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# **CREDIT RISK STRESS TESTING**

THE PORTUGUESE ENVIRONMENT, MACROECONOMIC  
SCENARIOS AND THE ESTIMATION OF LOSSES FOR  
CORPORATE SECTORS

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### **Abstract**

This study focuses on the development of a macroeconomic credit risk model for the prediction of corporate default rates, conditional on the observed economic environment. Data relative to the Portuguese economy was utilized for the development of the model, regarding the period from 2002 to 2012. The results suggest a clear link between macroeconomic factors, such as GDP, interest rates, unemployment and corporate indebtedness, to the default rates observed. Furthermore, the introduction of a Merton-based analysis of the loss distributions permitted the analysis of expected and unexpected losses, alongside Basel II capital requirement evolutions.

**KEYWORDS:** *credit risk, stress testing, macroeconomic indicators, corporate portfolio*

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# 1 Introduction

Recent years have seen great development in the credit risk (CR) area, being it is one of the greatest risk faced by banks nowadays, a fact which the current financial crisis greatly underlined. Therefore, it is of the utmost importance to study and understand CR, so as to model it in a way allowing financial supervisors, corporate and banking sectors to better define goals in dealing with the risk arising from credit portfolios.

This work will develop a basis framework for CR modelling, which attempts, on the one hand, at determining default rates (DR), at an aggregate level, for six different sectors of corporates; whilst, on the other hand, at combining the obtained defaults with a multi-factor Merton-type multi-factor approach, which allows a richer analysis of loss distributions (LD)<sup>1</sup> and correlation effects amongst the different sectors, known as sector concentrations.

This model will allow for the development of stress tests, which are indispensable measures for the risk control of a firm, as they provide not only a forward-looking analysis on CR, but also an analysis on their risk tolerance and the effectiveness of risk contingency plans. The stress scenarios developed will be mainly structural, focusing on creating specific states of the economy.

The work is organized as follows: Section 2 reviews the literature on the subject, whilst Section 3 provides a thorough description of the methodology in the macroeconomic model. Section 4 specifies the data utilized and the empirical model obtained. Sections 5 and 6 simulate the default rates and loss distributions. Stress testing analysis is developed in Section 7, and final remarks can then be found in Section 8.

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<sup>1</sup> The analysis will focus on expected and unexpected losses, and capital requirements.

## 2 Literature Review

Wilson (1997a, 1997b) developed the *Credit Portfolio View*<sup>2</sup>, one of the first models to postulate an exogenous contemporaneous relationship between macroeconomic variables and DRs. It has been studied and applied in the Austrian economy (Boss, 2002) – finding evidence on the link between industrial production, inflation, the stock market, nominal interest rate and oil price and aggregate DR – and in the Finnish economy (Virolainen, 2004) – using the same macroeconomic factors to study different sectors of the economy, concluding that overall GDP deviations from trend, interest rates and debt of a sector are significant in the analysis.

Several other studies have more recently focused on the macroeconomic determinants of non-performing loans (NPLs). Salas and Saurina (2002) determine a great impact of GDP growth on NPLs, finding evidence of rapid transmission between the macroeconomic scenario and NPLs. Louzis et al. (2012) use a dynamic model to determine NPLs sensitivity to GDP growth, lending rates, unemployment and public debt, paired with bank-specific variables, finding strong evidence of a link between these variables and DRs in the Greek banking sector.

In what concerns the design of LDs for specific portfolios, Bonti et al. (2006) build a multi-factor portfolio model, which takes into account the correlation between systematic risk factors – in that case sector correlations – present in the economy, when determining losses in a certain portfolio. This model has been adapted and used to test the German economy's sensitivity to crisis in the automobile sector by Duellmann and Erdelmeier (2009), finding evidence of significant increase in expected and unexpected losses due to the effects of intersector correlations.

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<sup>2</sup> Developed for and adopted by McKinsey & Co.

The literature on the subject of CR is vast and ever growing. Many authors underline the importance of macroeconomic developments in the evolution of CR, still, recent studies have shown that correlation between sectors has great impact in tail measurements in CR. The model developed will attempt at combining these models, to create a model that will not only be conditional on the state of the economy, but that will also take into account the sector concentrations present in the specific portfolios.

### **3 Methodology – The Merged model**

According to Simons and Rolwes (2008), the model developed should be classified as fundamental, macroeconomic based and exogenous, since it assumes a maintaining relationship between the economy and the macroeconomic factors used to model it.

This macroeconomic credit default model is characterized by the assumption of a contemporaneous relationship between DR and a number of macroeconomic factors, which depict a state of the economy at a specific point in time. Furthermore, it provides a sectorial division of the economy which allows a deeper analysis of the effect of similar macroeconomic variables in different sides of the economy, but allow also to better grasp the effects each sector plays in the evolution of overall DRs. The work is largely derivative of the model employed by Virolainen (2004), though it has been complemented with the loss analysis from the Bonti et al. (2006), which allows an extension to the analysis of sector concentration effects in LDs.

First and foremost, DRs must be set. These are defined in such a way that they will depend on a macroeconomic index through a logistic functional form<sup>3</sup>:

$$p_{j,t} = \frac{1}{1+\exp(y_{j,t})} \quad (1)$$

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<sup>3</sup> This form is largely used to guarantee that DRs vary between 0 and 1.

where  $p_{j,t}$  represents a specific DR for a sector at a given time and  $y_{j,t}$  the corresponding macroeconomic index for said industry at such time. As so, the relationship between DR and the macroeconomic index will be such that the macroeconomic index is positively correlated to the state of the economy and negatively correlated to the DR,  $p_{j,t}$ . The macroeconomic index can be defined as a logit transformation of the DR of a specific sector at a given time,

$$y_{j,t} = L(p_{j,t}) = \ln \left( \frac{1-p_{j,t}}{p_{j,t}} \right) \quad (2)$$

The macroeconomic index will then be modelled on a set of macroeconomic variables,

$$y_{j,t} = \beta_{j,0} + \beta_{j,1}x_{1,t} + \beta_{j,2}x_{2,t} + \beta_{j,3}x_{3,t} + u_{j,t} \quad (3)$$

where  $\beta_{j,i}$  represents the vector coefficient for the  $i^{\text{th}}$  macroeconomic variable,  $x_{i,t}$ <sup>4</sup>, in the  $j^{\text{th}}$  sector of the economy and  $u_{j,t}$  the error term of the regression, assumed independent and identically normally distributed.

Each of the explanatory macroeconomic variables will be expected to follow an autoregressive process of order 2<sup>5</sup>,

$$x_{i,t} = b_{i,0} + b_{i,1}x_{i,t} + b_{i,2}x_{2,t} + b_{i,3}x_{3,t} + v_{j,t} \quad (4)$$

where  $b_i$  a set of regression coefficients for each of the macroeconomic variables, and  $v_{j,t}$  the error term of the regression, independent and identically normally distributed.

Using both equations (3) and (4) alongside the error terms<sup>6</sup>, it is possible to determine a forecast on the evolution of each industry's DRs and the corresponding macroeconomic variables for a desired period, conditional on the observable state of the economy at the end of the sample period.

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<sup>4</sup> Independent variables will be described in further detail in the next section.

<sup>5</sup> Following the model stated by Virolainen (2004).

<sup>6</sup> Both the vector of error terms ( $E$ ) and the variance-covariance matrix ( $\Sigma$ ), defined as:

$$E = \begin{pmatrix} u \\ v \end{pmatrix} \sim N(0, \Sigma), \quad \Sigma = \begin{bmatrix} \Sigma_u & \Sigma_{u,v} \\ \Sigma_{v,u} & \Sigma_v \end{bmatrix}$$

It is also possible to devise several different stress scenarios, resulting from changes in the macroeconomic setting in each time set. Any of the macroeconomic variables can be stressed, by introducing the specific shock into the simulated vector of error terms, divided by its standard deviation, which will allow the normalization of the vector. By maintaining other variables stable, it will be possible to evaluate specific shocks in the economic environment, and determine the response of DRs to those changes.

Finally, after forecasted DRs have been determined, it is possible to use a multi-factor portfolio model<sup>7</sup>, with a specific predetermined representative portfolio of the Portuguese banking system, to determine LDs for the different scenarios created<sup>8</sup>.

Crucial to this model is the idea that a certain loan will default if the default trigger  $Y_i$  falls below the default barrier  $c_i$ <sup>9</sup>. Said trigger is defined by two risk components:

$$Y_i = r \cdot X_{j(l)} + \sqrt{1 - r^2} \cdot \epsilon_i \quad (5)$$

The first is the sector dependent systematic risk factor  $X_{j(l)}$  and the second is the borrower dependent or idiosyncratic risk factor  $\epsilon_i$ , which are weighted according to asset correlation, determined by the Basel II formula for corporates<sup>10</sup>. Both,  $X_{j(l)}$  and  $\epsilon_i$ , are pairwise independent and present a joint standard normal distribution. The systematic risk factor  $X_{j(l)}$  will be dependent on the correlation between DRs in different sectors and a number of independent standard normal risk factors  $Z_k$ ,

$$X_{j(l)} = \sum_{k=1}^J a_{j(l),k} \cdot Z_k \quad (6)$$

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<sup>7</sup> Developed by Bonti et al. (2006) and further developed by Duellmann and Erdelmeier(2009).

<sup>8</sup> This model will replace the binomial draw used by Virolainen (2004) to determine loss distributions.

<sup>9</sup> Where  $c_i$  will be the inverse of the cumulative normal distribution for the specific loan's DR.

<sup>10</sup>  $Asset\ Correlation\ (r) = 0.12 \times \frac{1 - e^{-50 \times PD}}{1 - e^{-50}} + 0.24 \times \frac{1 - e^{-50 \times PD}}{1 - e^{-50}}$

<sup>11</sup> The  $a_{j(l),k}$  factors are obtained from the Cholesky decomposition of the correlation matrix  $\Omega$ , the correlation matrix between sectors.

Finally, through the use of a Monte Carlo simulation, it is possible to determine the losses of a specific portfolio, which will allow the analysis of the average loss an institution is expected to have in a certain year – through expected losses<sup>12</sup>, a function of DR, exposure-at-default and loss-given default<sup>13</sup> – but also the analysis of possible, yet unforeseen losses – unexpected losses<sup>14</sup>. Furthermore, the analysis of capital requirements<sup>15</sup> evolution will, alongside the previous measures, be crucial to what Sir David Walker (2009) considers essential in the context of stress testing, “*to understand the circumstances under which the entity would fail and be satisfied with the level of risk mitigation that is built in*”.

#### 4 Data and Default modelling

The afore-described model will be adapted to the Portuguese reality and data. Since data on DRs is not readily available for the general public, we take a broader definition of default and employ quarterly data on non-performing loans from non-financial firms<sup>16</sup>, available for the period from the 4<sup>th</sup> quarter of 2002 until the 2<sup>nd</sup> quarter of 2012, obtainable through the Bank of Portugal.

This set of data is then separated into 6 different sectors<sup>17</sup>, according to the NACE 2 sections<sup>18</sup>, which are: agriculture (*AGR*); industry and manufacturing (*I&M*); construction and real estate (*CRE*); trade, hotels and restaurants (*THR*); support

<sup>12</sup>  $Expected\ Losses = DR \cdot EAD \cdot LGD$

<sup>13</sup> Loss given default (LGD) is assumed constant at a 45% level, slightly less conservative than the usual *rule-of-thumb* of 50% recovery rate.

<sup>14</sup> Unexpected losses represent the difference between Value-at-Risk at a certain confidence level, usually 99% or 99.9%, and the expected losses in a portfolio.

<sup>15</sup> Capital requirements are calculated using the Basel II formula:

$$K = \left[ LGD \cdot \Phi \left[ (1-r)^{-0.5} \cdot \Phi^{-1}(PD) + \left( \frac{r}{1-r} \right)^{0.5} \cdot \Phi(0.999) \right] - PD \cdot LGD \right] \cdot [1 - 1.5 \cdot b(PD)]^{-1} \cdot [1 + (M - 2.5) \cdot b(PD)]$$

<sup>16</sup> The ratio of non-performing loans will from now only commonly be referred to as default rate.

<sup>17</sup> Statistical information obtained on non-performing loans ratio was broken down into all 21 NACE 2 sections. Using yearly information on the average number of firms per section it was possible to group these ratios into 6 different sectors of the economy.

<sup>18</sup> Statistical classification of economic activities – see further detail in *Table 1.1*, Section 1, Appendix.

activities (*SA*); and other services and activities (*OSA*). Assuming the data on non-performing loans could be considered a close proxy to DRs in the corporate sector, using data on total number of companies, sector DRs were compiled. *Figures 2.1 and 2.2*, in Section 2 of the Appendix, show the evolution of the DRs for the period under consideration, from 2002:Q4 to 2012:Q2, a set of 42 observations.

As can be seen, sector DRs appear highly correlated, following a downward trend approximately until 2008, from which on there is an increase in all sectors, a behaviour most certainly arising from the global financial crisis, a moment of economic downturn which affected all sectors of the economy. This analysis shows a greater impact in the CRE sector, a result of the construction boom experienced in the previous years due to what could be considered a real-estate bubble. Sectors 2 and 4, I&M and THR, follow CRE as the most affected sectors by the economic downturn. On the other hand, though also showing signs of increase, the remaining sectors display smoother paths.

This can be analysed in *Figure 2.2*, which depicts the evolution of the overall DR in the economy. The lowest value taken by the overall DR is of 1.80% in the last quarter of 2007, from which on there is a clear upward trend, up to the maximum value of 7.90% in the second quarter of 2012, confirming the effect of the 2008 financial crisis and further on of the sovereign debt crisis affecting the Euro Zone.

The calculated sectorial DRs will suffer a logit transformation, creating the dependent variable, the sectorial macroeconomic index. Following previous work on the subject, the main factors aiming at explaining DRs are based on three different sets of measures: profitability, indebtedness and interest rates. Defining the model as such will allow a parsimonious analysis, focusing on factors which, whilst extremely significant to the development of the DRs, are easily understandable and allow an important evaluation of

the effects their variations take on the evolution of DRs and LDs. Furthermore, the same variables are used to explain DRs across sectors, permitting an analysis of the effects of macroeconomic indicators separately yet transversely through sectors.

For profitability, GDP is used, both the annual percentage growth rate and a measure of deviations from trend, which are the residuals obtained by regressing log GDP on a time trend. As an additional measure, unemployment rate is also utilized. As for indebtedness, an index is created<sup>19</sup> which presents the total debt of the sector divided by the value added by said sector. This index, though specific for each sector, does not undermine one of the main characteristics of the model, which is its similarity across sectors. Finally, for interest rate measures, variables included are the Euribor – 3-month, 6-month and 12-month – but also the spread between the average interest rate charged on non-financial firms and the Euribor, also at three different maturities.

Taking into account that the dependent variable will be the macroeconomic index, GDP measures will be expected to carry a positive sign, since a higher GDP implies a better state of the economy, a higher macroeconomic index, and in turn a lower DR. On the other hand, unemployment is expected to carry a negative sign, as will interest rate variables and the debt index<sup>20</sup>.

The modelling is done through the use of the seemingly unrelated regressions (SUR) model, which assumes the dependent variables of different equations are in fact correlated<sup>21</sup>. The use of the SUR model allows an increase in the efficiency of the estimators, since it takes into account the contemporaneous correlations between the

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<sup>19</sup> Debt index is based on the work of Virolainen (2004).

<sup>20</sup> Virolainen (2004) postulates a negative relationship between debt ratio and the macroeconomic index, although other studies (Pesola, 2001; Kalira and Scheicher, 2002) have found these results to be ambiguous.

<sup>21</sup> The model was proposed by Zellner (1962) and as had extensive practical used in the financial area.

error terms of different regressions, transforming them into zero. The results of the SUR estimates are reproduced in *Table 3.2*, Section 3 in the Appendix. The final independent variables used are: the sectorial debt index; the 3-month spread, which proved far more significant than the Euribor, since it displays a far smaller correlation with the GDP variable; the deviations from GDP trend, since the growth rate does not fully attain the impact of GDP changes in the dependent variable, and finally, the unemployment rate<sup>22</sup>. In general, the Adjusted  $R^2$  measure suggests the model is well specified and has a quite high explanatory power, averaging 90% across all sectors. Nevertheless, some issues must be referred, regarding both the sign carried by some of the explanatory variables and also their statistical significance.

First and foremost, debt index, though significant in most sectors, proved to be statistically not significant at a 10% level both for CRE sector and for OSA. Furthermore, though being significant at a 1% significance level, for sectors 1 and 5, AGR and SA respectively, it carries a positive sign, unlike what was expected. It may be realistic to justify this on the specific characteristics of the Portuguese universe of non-financial firms. According to the Portuguese Central Bank Balance-Sheet Database, in 2009, the large majority of the industrial fabric in Portugal was composed of small and medium companies. Firms of this size are usually bank-dependent and have access only to short-term loans, especially when considering a large part of the sample period is affected by the financial crisis, which exponentially increased banks' risk aversion, therefore conditioning firms' access to loans. The variable was, nonetheless, included in the model, since it showed statistical relevance.

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<sup>22</sup> Further details on the explanatory variables and the dependent variable can be found in the Table 3.1, Section 3, and Figures 3.1, 3.2 and 3.3, Section 3, Appendix.

Other explanatory variables were introduced, including Production Index, the Harmonized Index of Consumer Prices, and the returns on the PSI 20, but proved to be generally statistically not significant, with next to no impact in the adjusted  $R^2$  measure. As for the autoregressive processes, they provided an adequate model for the evolution of the explanatory variables – the results can be found in *Table 3.3*, Section 3.

## 5 Simulating Default Rates

Following the construction of the model and its application to the Portuguese data, it is possible to determine a set of DRs for a period in the future through the use of equations (1) and (4), as well as the error terms and their respective variance-covariance matrix.

The first step is to decompose the variance-covariance matrix using the Cholesky decomposition method<sup>23</sup>. Secondly, a matrix of standard normal vectors of  $(j + i) \times 1$  dimensions is drawn,  $Z_{t+s}$ , which will be transformed into the vector of innovations through  $E_{t+s} = C'Z_{t+s}$ . This will provide simulated realisations of the error terms, that together with the AR(2) processes will determine paths for the explanatory variables, taking into account the correlations between macroeconomic factors.

Using equation (3) and its determined coefficients alongside equation (1), it is possible to determine the simulated path, for a period of 12 quarters, for the sectorial DRs.

It is important to analyse what should be considered a *baseline* case, one in which there are no shocks in the economy, therefore its state is determined solely by the equations estimated for the development of the macroeconomic variables and the verified scenario in the end of the sample. *Figure 5.1*, Appendix, demonstrates a clear, though not steep for most of the sectors, upward trend. The analysis of the overall DR confirms the

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<sup>23</sup> The Cholesky decomposition matrix is defined as  $C$ , so that  $\Sigma = CC'$ .

expectations of further growth in DRs, despite no shocks to the economy. This is most possibly a result of the sample collected, which includes a more than 4 year-wide recessionary period, representing around 20% of the sample, thus creating a negative bias in the analysis.

## **6 Loan Portfolio and Loss Distribution**

The continuation of the analysis of the macroeconomic model developed requires the construction of LDs associated with the forecasted DRs. For said purpose, data on a specific loan portfolio was procured. The portfolio is representative of the Portuguese economy, constituted by 3564 borrowers, with a total exposure of 5.227.949.014€<sup>24</sup> – further detail on the portfolio can be found in Section 4, Appendix.

The next subsections will allow for a brief analysis of the LDs generated by the aforementioned *baseline* scenario. The correlation matrix between sectors is assumed constant, which is one of the shortcomings of the analysis presented, although it is still possible to analyse the short-term effects of the different scenarios.

Employing the DRs obtained from the *baseline* case, it was possible to reach the LD generated by the average of the next 4 quarters forecasted yearly default probabilities. Due to the model's biasedness towards a negative scenario in the future, results are above what would be expected, with expected losses (EL) arising to 2.74% of the total exposure, and unexpected losses (UL) of the 99% (99.9%) percentile of 6.55% (8.13%) (see *Table 5.1*, Appendix), meaning that there is a 1%(0.1%) possibility there will be losses in the portfolio which will exceed those expected by 239% (279%).

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<sup>24</sup> The loan portfolio analysed was provided from previous work by Samuel da Rocha Lopes (2009, 2010), originating from the Portuguese Credit Register, maintained by the Bank of Portugal. The sample was selected to reflect the specificities of the Portuguese economy, so that it may be considered representative. The sample was reduced to include only the NACE 2 sections studied and due to computational limitations.

The LD presents skewedness to the left, since the majority of the simulated losses are in the [0,10] interval<sup>25</sup>. Lastly, the *baseline* scenario demands capital reaching 15.89% of the total risk-weighted assets, showing the clear signs of negative outlook predicted for the Portuguese economy in the forecasted period.

## **7 Stress Tests**

As aforementioned, the model developed allows for an analysis of specific shocks in the economy. We will focus on the effects of negative shocks in GDP, increases in interest rate spreads and finally a combination of both of these scenarios. Furthermore, it proved relevant to scrutinise effects of persistent shocks, versus those of less lasting effects, still with the same magnitude – shocks considered persistent last over 4 quarters, whilst the other only 2. An analysis of the effects on DRs will first be achieved, followed by an analysis of the LDs for the representative portfolio and, finally, an analysis of sectorial capital requirements will be postulated. Probabilities of default utilized in the LD reflect only the first year average; nevertheless, the effects on the DRs can be seen throughout the 12 quarter forecasted period.

The analysis focuses on the stress testing of the macroeconomic variables. Yet, through the use of the multi-factor model, it is also possible to stress other components of the model which were, for purposes of simplicity, maintained constant, such as the Loss-Given-Default – maintained at a constant 45% level – and the sector correlation matrix.

### **GDP Stress Scenarios**

Four different scenarios of stress are analysed, two mild – representing deviation from trend to increase 3% over a one-year period – and two extreme – demonstrating 6% decreases, one being persistent and the other not.

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<sup>25</sup> Each loss class represents a loss of €1.5 million.

The not persistent scenario takes an initial larger toll on the DRs, as would be expected given the assumption of larger changes. However, towards the end of the period, both scenarios converge, as can be seen in *Figure 6.1*, Appendix.<sup>26</sup> DRs show increases averaging 0.85%, for the *mild* scenario, whilst the *extreme* scenario shows jumps in DRs nearing 2.20%.

Sector-wise analysis of DRs allows the conclusion that the SA sector shows the highest response to GDP changes, exponentially growing by more than 120% by the end of the 12 quarters. It is followed closely by the CRE sector, which shows an average increase of 107%. These results come to confirm the expectations that recent years' developments in the Portuguese economy greatly affect the model – in the last 4 years, the GDP downturn has been in line with the demise of several CRE sector firms, due to the bursting of the real estate bubble, and has shown great impact in the service sector, mostly comprised in the SA sector.

Both the AGR sector and the OSA sector show smaller responses, actually decreasing over time in the *mild* scenario. When analysing the evolution of these sectors' DRs over the previous year, which have already comprised a significant GDP downturn, it is clear that their paths have been far smoother than those of remaining sectors, fact taken into account by the model generating the milder responses seen. Overall, DRs show jumps of over 60% from the observed values in 2012:Q2.

In what regards the LDs, seen in *Figure 6.3*, Appendix, increases in ELs around 0.38% of the total exposure are observed, when compared to the *baseline* scenario, and ULs in the 99% (99.9%) percentile show intensifications of 0.26% (0.81%) of the total exposure. Finally, the rise in capital requirements is also moderate, increasing from the

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<sup>26</sup> An analysis of DR differences can be seen in Table 6.1, Appendix.

observed 15.89% in the *baseline* scenario to an average of 16.26% in the *mild* scenario and 16.64% in the *extreme* scenario<sup>27</sup>.

### **Interest Rate Stress Scenarios**

Much like the previous analysis, there are four scenarios under scrutiny, two in which the spread increase is of 1.5% and two where it is of 3%. Similarly, we see the effect of not persistent shocks in the beginning of the forecast, but final results are nearly equal.

The sectorial analysis shows, yet again, Sectors 3 and 5 to have greater sensitivity to changes in the interest rate, increasing by more than 150% from the values in 2012:Q2. THR sector follows in a close third, jumping nearly 100%. In this case, the three sectors mentioned present the largest debt ratios, proving the link between the average level of debt level in an industry and its sensitivity to the interest rate level is present.

The LD analysis demonstrates that, despite the initial analysis of DRs indicating larger variations in the DRs, overall the ELs are lower than those found in the GDP scenarios, with increases from the *baseline* scenario averaging 0.16% of the total exposure. UL, 99% and 99.9%, show also little increase relative to the *baseline* scenario, respectively 0.03% and 0.10% of total exposure. Last but not least, capital requirements, which depend directly on the DRs, show larger increases from the *baseline*, 0.96% in the *extreme* case and 0.53% in the *mild* scenario.

### **Interest Rate and GDP Stress Scenario**

In the final stress analysis, both the *extreme* scenarios of GDP and interest are combined. As would be expected, Sectors 5 and 3 show the greatest responses to the shock, although all sectors DRs increase by more than 15%.

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<sup>27</sup> Further details can be found in *Table 6.4* and *Figure 6.3* in Section 6, Appendix.

ELs increase by 0.73% of total exposure, relative to the *baseline* scenario, and by 0.5% and 0.21% relative to the *extreme* interest scenarios and GDP scenarios, respectively. UL are also higher by 0.31% and 0.78% for 99% and 99.9% percentiles, respectively. Overall, the LD presents fatter tails and a smaller bias towards the left when compared to the *baseline* and other *extreme* scenarios.

This scenario does predict smaller losses than those that would arise simply from the addition of losses in the individual stress cases. This result, though counter-intuitive, arises from the fact that in previous analyses the correlation between macroeconomic factors is taken into account. Therefore, changes in the spread variable – in the case of the GDP stress scenarios – or the GDP variable – in the interest stress scenarios – are already foreseen even in the case of only one macroeconomic variable being stressed.

## **8 Conclusions**

This work provides an analysis of the merger of two models: one which allows the forecasting of sector-wide DRs based on the current macroeconomic conditions and their evolution, and another which takes into account inter-sector correlations and their effect in the predicted losses for a specific portfolio. It provides a simple and understandable analysis – both at an aggregate level but also through the use of a representative portfolio of the Portuguese economy –, yet comprises the necessary tools to allow for the construction of several stress scenarios, be it of macroeconomic fluctuations or changes in the underlying hypothesis – as the recovery rate and the correlation between sectors of the economy –, the analysis of which are crucial to the understanding of default and loss evolutions.

Overall, the model showed to be adjusted to the current Portuguese macroeconomic setting, proving the link between GDP, unemployment and interest rates, and the

evolution of DRs across the economy. The indebtedness measure evidenced more ambiguity in its results, most possibly determined by the overall characteristics of the Portuguese corporate sector, characterized by small and medium sized firms, with lower access to the debt markets and debt in general.

Nonetheless, some shortcomings must be taken into account, especially those arising from data availability. The time span to which the data is referent, from 2002 to 2012, includes several years of economic downturn, which lead to the display of a negative bias in the general evolution of macroeconomic variables in the market, deeming the *baseline* scenario analysis more adverse than initially expected. Still, analysis of different scenarios is possible, considering the strictness of the initial case is considered.

Further extensions can be made to the model. It would be interesting to allow for more complex models to determine the forecasts of macroeconomic variables. Moreover, it would be especially noteworthy to allow default rates to depend not only on the sector of the economy to which they pertain, but also on the score associated with that specific loan. Furthermore, a deeper analysis of the sector correlations in times of financial distress would greatly improve the model, by allowing specific stress scenarios to be adjusted according to the determined sector correlation associated with that specific environment. Additionally, the model allows for the study of different portfolios, allowing the analysis of specific credit portfolios pertaining to specific banks or firms.

All in all, the analysis conducted could be of great value to the Portuguese economy, be it in the area of credit risk management, or even for financial supervisory purposes or even financial stability analysis, proving the model to be a valuable tool in such times of worldwide economic instability.

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## Appendix

### Section 1: Sector division

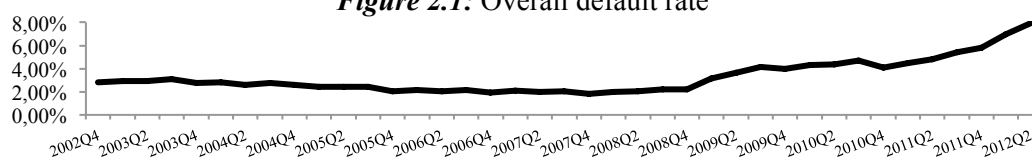
For purposes of simplicity and comparability, sector division was made according to NACE 2 sections; the first level division of economic activities consisted of 21 alphabetical codes<sup>28</sup>, which were grouped into 6 sectors as follows:

**Table 1.1:** NACE 2 Sector Division

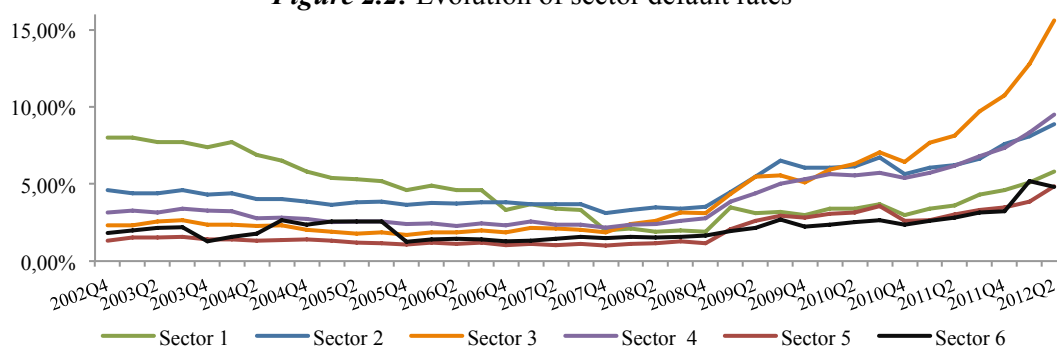
Number	Sector	NACE 2 Definition	Section
1	Agriculture	Agriculture, Forestry and Fishing	A
2	Industry & Manufacturing	Mining and quarrying	B
		Manufacturing	C
		Electricity; Gas; Steam and air conditioning supply	D
		Water Supply; Sewerage. Waste Management and Remediation activities	E
		Construction & Real Estate	Construction Real estate activities
4	Trade, Hotels and Restaurants	Wholesale and retail trade; Repair of motor vehicles and motorcycles	G
		Accommodation and food services activities	H
		Transportation and storage	I
5	Support activities	Professional, scientific and technical activities	M
		Administrative and support service activities	N
6	Other services and activities	Information and communication	J
		Education	P
		Human health and social work activities	Q
		Arts, entertainment and recreation	R
		Other services activities	S

### Section 2: Evolution of DR – Aggregate and sectorial

**Figure 2.1:** Overall default rate



**Figure 2.2:** Evolution of sector default rates



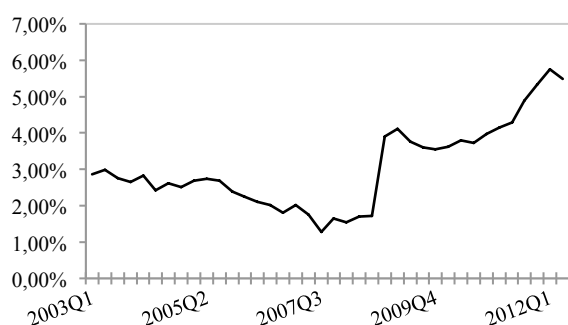
<sup>28</sup> Four of the sections were not included in the analysis due to the nature of the activities: financial and insurance activities (K); public administration and defence; compulsory social security (O); Activities of households as employers; undifferentiated goods and services; producing activities of households for own use (T); and activities of extraterritorial bodies and organization (U).

### Section 3: Empirical model

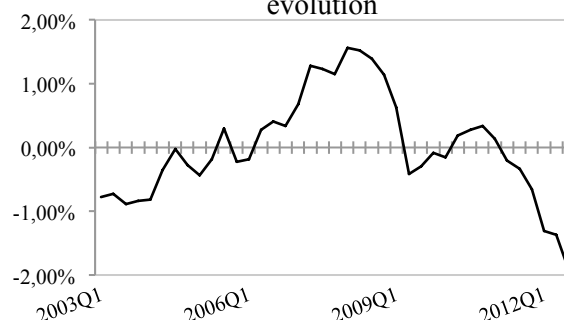
**Table 3.1:** Variable Definition

Variables	Definition
Macroeconomic Index	Logit transformation of each sector's default rate
Debt	Ratio between the total debt of a sector and the value added per said sector
3-Month Spread	Spread between the yearly interest rate charged to NFC and the 3 month Euribor
GDP	Residuals of log real GDP regressed on a constant and a time trend
Unemployment	Yearly rate of total unemployment

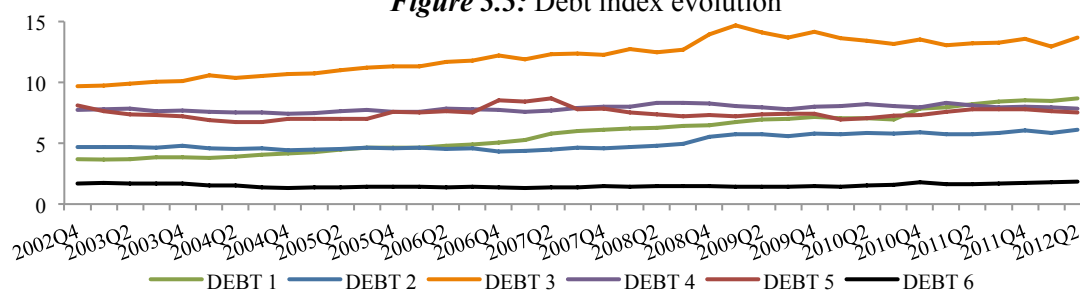
**Figure 3.1:** 3-Month Spread



**Figure 3.2:** Deviations from trend evolution



**Figure 3.3:** Debt index evolution



**Table 3.2:** SUR Regression estimates for the period 2002:Q4 to 2012:Q2

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6
Debt	0.24*** (8.14)	-0.07*** (-2.73)		-0.11** (-2.23)	0.12*** (3.56)	
Spread3M	10.71** (2.33)		-35.62*** (-6.01)	-15.47*** (-5.10)	-18.08*** (-5.21)	31.05*** (7.83)
Log Deviation	17.98*** (8.27)	5.18*** (7.81)	-4.93** (-2.42)	3.32*** (2.89)		29.53*** (12.04)
Unemployment	-0.10*** (-4.77)	-0.08*** (-9.49)	-0.14*** (-6.02)	-0.10*** (-7.00)	-0.12*** (-6.12)	
Constant	2.39*** (24.04)	4.18*** (42.25)	5.82*** (41.93)	5.53*** (15.75)	4.84*** (18.99)	2.18*** (17.25)
Adj. R <sup>2</sup>	89.58%	90.71%	92.21%	92.07%	87.87%	78.76%

P-value: \*- significant at a 10% level; \*\*-significant at a 5% level; \*\*\*-significant at a 1% level

**Table 3.3:** Autoregressive process of order 2 for the period of 2002:Q4 to 2012:Q2

	Debt 1	Debt 2	Debt 4	Debt 5	Spread3M	LogDeviation	Unemployment
L1	0.94*** (29.20)	0.95*** (5.41)	0.78*** (4.51)	0.82*** (4.85)	1.07*** (6.14)	1.24*** (7.61)	1.39*** (9.09)**
L2	0.07 (-0.38)	0.05 (0.26)	0.03 (0.20)	-0.04 (-0.26)	-0.01 (-0.51)	-0.31* (-1.81)	-0.34 (-2.31)
Constant	0.08 (0.61)	0.04 (0.14)	1.49* (1.78)	1.69* (2.03)	0.001 (0.58)	-0.001 (-0.63)	-0.03 (-0.14)
Adj. R <sup>2</sup>	98.70%	92.69%	62.65%	59.18%	85.66%	82.32%	97.77%

P-value: \*- significant at a 10% level; \*\*-significant at a 5% level; \*\*\*-significant at a 1% level

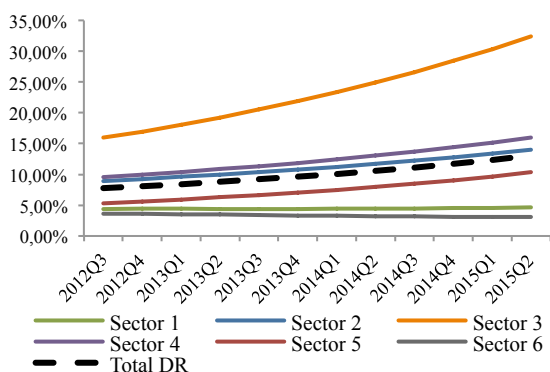
## Section 4: Loan Portfolio characteristics

**Table 4.1:** Loan Portfolio characteristics

Sector	NACE 2	Exposure (€)	% Exposure	# Borrowers	% Borrowers
Sector 1	A	25 731 401 €	0.49%	72	2.02%
	B	14 660 942 €	0.28%	16	0.45%
Sector 2	C	328 714 651 €	6.29%	536	15.04%
	D	2 478 772 283 €	47.41%	105	2.95%
	E	169 912 962 €	3.25%	66	1.85%
Sector 3	F	742 885 928 €	14.21%	811	22.76%
	L	612 532 975 €	11.72%	541	15.18%
Sector 4	G	123 847 439 €	2.37%	519	14.56%
	H	418 974 305 €	8.01%	303	8.50%
	I	80 981 010 €	1.55%	213	5.98%
Sector 5	M	28 599 822 €	0.55%	170	4.77%
	N	124 879 078 €	2.39%	94	2.64%
Sector 6	J	3 078 759 €	0.06%	51	1.43%
	P	- €	0.00%	0	0.00%
	Q	72 648 116 €	1.39%	44	1.23%
	R	1 711 954 €	0.03%	20	0.56%
	S	17 389 €	0.00%	3	0.08%
<b>Total</b>	<b>17</b>	<b>5 227 949 014 €</b>	<b>100%</b>	<b>3564</b>	<b>100%</b>

## Section 5: Baseline Scenario

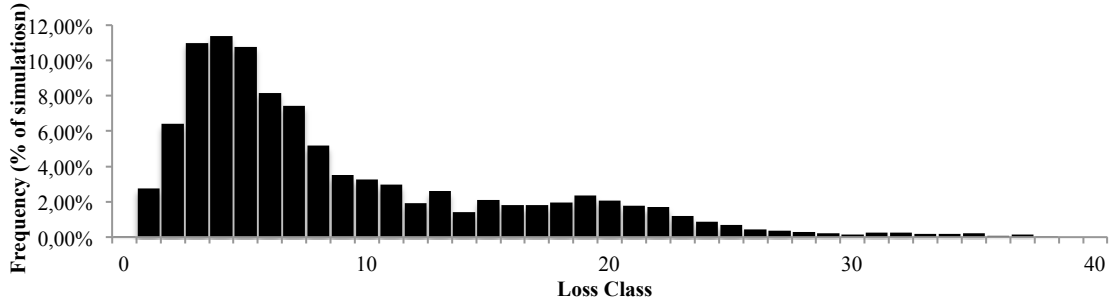
**Figure 5.1:** Default rates per sector in baseline scenario



**Table 5.1:** Loss analysis in the baseline scenario

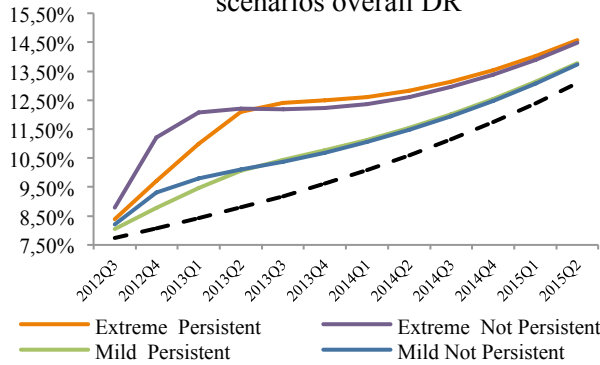
	Baseline
Expected Loss	2.74%
Unexpected Loss (99%)	6.55%
Unexpected Loss (99.9%)	8.13%
Capital Requirements	15.89%

**Figure 5.3:** Loss Distribution in *baseline* Scenarios

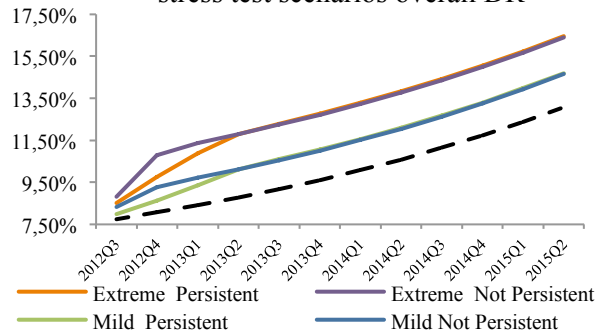


**Section 6: Stress Tests**

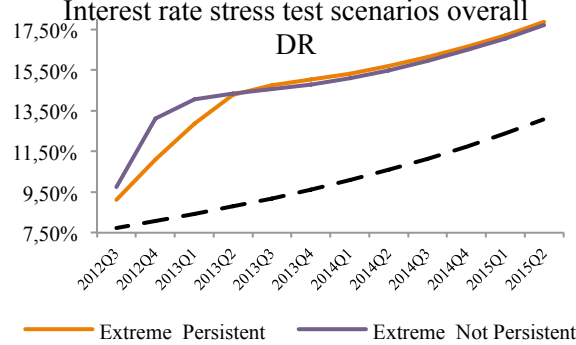
**Figure 6.1:** Analysis of GDP stress test scenarios overall DR



**Figure 6.2:** Analysis of Interest rate stress test scenarios overall DR



**Figure 6.3:** Analysis of GDP and Interest rate stress test scenarios overall DR



**Table 6.1:** Analysis of DRs in GDP rate stress tests

	Extreme		Mild	
	Persistent	Not Persistent	Persistent	Not Persistent
Persistent - Not Persistent	-0.13%			
Differences to Baseline	2.13%	2.26%	0.76%	0.93%
Extreme - Mild	1.24%	1.32%	-	-

**Table 6.2:** Analysis of DRs in Interest rate stress tests

	Extreme		Mild	
	Persistent	Not Persistent	Persistent	Not Persistent
Persistent - Not Persistent	-0.11%			
Differences to Baseline	2.91%	2.79%	1.07%	1.33%
Extreme - Mild	1.54%	1.57%	-	-

**Table 6.3:** Analysis of DRs in GDP and Interest rate stress tests

	Extreme	
	Persistent	Not Persistent
Persistent vs. Not Persistent	-0.13%	
Differences to Baseline	2.13%	2.26%

**Table 6.4:** Loss distribution analysis of GDP stress tests

	Extreme		Mild	
	Persistent	Not Persistent	Persistent	Not Persistent
Expected Loss	3.31%	3.20%	2.95%	3.01%
Unexpected Loss (99%)	7.01%	6.84%	6.64%	6.73%
Unexpected Loss (99.9%)	8.83%	8.94%	9.02%	8.96%
Capital Requirements	16.55%	16.72%	16.22%	16.30%

**Table 6.5:** Loss distribution analysis of Interest Rate stress tests

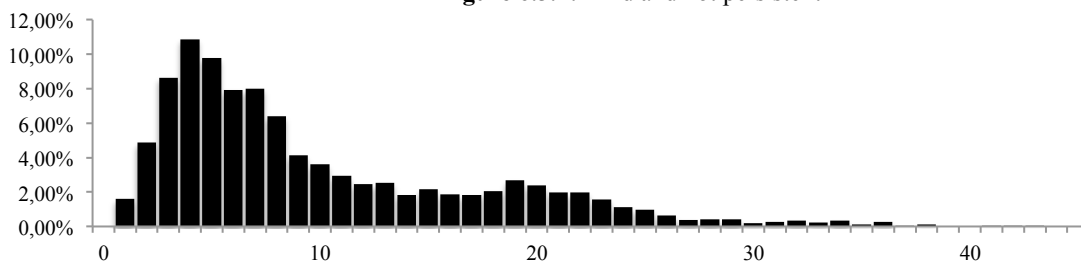
	Extreme		Mild	
	Persistent	Not Persistent	Persistent	Not Persistent
Expected Loss	2.95%	2.99%	2.82%	2.85%
Unexpected Loss (99%)	6.64%	6.60%	6.54%	6.54%
Unexpected Loss (99.9%)	8.29%	8.30%	8.18%	8.15%
Capital Requirements	16.40%	16.45%	16.16%	16.23%

**Table 6.5:** Loss distribution analysis of Interest Rate and GDP stress tests

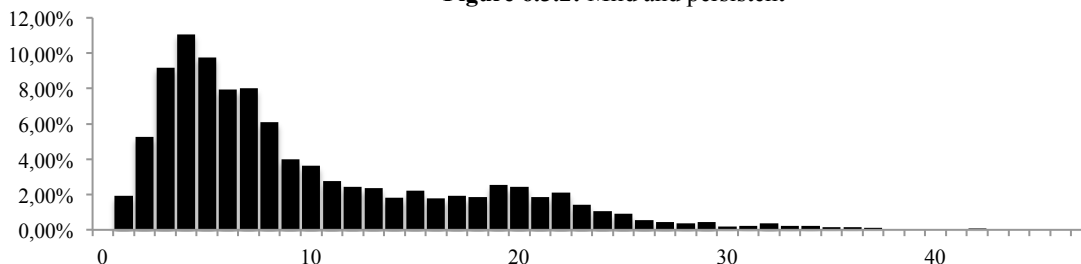
	Extreme	
	Persistent	Not Persistent
Expected Loss	3.55%	3.38%
Unexpected Loss (99%)	6.87%	6.86%
Unexpected Loss (99.9%)	8.93%	8.91%
Capital Requirements	17.61%	17.87%

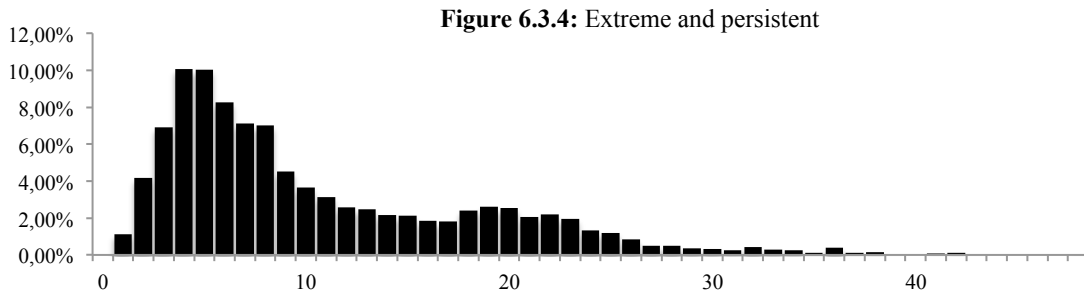
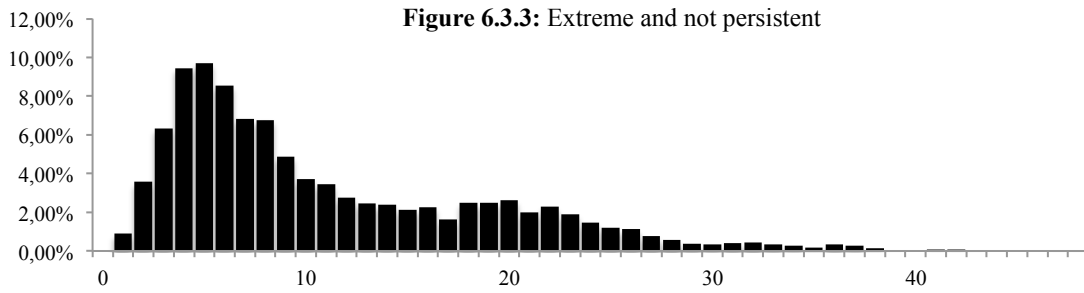
**Figure 6.3:** Loss distributions of GDP stress tests

**Figure 6.3.1:** Mild and not persistent

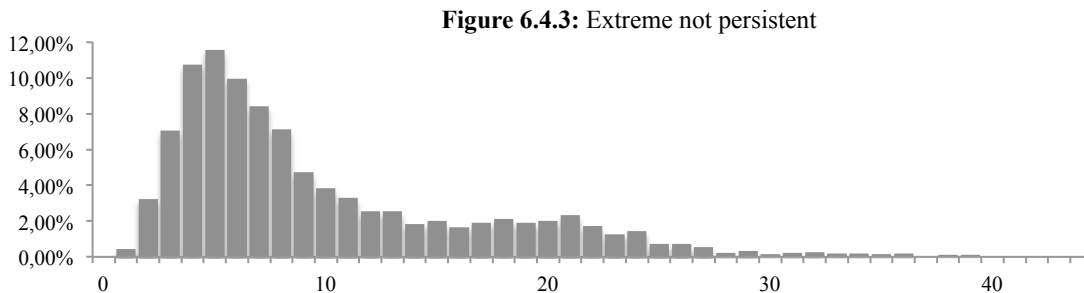
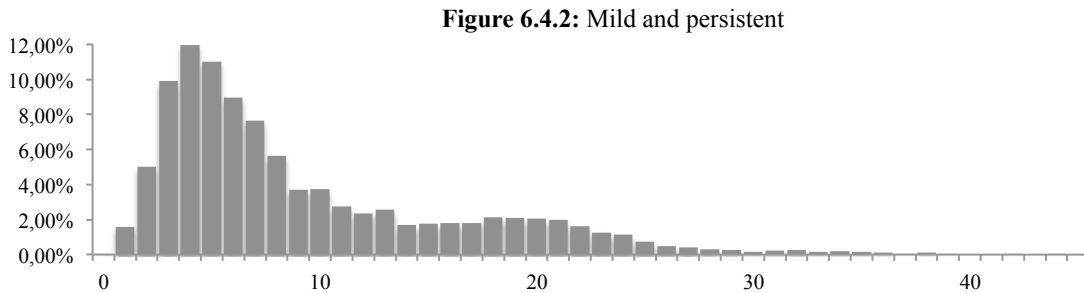
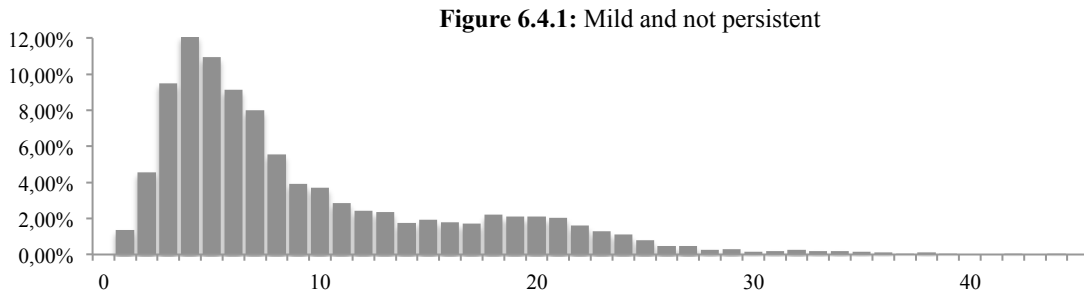


**Figure 6.3.2:** Mild and persistent

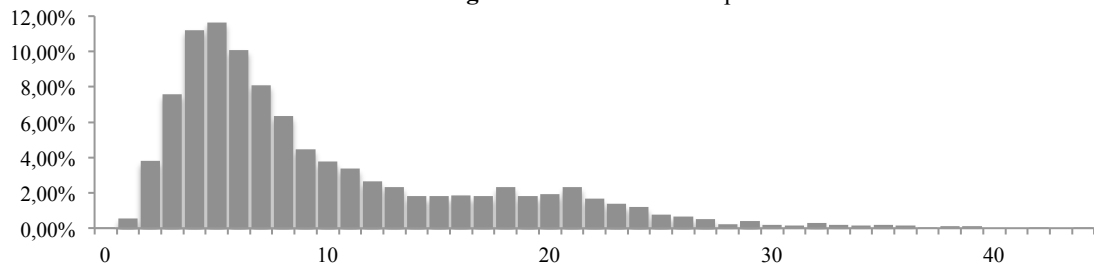




**Figure 6.4:** Loss distributions of Interest Rate stress tests

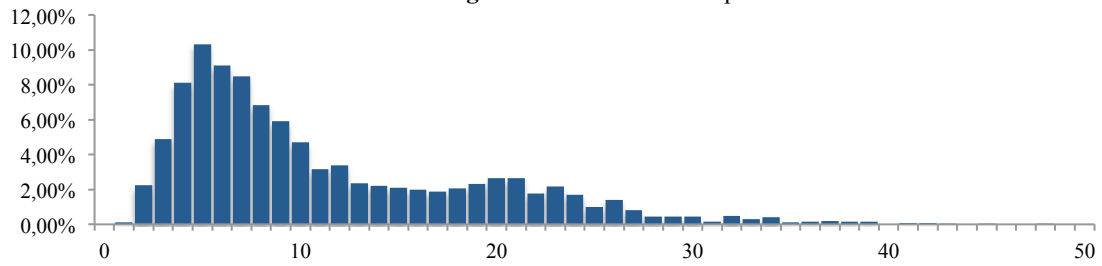


**Figure 6.4.4: Extreme and persistent**



**Figure 6.5: Loss distributions of Interest Rate and GDP stress tests**

**Figure 6.5.1: Extreme and persistent**



**Figure 6.5.2: Extreme and not persistent**

