projects a gradual increase in interest rates, reaching approximately 1.8% by 2012, while the stress scenario assumes a stronger increase, reaching around 3.1% by 2012. Actual interest rates increased only slightly in 2011, to approximately 1.3%, before declining sharply to around 0.2% in 2012, remaining well below both scenario projections.

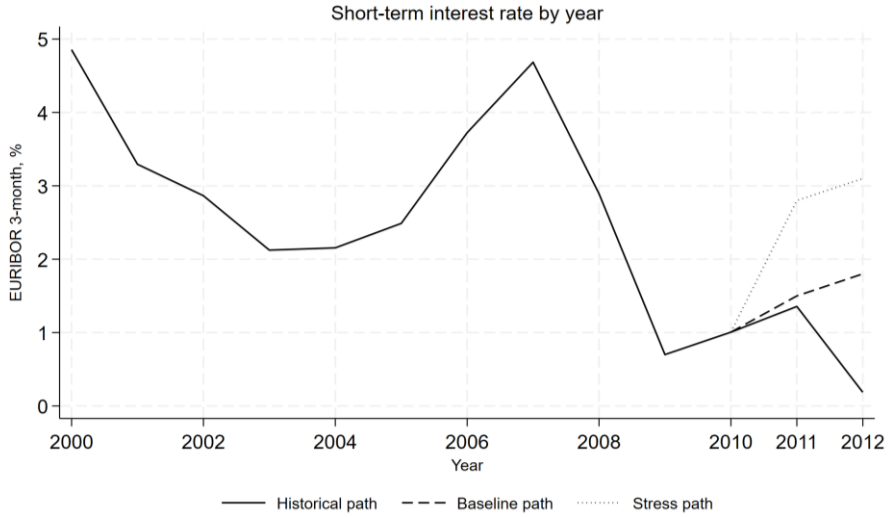



**Figure 4 - Short-term interest rate: Historical Values and Baseline and Stress Scenario Projections**

Overall, the realised macroeconomic environment differed materially from both scenarios. GDP growth and unemployment deteriorated more strongly than anticipated, particularly in 2012, while inflation remained higher and short-term interest rates considerably lower. These differences are particularly relevant when assessing the extent to which the stress test projections align with the subsequently observed data.

**Bank data**

Regarding descriptive statistics for the bank-level variables used in the analysis (Table 5), the projection dataset shows higher average P&I and lower average NII and NFCI ratios, indicating weaker profitability conditions and greater credit-risk recognition during the training period. The average Tier 1 ratio is higher in the projection sample (16.35%) than in the training sample (13.28%), although dispersion remains substantial in both periods. Balance-sheet composition also differs moderately, with loans representing a larger share of total assets and deposits a smaller share in the projection sample, suggesting greater credit exposure and reduced reliance on deposit funding.

| Variable | Training dataset (2000-2010) | | | Projection dataset (2011-2012) | | |
|---|---|---|---|---|---|---|
| | N | Mean | SD | N | Mean | SD |
| Deposits / total assets (%) | 212 | 61.30 | 19.07 | 39 | 57.60 | 22.32 |
| Loans / total assets (%) | 212 | 62.54 | 18.68 | 39 | 65.10 | 20.25 |
| NFCI ratio (%) | 212 | 0.59 | 0.44 | 39 | 0.49 | 0.30 |
| NII ratio (%) | 212 | 2.43 | 0.99 | 39 | 2.27 | 1.01 |
| NTI ratio (%) | 212 | 0.18 | 0.53 | 39 | 0.15 | 0.42 |
| OI ratio (%) | 212 | -0.67 | 3.42 | 39 | 0.99 | 1.59 |
| P&I ratio (%) | 212 | 1.84 | 1.70 | 39 | 3.78 | 1.81 |
| Tier 1 ratio (%) | 212 | 13.28 | 12.89 | 39 | 16.35 | 12.63 |
| Total assets | 212 | 17,673.59 | 27,067.69 | 39 | 22,402.68 | 34,263.52 |

**Table 5 - Bank-level descriptive statistics**

The training sample ranged from 13 banks in 2000 to 21 in 2004, remaining fairly stable afterwards (Figure 5). Bank characteristics are summarised annually using cross-sectional means and medians.




**Figure 5 - Number of Banks Included in the Training Sample, 2000-2010**

Bank size was highly heterogeneous throughout the training period. Mean total assets remained well above the median, reflecting the influence of relatively large institutions, and increased particularly after 2004. Average total assets were also higher in the 2011–2012 sample than during the training period (Table 5 and Figure 6).

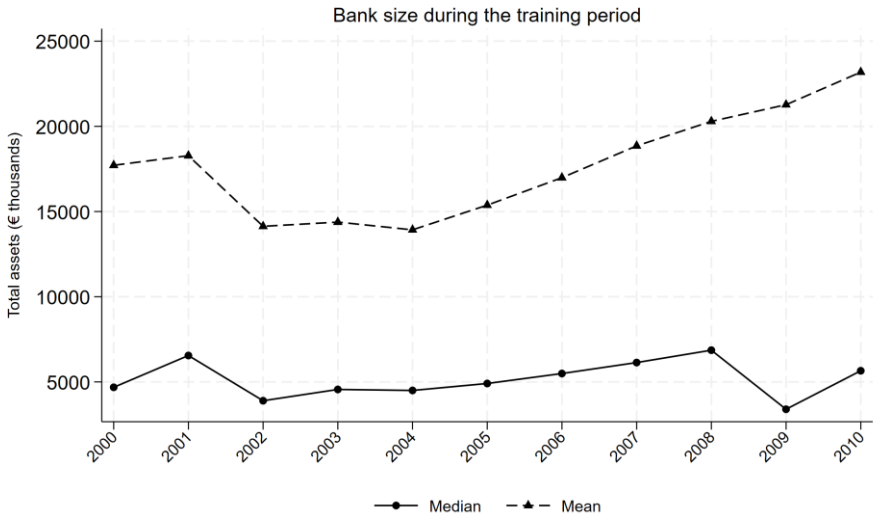



**Figure 6 - Mean and Median Bank Size During the Training Period, 2000-2010**

Regarding the evolution of banks' loans-to-total-assets and deposits-to-total-assets ratios (Figure 7), using both the mean and median across banks, the loans-to-assets ratio remained broadly stable between 60% and 70%. The gap between the mean and median widened from 2001 onwards, peaked in 2006, and subsequently reverted to levels close to the initial period by 2010, indicating a temporary increase in left skewness driven by banks with relatively low loan ratios. The cross-bank heterogeneity may lead banks to respond differently to macroeconomic and funding shocks during stress testing.

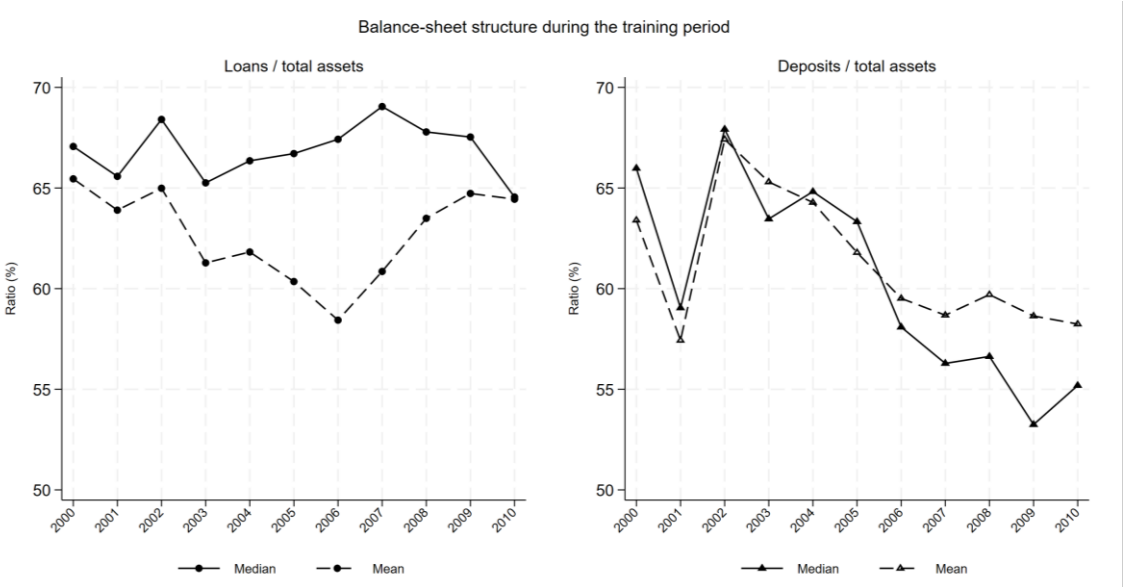



**Figure 7 - Mean and Median Balance-Sheet Ratios During the Training Period, 2000-2010**

After 2002, deposits represented a progressively smaller share of total assets, suggesting a reduced reliance on deposit funding. Until 2005, the mean and median followed

closely aligned paths, suggesting limited asymmetry in the distribution of deposit ratios. From 2005 onward, the mean generally exceeded the median, indicating right-skewness, with some banks maintaining relatively high deposit ratios while the typical bank had a lower share.

Regarding Tier 1 capital ratio, Figure 8 shows that its median remained relatively stable throughout the training period, while the mean generally exceeded the median, indicating a right-skewed distribution driven by highly capitalised banks. The sharp decline in the mean in 2008, not reflected in the median, suggests that a subset of banks, possibly highly capitalised, experienced a larger deterioration during the financial stress period. In subsequent years, this trend reversed, possibly reflecting supervisory pressure to strengthen capitalisation, as discussed above in section 4.

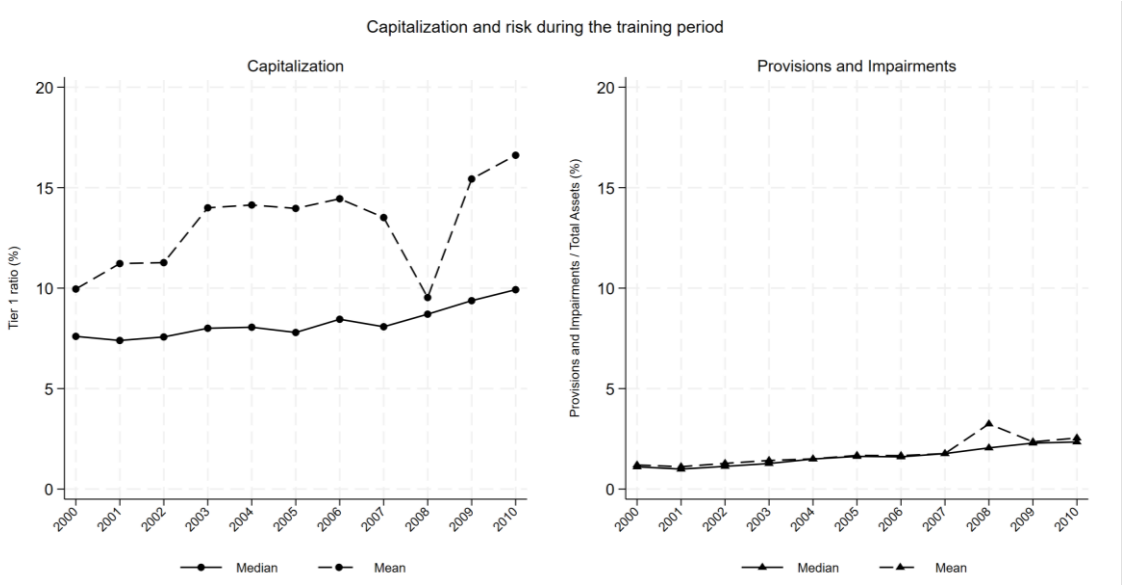



**Figure 8 - Mean and Median Capitalisation and Credit-Risk Indicators During the Training Period, 2000-2010**

P&I increased gradually over time, with a marked rise in the mean in 2008, before moderating thereafter. The increase in both mean and median suggests that higher credit risk-related charges were not confined to a small number of banks, indicating a broad-based increase in the recognition of credit risk across the sample. The sharper increase in the mean in 2008, relative to the median, suggests greater cross-bank dispersion, with some FIs experiencing substantially higher credit risk-related charges than the typical bank, potentially reflecting greater exposure to deteriorating asset quality or differences in the timing of risk recognition. The subsequent convergence of the mean and median suggests less cross-sectional asymmetry toward the end of the period. Overall, figure 8 suggests significant cross-

bank heterogeneity in the recognition of credit risk and asset quality adjustments in 2008.

Regarding banks' income structure (Figure 9), NII remained the dominant source of income, with its ratio fluctuating between approximately 2% and 3% of total assets, although it declined toward the end of the training period. NFCI ratio remained modest and stable at around 0.5%, while trading income ratio was smaller and more volatile, ranging between 0% and 0.4% and turning temporarily negative in 2008. The close mean and median values across the three ratios suggest limited asymmetry in these distributions.

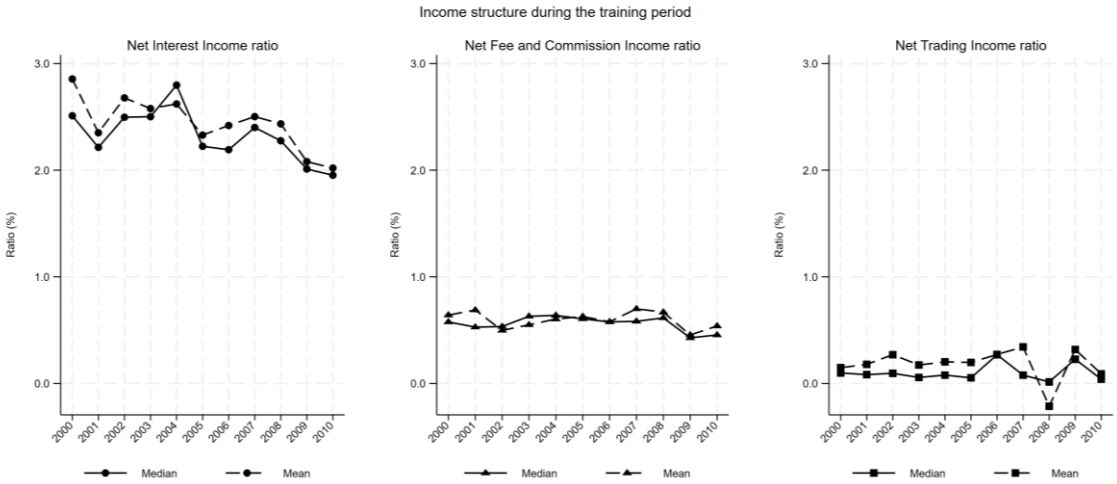



**Figure 9 - Mean and Median Income Components During the Training Period, 2000-2010**

## 5.3. Methodology

### 5.3.1. Tier 1 Ratio Projection

The goal of the stress-testing exercise is to project each bank's Tier 1 capital ratio for 2011 and 2012, under a baseline and a stress scenario. For bank $b$ in year $t$, the ratio is defined as Tier 1 capital relative to RWA, and thus requires projecting both:

$$Tier\ 1\ ratio_{b,t} = \frac{Tier1_{b,t}}{RWA_{b,t}} \tag{5.7}$$

The RWA projection follows a simplified balance-sheet assumption, with risk-weighted assets increasing by 5% annually. This represents a simplified annual adaptation of the CLASS assumption of fixed-rate asset growth with constant balance-sheet composition (Hirtle et al., 2016). The same growth rate is applied under the baseline and stress scenarios. This rationale is also applied to total assets, earning assets, and gross loans. Since total assets and RWA are assumed to grow at the same rate, the RWA-to-total-assets ratio, or RWA density, remains constant over the projection horizon. No scenario-dependent changes in

risk weights, such as those resulting from credit migration, or additional RWA shocks are imposed.

The numerator, Tier 1 capital, is initialised at its observed 2010 level and updated annually by adding projected net income and subtracting projected dividends:

$$Tier\ 1_{b,t} = Tier\ 1_{b,t-1} + Net\ Income_{b,t} - Dividends_{b,t} \tag{5.8}$$

Accordingly, the 2012 Tier 1 capital projection builds on the scenario-specific 2011 outcome. The model excludes new equity issuance, government recapitalisation, capital instrument conversions, acquisitions, and other discretionary capital actions. Under the capital accumulation rule in equation (5.8), Tier 1 capital evolves through projected net income and dividends, both of which depend on bank profitability.

Dividends are set at 50% of pre-tax profit when projected pre-tax profit is positive and at zero when it is non-positive in line with the GST methodology. This assumption allows banks to retain earnings when profitability deteriorates, helping preserve capital under stress (Tressel et al., 2022).

$$Dividends_{b,t} = \begin{cases} 0.5 \cdot Profit\ or\ loss\ before\ tax_{b,t}, if\ Profit\ or\ loss\ before\ tax_{b,t} > 0 \\ 0, if\ Profit\ or\ loss\ before\ tax_{b,t} \leq 0 \end{cases} \tag{5.9}$$

Net income is calculated as:

$$Net\ Income_{b,t} = Profit\ or\ loss\ before\ tax_{\ b,t} - Taxes_{b,t} \tag{5.10}$$

Following the GST framework, taxes are imposed through an auxiliary rule rather than an econometric model. For each bank, the effective tax rate is calculated using 2010 tax expense divided by 2010 pre-tax profit and is bounded between 0% and 30% (Tressel et al., 2022). If the effective tax rate is missing, it is set to zero. Projected taxes are zero whenever projected pre-tax profit is non-positive; otherwise, the bounded 2010 effective tax rate is applied to projected pre-tax profit:

$$Taxes_{b,t} = \begin{cases} \tau_b \cdot Profit\ or\ loss\ before\ tax_{\ b,t}, if\ Profit\ or\ loss\ before\ tax_{\ b,t} > 0 \\ 0, if\ Profit\ or\ loss\ before\ tax_{\ b,t} \leq 0 \end{cases} \tag{5.11}$$

Where $\tau_b = min\left(30\%, max\left(0, \frac{Tax\ expense_{b,2010}}{Pre-tax\ profit_{b,2010}}\right)\right)$.

As for the profit or loss before tax, the projection is subsequently calculated as:

$$Profit\ or\ loss\ before\ tax\ _{b,t} = NII_{b,t} + NFCI_{b,t} + NTI_{b,t} + OI_{b,t} - P\&I_{b,t}\ , \tag{5.12}$$

which requires projections of P&I, NII, NFCI, NTI and OI. The empirical structure used to generate these components is a simplified top-down adaptation of GST and CLASS, where macroeconomic scenarios are transmitted to bank profitability and ultimately to capital. The available Portuguese annual data do not support the full GST global scenario system, the detailed credit-risk architecture based on PD, LGD and granular exposures, or the extensive set of quarterly bank equations used in CLASS (Hirtle et al., 2016; Tressel et al., 2022). Thus, the implemented model estimates only a small set of reduced-form profitability relationships and uses auxiliary assumptions for trading income, OI, balance-sheet growth, taxes, dividends and RWA based on the two frameworks.

Consistent with the reduced-form GST methodology, projected P&L components are modelled according to their economic characteristics. P&I, NII, and NFCI are estimated separately using parsimonious specifications based on selected macroeconomic variables, while NTI and OI are projected using alternative approaches (Tressel et al., 2022). Due to data availability constraints, the macroeconomic information set is restricted to four indicators. For each P&L component, only macro-financial predictors consistent with the long-run multiplier restrictions imposed in the GST framework are retained [see Annex Table 1.2 in Tressel et al. (2022)].

P&I, NII and NFCI are projected econometrically using the following specifications:

$$P\&I\ ratio_{b,t} = \beta_0 + \beta_1 P\&I\ ratio_{b,t-1} + \beta_2 RealGrowth_t + \beta_3 Unemployment\ rate_t + \beta_4 \pi_t + \varepsilon_{b,t} \tag{5.13}$$

$$NII\ ratio_{b,t} = \gamma_0 + \gamma_1 NII\ ratio_{b,t-1} + \gamma_2 RealGrowth_t + \gamma_3 Unemployment\ rate_t + \gamma_4 \pi_t + \mu_{b,t} \tag{5.14}$$

$$NFCI\ ratio_{b,t} = \delta_0 + \delta_1 NFCI\ ratio_{b,t-1} + \delta_2 RealGrowth_t + \delta_3 Unemployment\ rate_t + \delta_4 \pi_t + \delta_5 i_t + \vartheta_{b,t} \tag{5.15}$$

The regressions are estimated using pooled ordinary least squares (OLS) over the cleaned 2000-2010 sample, subject to the one-year lag requirement (see Annex A for sample-cleaning details). The specifications do not include bank fixed effects, random effects, or year fixed effects. The objective is not causal parameter estimation but stress-test calibration; therefore, the pooled specification is used as a reduced-form forecasting relationship

consistent with the GST approach. Huber–White heteroskedasticity-robust standard errors are computed using Stata's vce(robust) option. Regression results are reported in Annex B.

Macroeconomic regressors vary only over time and are common across banks, while the dependent variables and their lags vary by bank and year. Estimated coefficients are used as forecasting parameters under both scenarios; coefficient-level inference therefore serves as supporting evidence rather than the sole basis for the stress-test conclusions. Robust standard errors are used in the historical regressions, while scenario projections rely on point estimates.

As for the NTI ratio, it is not estimated by an OLS model, but rather through the historical mean-minus-volatility rule. This option reflects the IMF's finding that panel regressions for NTI ratios generally display weak in-sample predictive power (Tressel et al., 2022). The model calculates each bank's historical NTI ratio mean, $\overline{NTIR_b}$, and standard deviation, $\sigma_{b,2000-2010}(NTIR)$. The baseline projection is set equal to the historical bank-specific mean, while the stress projection is one historical standard deviation below that mean. The same calibration is used in both projection years:

$$NTI\ ratio_{b,t} = \overline{NTIR_b} - a_t \cdot \sigma_{b,2000-2010}(NTIR)\,, \tag{5.16}$$

where $a_t = 0$, under the baseline projection, and $a_t = 1$, under the stress projection.

Finally, the OI is also not modelled econometrically but rather projected using its historical average, $\overline{OI\ ratio_{b,2000-2010}}$. This choice reflects the fact that OI typically aggregates a heterogeneous set of residual accounting entries, including miscellaneous operating and non-operating components, which are difficult to relate to a small macroeconomic set in a stable and economically interpretable way. Based on GST, the projected total assets path is identical across both scenarios (Tressel et al., 2022). For each bank, the OI ratio is set equal to:

$$OI\ ratio_{b,t} = \overline{OI\ ratio_{b,2000-2010}} \tag{5.17}$$

The projected values of the five pre-tax profit and loss components in equation (5.12) are combined to obtain pre-tax earnings for 2011 and, subsequently, for 2012. The estimation is recursive because the projected ratios enter the following year's equations as lagged values. For 2011, the lagged dependent variable is the bank's observed 2010 ratio. For 2012, the lag is the model's own 2011 projection under the same scenario. Consequently, baseline and

stress paths can diverge further in the second year because the scenario-specific 2011 forecast becomes the state variable entering the 2012 equation.

Given the projected profit before tax for each bank, taxes, net income, and dividends are determined according to equations (5.9)–(5.11). These projections are then used to update Tier 1 capital through equation (5.8), which ultimately allows the calculation of the bank's projected Tier 1 capital ratio under each scenario.

### 5.3.2. Assessment

To assess the results of the exercise, we use three complementary approaches: sector-level Tier 1 ratio aggregation, cross-bank distribution analysis, and comparison of projected and realised outcomes.

Sector-level Tier 1 ratios are summarised using three aggregation methods: the unweighted cross-sectional distribution, an RWA-weighted mean, and a total-assets-weighted mean. Observed 2010–2012 ratios use actual RWA or total assets as weights, while baseline and stress estimates use the corresponding projected weights. Unlike the unweighted measure, the weighted averages give greater importance to banks with larger system-wide risk exposures or balance sheets.

Second, we compare the cross-sectional distributions of observed, baseline, and stress Tier 1 ratios using histograms. To ensure comparability, common bin cut-offs are used across years and scenarios, in line with BPLIM confidentiality requirements (Banco de Portugal Microdata Research Laboratory, 2026).

The third approach compares projected Tier 1 ratios with realised values for 2011 and 2012. This comparison is intended as a hypothetical benchmark rather than a strict *ex-post* evaluation, since realised capital ratios may incorporate developments not captured by the model, such as management actions and capital interventions. For each bank, the projection deviation is defined as the difference between the scenario, denoted by s, and the observed Tier 1 ratio:

$$Scenario\ deviation_{s,b,t} = Tier\ 1\ ratio_{s,b,t} - Tier\ 1\ ratio_{actual,b,t} \tag{5.18}$$

$$Absolute\ scenario\ deviation_{s,b,t} = \left|Scenario\ deviation_{s,b,t}\right| \tag{5.19}$$

For confidentiality, bank-level errors are not reported. For each year and scenario, we report the mean projection error and mean absolute projection error across banks.

## 6. Results

Table 6 presents the statistics of observed and projected (baseline and stress) Tier 1 ratios for 2010-2012. The observed mean declined from 16.61% in 2010 to 12.06% in 2011, before recovering to 14.57% in 2012, while the median increased gradually from 9.92% to 11.68%. The persistent mean-median gap indicates a right-skewed distribution, with some banks displaying relatively high Tier 1 ratios. Dispersion peaked in 2011, when the standard deviation reached 20.81 percentage points (p.p.), before declining to 15.98 p.p. in 2012.

| Year | Observed | | | Baseline Scenario | | | Stress Scenario | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | Standard deviation | Mean | Median | Standard deviation | Mean | Median | Standard deviation |
| 2010 | 16.61 | 9.92 | 13.02 | - | - | - | - | - | - |
| 2011 | 12.06 | 10.50 | 20.81 | 16.95 | 10.45 | 13.13 | 16.38 | 9.90 | 13.13 |
| 2012 | 14.57 | 11.68 | 15.98 | 17.20 | 11.32 | 12.84 | 16.21 | 10.20 | 12.80 |

**Table 6 - Distribution of observed and projected Tier 1 ratios, 2010–2012**

The stress scenario consistently produced lower Tier 1 ratios than the baseline, with the gap widening in 2012. The mean difference increased from 0.57 p.p. in 2011 to 0.99 p.p. in 2012, while the median difference rose from 0.55 p.p. to 1.12 p.p. Projected standard deviations, however, were nearly identical across scenarios and remained close to the 2010 observed level. The stress scenario shifts the distribution towards lower Tier 1 ratios rather than materially increasing dispersion.

Projected means exceeded observed means in both 2011 and 2012, whereas projected medians, particularly under the baseline scenario, were closer to observed values. This suggests that the framework captures the centre of the distribution better than its upper tail.

Table 7 reports RWA- and total-assets-weighted mean Tier 1 ratios. In 2010, the observed weighted means were 8.90% and 8.99%, respectively, well below the unweighted mean in Table 6. This suggests that higher Tier 1 ratios were concentrated among smaller banks, while larger institutions tended to exhibit lower capital ratios. The same pattern persists in 2011 and 2012, with both observed weighted means remaining below the corresponding unweighted means. The sharper decline in the unweighted mean in 2011 (-4.55 p.p.), compared with the RWA- and total-assets-weighted means (-0.61 p.p. and -0.46 p.p., respectively), suggests greater deterioration among smaller banks. In 2012, the weighted

means recovered slightly more (+2.69 p.p. and +2.64 p.p., respectively) than the unweighted mean (+2.51 p.p.), suggesting that the recovery was also pronounced among larger banks.

In 2011-2012, the stress scenario consistently produced lower weighted Tier 1 ratios than the baseline. The RWA-weighted mean fell from 9.27% under the baseline to 8.72% under stress in 2011, and from 9.90% to 8.92% in 2012. Similarly, the total-assets-weighted mean fell from 9.36% to 8.80% in 2011 and from 10.01% to 8.80% in 2012. The baseline-stress gap widened in 2012, indicating a stronger adverse effect in the second year of the stress horizon, particularly when weighted by total assets.

| Year | Tier 1 ratio RWA-weighted mean | | | Tier 1 ratio total-assets-weighted mean | | |
|---|---|---|---|---|---|---|
| | Observed | Baseline Scenario | Stress Scenario | Observed | Baseline Scenario | Stress Scenario |
| 2010 | 8.90 | - | - | 8.99 | - | - |
| 2011 | 8.29 | 9.27 | 8.72 | 8.53 | 9.36 | 8.80 |
| 2012 | 10.98 | 9.90 | 8.92 | 11.17 | 10.01 | 8.80 |

**Table 7 - RWA- and Total-Assets-Weighted Mean Tier 1 Ratios, 2010–2012**

Figure 10 below compares the cross-sectional distribution of observed Tier 1 ratios with those of the baseline and stress projections. In the observed data, 12 banks had ratios below 12% in 2010, rising to 14 in 2011 before returning to 12 in 2012. This indicates a temporary deterioration in 2011, followed by partial recovery.

Regarding projections, in 2011, the baseline and stress scenarios produced identical category counts: 8 banks below 9%, 4 between 9% and 12%, and 8 at or above 12%. Nonetheless, identical counts do not necessarily imply identical bank-level classifications, as movements between categories may offset each other. The distributional effect becomes clearer in 2012. Under the baseline, the number of banks with Tier 1 ratios below 9% falls from 8 to 5, while those with ratios in the 9-12% range increase from 4 to 7. Under the baseline, the below-9% category decreases by 3 banks while the 9–12% category increases by 3; under stress, the category counts remain unchanged from 2011.

Overall, the stress effect is more consequential in the second year of the stress horizon and concentrated among lower- and intermediate-Tier 1 ranges. Rather than causing a broad deterioration, it mainly prevents the improvement projected under baseline for some banks.

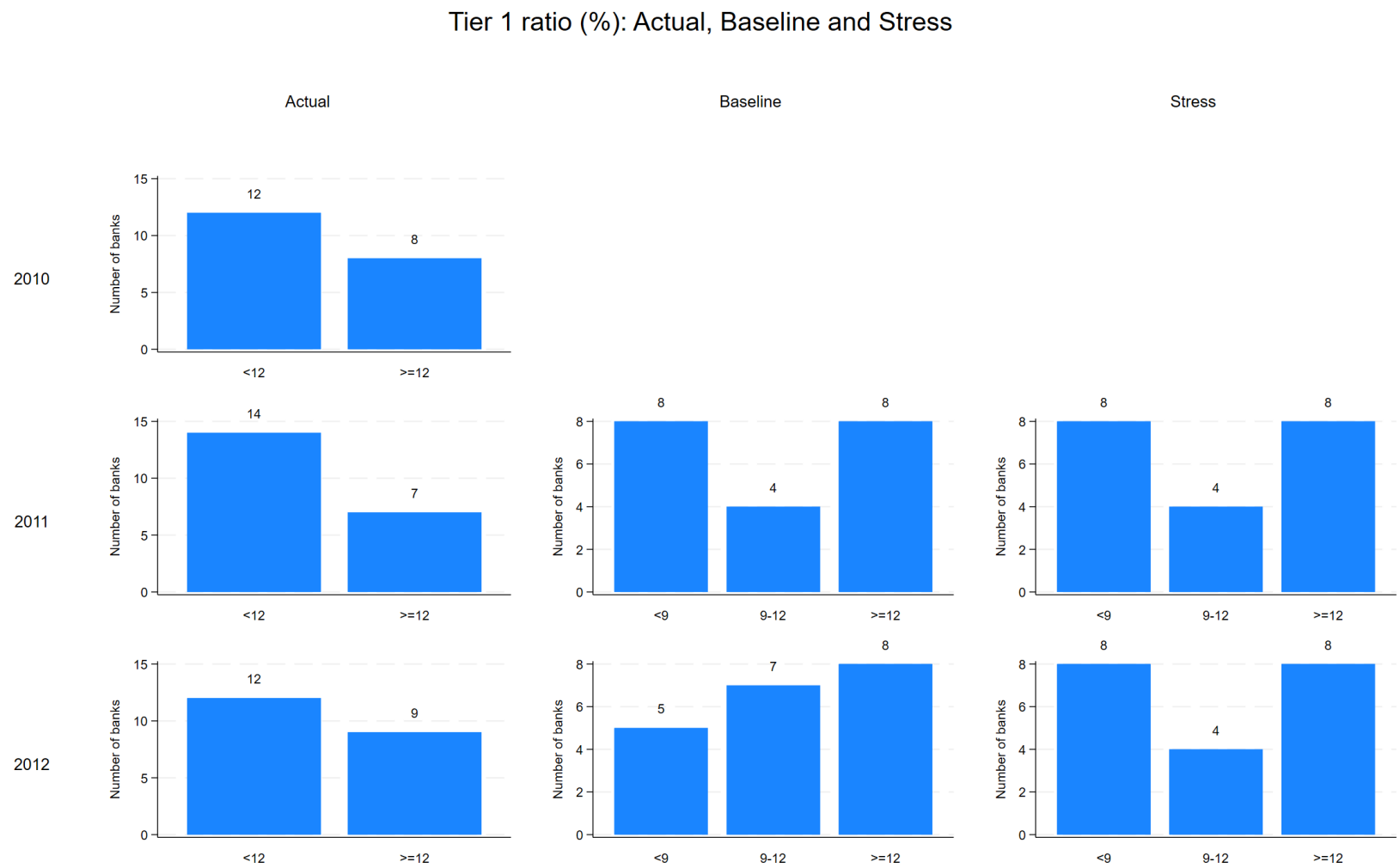



**Figure 10 - Distribution of Observed and Projected Tier 1 Ratios, 2010–2012**

**Note:** Common bin cut-offs are used across years and scenarios, in line with BPLIM confidentiality requirements (Banco de Portugal Microdata Research Laboratory, 2026).

Table 8 reports the mean differences between projected and observed Tier 1 ratios for the individual banks. Under the baseline scenario, projections exceeded observed ratios by an average of 1.20 p.p. in 2011 and by 0.64 p.p. in 2012, while the absolute error increased from 2.34 to 3.70 p.p. The smaller mean projection error alongside the higher absolute error suggests greater heterogeneity in bank-level errors in 2012, with positive and negative deviations increasingly offsetting each other.

| Year | Tier 1 ratio Baseline vs Actual | | Tier 1 ratio Stress vs Actual | |
|---|---|---|---|---|
| | Baseline minus actual (p.p.) | Absolute baseline error (p.p.) | Stress minus actual (p.p.) | Absolute stress error (p.p.) |
| 2011 | 1.20 | 2.34 | 0.62 | 2.43 |
| 2012 | 0.64 | 3.70 | -0.33 | 3.89 |

**Table 8 - Mean Projection Errors and Mean Absolute Errors in Tier 1 Ratios, 2011–2012**

**Note:** Projection error and absolute projection error are defined in equations (5.18) and (5.19).

Under the stress scenario, the mean projection error declined from 0.62 p.p. in 2011 to -0.33 p.p. in 2012, indicating a shift from over- to underprediction. The absolute stress error increased from 2.43 p.p. to 3.89 p.p. Although stress projections were closer to realised outcomes than baseline projections, absolute stress deviations were slightly larger than those of the baseline scenario in both years, indicating no improvement in bank-level fit.

The baseline-stress gap difference also widened from approximately 0.58 p.p. in 2011 to 0.97 p.p. in 2012, indicating a stronger downward effect of the stress scenario in the second year. Overall, the larger absolute deviations in 2012 suggest lower projection accuracy over the longer horizon, while the small gaps partly reflect offsetting bank-level errors.

## 7. Discussion

This section discusses the results in relation to this dissertation's research question: whether vulnerabilities in the Portuguese banking sector could have been identified using information available at the start of the 2011–2012 projection horizon and a top-down stress test framework.

The results suggest that they could, although only in a qualified sense. The stress scenario consistently produces weaker Tier 1 outcomes than the baseline, with a wider gap in 2012. In addition, pre-2011 bank-level data reveal vulnerabilities related to funding structure, credit exposure, profitability, credit-risk recognition, and capital buffers. Together, these findings suggest that a simplified stress-test framework could have helped to reveal broad vulnerabilities in the Portuguese banking sector, although it would not have predicted the timing, magnitude, or specific form of the subsequent distress.

Projected Tier 1 ratios show an increasing divergence between the baseline and stress scenarios, particularly in 2012. Table 6 shows lower mean and median ratios under the stress scenario than under the baseline in both years, with a wider difference in 2012. Table 7 shows the same result when applying either RWA or total-assets weighting, indicating that the decline in projected capital ratios is robust to the weighting scheme.

Projected standard deviations remain similar across scenarios, suggesting that the stress scenario does not materially increase cross-bank dispersion, despite shifting projected capital ratios downwards and, by 2012, changing the composition of the lower and intermediate Tier 1 ranges.

Figure 10 provides complementary evidence on the distribution of projected Tier 1 ratios. In 2011, baseline and stress scenarios generate identical category counts, despite lower mean and median ratios under stress. This does not imply identical bank-level outcomes, as individual movements across categories cannot be identified due to confidentiality restrictions. In 2012, however, differences become more visible: 8 banks fall below the 9% Tier 1 ratio cut-off under stress compared with five under the baseline, while 4 banks remain in the 9–12% range under stress compared with seven under the baseline. The number of banks at or above 12% remains unchanged at eight in both scenarios. The stress scenario therefore increases the concentration of banks observed in the lower capital range, indicating greater pressure on the capital positions of banks in the lower and intermediate Tier 1 ranges.

The stronger 2012 impact reflects the model's recursive structure: 2011 stress outcomes feed into 2012 projections through lagged effects, allowing weaker profitability and capital outcomes in the first year to affect subsequent projections. This cumulative transmission of adverse conditions mainly affects lower and mid-Tier 1 banks by limiting baseline improvements rather than causing broad deterioration.

Comparison with realised Tier 1 ratios provides additional context for interpreting the projections. Table 8 shows that the mean signed stress-minus-actual gap is closer to zero than the baseline error in both years, while the mean absolute stress gap is slightly larger. Stress projections are therefore not necessarily more accurate at the bank level simply because their average outcome is closer to realised values. Small average gaps may partly reflect offsetting positive and negative errors across banks. This distinction is important because the stress scenario represents a counterfactual designed to assess resilience under unfavourable conditions rather than a forecast of the exact path followed by the banking sector.

The stress-test results show how adverse macroeconomic conditions could have affected capital positions. However, assessing whether these vulnerabilities could have been identified *ex-ante* also requires examining whether relevant weaknesses were already visible using information available before the projection period.

Pre-2011 bank-level evidence had already pointed to vulnerabilities in the Portuguese banking sector. Figure 7 shows a persistently high loan share, with loans representing around 60–70% of total assets throughout the training period, while the declining share of deposits after 2002 suggests increasing reliance on alternative funding sources. These characteristics indicate that Portuguese banks entered the sovereign debt crisis with substantial credit exposures and a funding structure that had become less dependent on stable deposit financing.

Credit-risk indicators also showed signs of deterioration before the projection horizon. Figure 8 shows a marked increase in P&I in 2008, followed by some moderation thereafter. Since P&I captures credit-risk recognition and asset-quality concerns rather than direct measures of realised losses, this increase should be interpreted as evidence of rising credit-risk pressures and greater recognition of potential asset deterioration. Capitalisation was also heterogeneous across banks. In 2010, the unweighted mean Tier 1 ratio was 16.61%, while

the median was 9.92%; RWA- and total-assets-weighted means were close to 9%, suggesting that larger banks tended to operate with lower Tier 1 ratios than the typical institution.

Profitability indicators provide further evidence of the mechanisms through which vulnerabilities could have affected capital outcomes. Net interest income weakened towards 2009–2010, while net trading income became temporarily negative in 2008. Net fee and commission income remained comparatively stable. Together with rising P&I, these patterns indicate increasing pressure on profitability and retained earnings before the projection period. This is relevant because retained earnings represent an important channel through which macroeconomic stress affects Tier 1 capital in the model. However, the simplified treatment of net trading income, other income, taxes, and dividends limits the representation of institution-specific responses to stress.

Taken together, these pre-2011 indicators provide complementary evidence that relevant vulnerabilities were already observable using available information. The stress test adds value by quantifying how adverse macroeconomic conditions could have affected banks' capital positions and amplified vulnerabilities.

The stress scenario should be interpreted as a counterfactual designed to reveal vulnerabilities rather than as an *ex-post* reconstruction of the Portuguese crisis. It captures the direction of deterioration in economic activity and unemployment without attempting to reproduce exactly the conditions that materialised during the sovereign debt crisis. Realised unemployment exceeded the stress scenario assumptions in both years, while GDP growth was less negative than assumed in 2011 but weaker in 2012. Inflation and short-term interest rates also differed materially from the scenario assumptions. Therefore, the scenario provides a coherent representation of unfavourable macroeconomic conditions, while remaining distinct from the actual path of the Portuguese economy during the crisis.

Several modelling limitations constrain the strength of the conclusions. First, the framework captures solvency vulnerabilities but does not explicitly model several channels that were important during the Portuguese crisis. In particular, sovereign spreads, bank-specific funding costs, housing prices, and liquidity conditions are excluded. These omissions limit the ability of the model to capture funding stress, sovereign-bank interactions, and liquidity pressures.

Second, credit risk is captured through P&I rather than granular credit-risk parameters such as PD, LGD, and EAD measures. While this approach is consistent with the use of

publicly available data, it provides a less detailed representation of asset-quality deterioration. Furthermore, the RWA-to-total-assets ratio is held constant, preventing deteriorating asset quality from generating scenario-dependent changes in risk weights.

Third, the empirical framework is constrained by data availability and modelling choices. The short 2000-2010 training period, annual frequency of observations, and pooled OLS methodology limit the ability to capture nonlinearities and heterogeneous responses under severe stress.

A further limitation concerns the capital measure used. The analysis relies on Tier 1 ratios rather than the CET1 measure used in modern Basel III stress-testing frameworks. Although appropriate for the historical period analysed, this limits direct comparability with current supervisory exercises.

A separate limitation relates to confidentiality restrictions imposed by Banco de Portugal Microdata Research Laboratory (2026). The inability to disclose individual banks and extreme observations prevents identifying which institutions experienced the largest deterioration and limits the interpretation of movements within the projected distribution. Accordingly, the below-9% category in Figure 10 should be interpreted as a relatively weak capital range rather than a direct count of banks breaching the 8% Tier 1 benchmark (Banco de Portugal, 2008a).

The comparison with realised capital ratios is also affected by interventions outside the model. Actual Tier 1 ratios recovered in 2012 despite weaker GDP growth and higher unemployment. This divergence does not necessarily imply that underlying vulnerabilities disappeared. During this period, the banking sector underwent significant recapitalisation, public capital support, and deleveraging (European Commission, 2016). Since the model allows capital to evolve mainly through projected profitability and retained earnings, government recapitalisation, equity issuance, capital instrument conversions, and other discretionary actions are not incorporated into the stress-test equations. Consequently, realised Tier 1 ratios provide an imperfect benchmark for evaluating projected outcomes.

Overall, the evidence supports a qualified answer to the research question. A simplified top-down stress test using information available at the start of the 2011–2012 horizon could have revealed broad vulnerabilities in the Portuguese banking sector and shown that adverse macroeconomic conditions would weaken capital positions, with effects becoming more pronounced over time. This conclusion is consistent with vulnerabilities already visible

before 2011, including declining reliance on deposit funding, rising credit-risk recognition, and heterogeneous capital buffers. However, the framework could not capture the full complexity of the crisis, as important channels such as liquidity pressures, sovereign risk, changing risk weights, feedback effects, and discretionary capital interventions were not explicitly modelled.

## 8. Conclusion

This dissertation examined whether a simplified top-down solvency stress-testing framework, applied retrospectively using information available at the time, could have identified vulnerabilities in the Portuguese banking sector that became apparent during the sovereign debt crisis. The analysis draws mainly on the GST and CLASS frameworks and uses research-accessible bank data and publicly available macro-financial information. Historical relationships were estimated over 2000-2010 and used to project Tier 1 capital ratios for 2011-2012 under baseline and stress scenarios.

The results show that the stress scenario consistently generates weaker capital outcomes than the baseline, with the gap widening in 2012. Both RWA- and total-assets-weighted mean Tier 1 ratios are lower under stress, and the projected distribution becomes even less favourable relative to the baseline in the second year. Importantly, this widening gap primarily reflects the inability of banks to achieve the capital improvements projected under the baseline scenario, rather than a broad-based deterioration in capital ratios under stress. This effect is particularly visible among lower and mid-Tier 1 banks, indicating increasing pressure on their capital positions over the stress horizon. The recovery in observed Tier 1 ratios in 2012 should not be interpreted as contradicting the vulnerability signal provided by the exercise, as observed capital outcomes were influenced by recapitalisation and regulatory interventions that are not captured by the model's simplified capital-accumulation assumptions.

Overall, the findings suggest that a simplified top-down stress test, applied at the start of the 2011-2012 projection horizon, could have provided useful information on the sensitivity of Portuguese banks' capital positions to adverse macro-financial developments. A declining share of deposit funding, heterogeneous capital buffers, and heightened P&I were already visible in the 2000-2010 bank data. Nevertheless, the framework would not have anticipated the full scale or specific form of the subsequent distress. Important crisis channels – including sovereign risk, liquidity and funding pressures, scenario-dependent changes in RWA, macro-financial feedback effects, and discretionary capital interventions – are not explicitly incorporated in the model.

These conclusions should be interpreted in light of the exercise's methodological and data constraints. Annual data and the relatively short 2000-2010 training period limit the number of available observations and the econometric complexity, motivating pooled OLS

and a parsimonious set of macroeconomic predictors. Credit risk is captured through P&I rather than granular PD, LGD, and EAD measures, while the RWA-to-total-assets ratio is held constant, preventing deteriorating asset quality from generating scenario-dependent increases in risk weights. Several income-statement and capital components are also projected using simplified assumptions rather than bank-specific behavioural models, while confidentiality restrictions limit the analysis of individual institutions and extreme outcomes.

Future research could address these limitations using higher-frequency and more granular supervisory or Pillar 3 data, dynamic panel methods, scenario-dependent RWA projections, and explicit modelling of sovereign-bank and solvency-liquidity interactions, as well as management and policy responses under stress. Such extensions could better capture institution-specific vulnerabilities and amplification mechanisms. Overall, the Portuguese case illustrates the value of transparent top-down stress testing using research-accessible data as a complement to supervisory analysis, while also showing how model design and data availability shape the vulnerabilities that can be detected.

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## Annex A – Sample Selection

To construct the training sample, we restrict the bank dataset to 2000-2010. We then subject the sample to bank-year, and bank-level filters designed to retain institutions with usable solvency information, a meaningful commercial-banking profile, and sufficient time-series continuity for lagged-ratio estimation.

Observations are excluded when the Tier 1 ratio, total capital ratio, gross loans, deposits, or total assets are missing, as these variables are required to project P&L ratios and, thus, Tier 1 ratios. Prudential ratios are also checked for consistency. To avoid retaining observations likely associated with liquidation or severe distress, we exclude the observations for which the Tier 1 ratio is negative in two consecutive periods.

Commercial banking activity is assessed using the loans-to-assets and deposits-to-assets ratios. Following the rationale of Alessi et al. (2021), but adapting it to the institutional information available in our data, a bank-year is classified as having a non-commercial profile when either ratio is below 20%. To account for atypical balance-sheet structures during initial reporting periods, observations from a bank's first three reporting years are excluded when the bank exhibits a non-commercial profile or a Tier 1 ratio above 50%. Banks displaying a non-commercial profile in more than one-third of their observed periods are removed from the sample.

Minimum time-series requirements are then imposed. Banks must retain at least two annual observations and at least one pair corresponding to consecutive calendar years. No statistical imputation is performed.

The resulting 2000-2010 panel constitutes the cleaned training sample. For the projection exercise, the analysis subsequently retains the subset of surviving banks observed in 2010.

## Annex B – OLS Regressions Results

This annex presents the full results of the OLS regressions underlying our empirical analysis. All specifications include macroeconomic controls and robust standard errors.

```
. reg prov_ratio L.prov_ratio growth unemployment inflation if inrange(year, 2000, 2010), vce(robust)

Linear regression                               Number of obs     =        188
                                                F(4, 183)         =      55.53
                                                Prob > F          =     0.0000
                                                R-squared         =     0.2706
                                                Root MSE          =     .01526

------------------------------------------------------------------------------
             |               Robust
  prov_ratio | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
  prov_ratio |
         L1. |   .8872625   .1043015     8.51   0.000     .6814744    1.093051
             |
      growth |   -.001658   .0009724    -1.71   0.090    -.0035765    .0002606
unemployment |   .0018522    .001127     1.64   0.102    -.0003714    .0040758
   inflation |   .0025884   .0019868     1.30   0.194    -.0013316    .0065084
       _cons |  -.0153404   .0117336    -1.31   0.193     -.038491    .0078102
------------------------------------------------------------------------------
```

**Table B.1 – OLS Regression Results: Provisions and Impairments Ratio**

```
. reg nii_ratio L.nii_ratio growth unemployment inflation if inrange(year, 2000, 2010), vce(robust)

Linear regression                               Number of obs     =        188
                                                F(4, 183)         =      19.67
                                                Prob > F          =     0.0000
                                                R-squared         =     0.7190
                                                Root MSE          =     .00488

------------------------------------------------------------------------------
             |               Robust
   nii_ratio | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
   nii_ratio |
         L1. |   .7674313   .1223044     6.27   0.000     .5261232    1.008739
             |
      growth |   .0001311   .0003228     0.41   0.685    -.0005057    .0007679
unemployment |   .0006431    .000366     1.76   0.081    -.0000791    .0013653
   inflation |   .0013075   .0005477     2.39   0.018     .0002269     .002388
       _cons |  -.0037931   .0038397    -0.99   0.325    -.0113688    .0037827
------------------------------------------------------------------------------
```

**Table B.2 – OLS Regression Results: Net Interest Income Ratio**

```
. reg nfci_ratio L.nfci_ratio growth unemployment inflation i if inrange(year, 2000, 2010), vce(robust)

Linear regression                               Number of obs     =        188
                                                F(5, 182)         =      30.66
                                                Prob > F          =     0.0000
                                                R-squared         =     0.7285
                                                Root MSE          =     .00223

------------------------------------------------------------------------------
             |               Robust
  nfci_ratio | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
  nfci_ratio |
         L1. |   .8616626   .0699003    12.33   0.000     .7237435    .9995817
             |
      growth |   .0002778   .0001249     2.22   0.027     .0000313    .0005242
unemployment |   .0000939   .0001446     0.65   0.517    -.0001913    .0003792
   inflation |  -.0001294   .0002782    -0.46   0.642    -.0006782    .0004195
           i |   .0000203   .0003024     0.07   0.947    -.0005765     .000617
       _cons |   .0001843   .0015929     0.12   0.908    -.0029587    .0033272
------------------------------------------------------------------------------
```

**Table B.3 – OLS Regression Results: Net Fee and Commission Income Ratio**