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Were Swedish Banks Prepared for the Great Lockdown?

Stress Testing Banks' Capital Levels in Light of Historical Crises and Covid-19

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Abstract

In modern history, Sweden has experienced two major financial crises: the early 1990s and the global financial crisis in 2008. During the last decades, there has been an increased global focus on regulating and supervising banks, where Basel III is the leading framework. Today, one of the most debated issues within the global economy is Covid-19. It is uncertain how the pandemic will affect countries' economies and financial sectors. This paper has two major purposes. First, to examine if banks' capital resilience has improved with the introduction of the Basel framework and Basel III in specific. Second, to examine how banks manage different scenarios of Covid-19. To accomplish this, we perform five top-down stress tests on four major banks in Sweden. Two stress tests are connected to the historical financial crises, i.e. the 1990s and the 2008 crises. Three stress tests are different scenarios of Covid-19, which vary in magnitude. In our paper, we find that banks' capital resilience has improved. For Covid-19, we find that if the aftermath of the pandemic follows the current forecasts, banks manage the consequences of Covid-19 well. However, the forecasts are uncertain. If the aftermath is more severe than current forecasts, there is a risk that the Swedish government needs to intervene to save the banking sector.

Keywords: Basel, Covid-19, Financial Crises, Financial Stability, Macroprudential, Stress Tests

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Abbreviations

Abbreviation	*Definition*
BIS	Bank of International Settlement
CET1	Common Equity Tier 1
EBA	European Banking Authority
ECB	European Central Bank
KI	National Institute of Economic Research
LGD	Loss Given Default
NFCM	Net Fee and Commission Margin
NIM	Net Interest Margin
PD	Probability of Default
RWA	Risk-weighted assets
SCB	Statistics of Sweden

1 Introduction

Covid-19 is arguably the most substantial economic crisis in Sweden in modern time. The International Monetary Fund (2020) states that there is a risk that the global economy faces the deepest recession since the Great Depression. During the first months of 2020, there have been reports of rapidly increased unemployment, significant drops in GDP, and decreased global demand (Rushe, 2020; Boissay & Rungcharoenkitkul, 2020; Fjellström, 2020). The economic situation is problematic, and the consequences of Covid-19 could be devastating.

In previous economic crises, banks have been significantly affected. For Sweden and Swedish banks, the largest crises in modern times are the financial crisis in the early 1990s and the financial crisis in 2008. Especially the crisis in the early 1990s affected Swedish banks. For instance, the Swedish government acquired the banks Nordbanken and Götabanken[1], to save the banks from their financial problems. As a result of global historical financial crises, an international cooperation was initiated to enhance financial stability, the Basel Committee (BIS, 2020). Their work consists of regulating and supervising banks. To accomplish this, the Committee has released three frameworks throughout the years, which consist of measures to enhance financial stability. The first framework, Basel I, was released in 1988. The second version of the framework, Basel II, was published in 2004. Shortly after the financial crisis in 2008, Basel III was released. Today's framework, i.e. Basel III, includes different capital requirements and measures to regulate banks. One of the measures is stress testing banks' capital levels. Stress tests simulate a given scenario and estimate how banks are affected by the scenario (Baudino et al., 2018). With the developments of new capital requirements and stress testing, the banking sector is now more regulated than ever before.

However, even if the banking sector is regulated rigorously, there are some concerns regarding the consequences of Covid-19. A global pandemic of this magnitude has never occurred in modern times. This implies that the consequences might also be something entirely new.

In this paper, we aim to examine two things. First, if the current banking regulation, Basel III, has improved the risk management of Swedish banks for capital resilience. We examine this by stress-testing the capital levels for four major banks in Sweden for the financial crises of the

[1] The two banks are Nordea today

early 1990s and 2008. These historical crises are performed in light of today's market conditions. Second, how banks manage the aftermath of Covid-19. We examine this by stress testing banks' capital levels for three scenarios of Covid-19. The consequences of Covid-19 are uncertain. To account for the unpredictable situation, we perform the scenarios with various magnitudes of the aftermath. All Covid-19 scenarios are based on different forecasts, where the third Covid-19 scenario also relies on statements from experts on the possible aftermath. The last scenario is the most adverse. This study aims to contribute to the field of financial stability, by examining if the banking sector's stability has improved in the last decades, with Basel III, and how the banking sector can withstand an entirely new threat, i.e. Covid-19.

We find that banks' resilience has improved for the two historical crises. Basel III appears to improve banks' risk management. Banks' capital levels endure the two historical scenarios. As a consequence of the 1990s financial crisis, the government had to intervene to save the banking sector. In our scenario, this is not needed, which implies that banks are more resilient today. For Covid-19, the banks manage the first and the second scenario without any significant problems. These two scenarios are in line with forecasts from the middle of April. If the consequences of the pandemic are not worse than these forecasts, our results imply that banks endure Covid-19. However, for the third, and most severe scenario, the Swedish government needs to inject capital into the banking sector to ensure its stability and survival. Without governmental intervention, there is a risk that the banking sector suffers severe economic damage.

This paper consists of six chapters. The first chapter refers to Basel III. The second chapter covers stress tests. It includes two approaches to stress tests, literature on stress tests, and how different central banks model their stress tests differently. The third chapter describes our approach for stress testing banks' capital level. In our fourth chapter we are laying out our scenarios. This includes both a description of the scenarios and the result of the stress tests. The fifth chapter is a discussion of the result.

2 Basel III

In the 1970s, there was a period with financial concerns. The oil crisis in 1973 is one of the most known examples of the turbulent time. The period was characterised by a volatile and troubled currency and banking market, where the German bank, Herstatt, failed in 1974 (BIS,

2020). As a consequence, the Basel Committee was founded. The main objective was to enhance financial stability through an increased and improved banking supervision. Since the creation of the Basel Committee, the organisation and the regulations have developed continuously, as results of various financial crises. For instance, Basel III was created as a response to the financial crisis in 2008. Today, the Committee's work towards regulating and supervising banks can be summarised in three pillars: capital and liquidity requirements, risk management and supervision, and market discipline (BIS, n.d).

The first pillar, in Basel III, refers to capital and liquidity requirements. It states how much capital banks need to have to be prepared for a potential external shock. Equation 1 shows one capital requirement, the ratio common equity of tier 1 (CET1) to risk-weighted assets (RWA). CET1 consists of the most liquid capital, e.g. retained earnings and common shares (BIS, 2019a). It is the capital that is used to cover losses (Daniëls et al., 2017). RWA consists of assets where the risk level of an asset is taken into consideration. During turbulent times the risk level increase for many assets, since the risk of default increases. If a bank has a large number of assets with a high degree of risk, RWA is higher, relative a bank with a low number of risky assets. The bank with the higher RWA is required to hold a larger amount of capital to fulfil the requirement, where the minimum requirement is 4.5 per cent for this measure.

$$\frac{CET1}{RWA} > 4.5\% \tag{1}$$

In addition to the minimum requirement, central banks and other regulating authorities can set a countercyclical buffer of up to 2.5 per cent. The Swedish Financial Supervisory Authority[2] reduced its countercyclical buffer in March 2020, from 2.5 to 0 per cent, due to Covid-19 (Finansinspektionen, 2020). This is a measure which decreases the level of capital that banks are required to hold. The measure is intended to facilitate banks' lending to the public during turbulent times. Finally, the three largest Swedish banks[3] have an additional 5 per cent requirement for the ratio CET1 to RWA, since the three banks are considered as crucial for the financial system (Svenska Bankföreningen, 2020). The ratio CET1 to RWA is a key measure for banks and is among the first reported numbers in banks' quarterly reports.

[2] Finansinspektionen in Swedish
[3] SEB, SHB and Swedbank

Besides the first pillar, the second and third pillars are crucial for banking supervision. The second pillar, risk management and supervision, states how banks should work with risk (BIS, 2019b). For instance, methods to measure risk and how supervisors should ensure that banks follow the requirements. This includes banks to conduct stress tests to ensure that the capital level is adequate. The third pillar, market discipline, refers to how banks should report their financial statements, e.g. where and how often reports should be published (BIS, 2019c).

The main idea with the banking regulations is to ensure financial stability. For capital and liquidity requirements, i.e. the first pillar, it is to ensure that banks have enough capital to manage an external shock and turbulent times. In this area, the ratio CET1 to RWA is one of the most used measurements. For the second pillar, the idea is to provide tools and guidelines for banks to work with risk. Lastly, the third pillar, standardises banks' reporting of financial documents, to increase banks' transparency.

3 Stress tests

In Basel III, stress testing banks' capital levels are a frequently used measure to ensure that banks fulfil different capital requirements. This chapter starts with an introduction to stress testing banks. Thereafter, a literature review of the area follows. Lastly, we compare four central banks models for conducting stress tests.

3.1 Introduction to stress test

Supervision of banks have increased substantially during the last 30 years. In Basel III, the second pillar includes measures for banks' risk management. One of the key measures, within risk management, is to conduct stress tests. The idea with stress tests is to create an adverse, but plausible, scenario for the economy and simulate how banks are affected by the scenario (Baudino et al., 2018). Results from the stress test are used for mainly two things. First, to examine if banks need to take actions to improve their risk management. Second, to examine if there is a need to inject capital in the banking sector during a crisis. To perform a stress test, there are two approaches available: the top-down or the bottom-up approach (Baudino et al., 2018). The first approach focuses on the entire banking sector rather than only an individual bank, while the bottom-up approach analyses how an individual bank manages the scenario. After this, the next step is to model how the scenario affects banks. Regardless if a top-down

or a bottom-up approach is performed the most common variables to analyse are banks' credit losses and net interest margin (Buncic et al., 2019).

One of the first things to do when performing a stress test is to create a scenario (Baudino et al., 2018). It should be an adverse scenario, which stresses banks' incomes and credit losses. However, it must be plausible. The scenario runs for a limited period of time, often a few years, and includes paths for key macroeconomic and financial variables (ECB, 2018). These variables are, for instance, GDP, various interest rates, and asset prices. The macroeconomic and financial variables capture the state of the economy, which affects banks' profit. For example, a scenario with increasing unemployment, falling asset prices and negative GDP growth increase banks' credit losses and reduce their incomes. The variables capture economic activity, where decreased activity increase the risk that the counterparty cannot repay its debt obligations, which increase credit losses. In addition to increased credit losses, decreased economic activity also decreases banks' incomes.

Depending on the aim of the stress test, the choice of approach differs (Baudino et al., 2018). If the aim is to do an economy-wide stress test, this is called a macroprudential stress test, the top-down approach is used. This tests how the entire banking sector and individual banks manage an external shock. It includes taking dispersion effects into account, where one bank's problem affects other banks. The top-down approach is often performed by central banks and uses their framework, i.e. assumptions, data, models, and scenarios. If the aim is to examine banks individually rigorously, this is a microprudential stress test, the bottom-up approach is used. In these cases, it is common that central banks provide a scenario for banks, whereas banks themselves perform the stress test. Thereafter, the banks return the results to the central banks, which summarises the stress tests.

The top-down and bottom-up approaches differ in several aspects (Buncic et al., 2019). The most distinguishing difference is the data. When banks perform the bottom-up approaches, they use their internal models and data. Banks' data is more detailed, where parts of it are confidential to the public, compared with the data that is used in the top-down approach. The confidential data includes information about various sectors. Consequently, the scenarios with the bottom-up approach can capture specific risks in different sectors. However, since banks use their own models and data in the bottom-up approach, it is difficult to compare different banks' results.

This is possible with the top-down approach. The top-down approach relies, in general, on macroeconomic-data and bank data that is available from banks' income statement.

Different authorities use different approaches. For instance, the European Banking Authority (EBA, 2018) regularly performs a bottom-up approach for the largest European banks and the European Central Bank (ECB, 2019) performs a top-down approach for the Euro area. Furthermore, in 2018 the Swedish Riksbank and EBA performed two independent stress tests with the same scenario (The Swedish Riksbank, 2019). The Swedish Riksbank conducted a top-down approach, and EBA performed a bottom-up analysis. For the scenario, the Swedish Riksbank estimated the credit losses to 771 billion SEK for the four largest banks in Sweden, while EBA estimated the credit losses to 155 billion SEK. However, it is not feasible to compare the two approaches since they make different assumptions and estimations. Even though it is difficult to compare the results from the different approaches, the results could complete each other. Because of this, it is beneficial to use more than one stress test as a support for a policy decision.

To conclude this section, which of the two approaches to apply for stress testing banks' capital depends on the aim of the test and data availability. For instance, if the aim is to perform an economy-wide stress test, where dispersion effects are included, a top down-approach is more suitable. Nevertheless, conducting a stress test is not a simple task to perform. Within the literature of stress testing banks, there is an ongoing discussion regarding the advantages and disadvantages of stress tests.

3.2 Literature on stress testing banks' capital level

Stress testing banks are, to some extent, controversial and criticised. Primarily two aspects are being criticised: using stress tests as warning signs and the problem of a false sense of security. Borio et al. (2012) state that using stress tests as warning signs is problematic. In their paper, they mention the financial crisis of 2008 as one example. Before the crisis, the stress test did not detect any future problems. Instead, they argue, stress tests created a false sense of security. Breuer and Summer (2018) proceed with the same hypothesis, stress tests can create problems. Stress tests are in general scenario-specific and do not cover all possible scenarios. Breuer and Summer state that most stress tests are based on an exogenous shock, a rapid decrease in GDP and the housing prices, for example. However, the financial crisis in 2008 rather evolved

endogenously. It started partly in the financial sector, for instance, with new collateralised debt obligations. (Hausman & Johnston, 2014). In general, financial crises often emerges endogenous. This development makes banks vulnerable (Reinhart and Rogoff, 2008).

In addition to the aspect of a false sense of security, Borio and Drehman (2011, p.9) mention "the paradox of instability", i.e. a financial system often appears to be strongest before it bursts. The belief of a strong financial system can lead to a questioning of the probability of the scenarios in the stress tests.

Despite the problems with stress tests, they can be a valuable asset, if they are used correctly. Borio et al. (2012) argue that if a crisis has erupted, then stress tests can be a powerful tool. In this event, it is not used as a warning system, and it is easy to create meaningful scenarios. Instead, a stress test can examine how much capital that needs to be injected in the financial system or to see which banks that are the weakest. Moreover, stress tests are commonly used during non-crisis periods as well.

3.3 Comparing top-down stress tests

There are several ways to perform stress tests. After the first choice, i.e. deciding between a top-down or a bottom-up approach, the second decision is to decide how to model the variables of interest. This paper uses a top-down approach for the stress tests in order to incorporate systemic risk in the financial sector and due to data restrictions. Therefore, we focus on comparing different models, from central banks that use the top-down approach. We compare the Swedish Riksbank, the Norwegian Central Bank, the German Bundesbank and the European Central Bank (ECB). For our stress tests, we use the Swedish Riksbank's models.

In general, central banks that use the top-down approach, model three variables: *credit losses*, *net interest margin* and *net fee and commission margin*. However, how central banks model these variables differs.

Comparing models for credit losses

For credit risk and credit losses, the models differ across the countries. The German Bundesbank and ECB use loss given default (LGD) and the probability of default (PD) for different sectors and loans, as a function of the scenario (The German Bundesbank, 2015; ECB, 2017). The two central banks even use microdata on households to estimate PD and LGD on

the mortgages portfolios. Combining PD and LGD can then estimate credit losses. The Swedish Riksbank (Buncic et al., 2019) uses a linear regression model, with different macroeconomic variables, for banks' credit losses. The Norwegian Central Bank's model (Dyre Syversten et al., 2015) differs as well. They model credit losses with two different loan loss functions. The first function is a flow of non-performing loans, i.e. loans with a high probability of default, and the second function is the stock of non-performing loans. These two functions create the change effect and the write-off effect. The change effect is defined as the new non-performing loans, and the write-off effect occurs when the non-performing loans are written-off, and thus creates loan losses. The models require similar data as PD and LGD.

Using PD and LGD for different sectors is beneficial (Buncic et al., 2019). It gives more detailed information and describes the scenario for different sectors better, in comparison to modelling banks' credit losses directly. The main disadvantage with models that use PD and LGD is that it requires a great deal of specific data, which can be difficult to gather for a long historical perspective. In contrast to the models that use PD and LGD, the linear regression that the Swedish Riksbank performs uses data that has been collected for an extended period. On account of this, the Swedish Riksbank's model for credit losses includes the early 1990s, a period when Swedish banks experienced high credit losses. Including a turbulent period in a model for credit losses is beneficial since this incorporates fluctuations in the data and provides more information to the model and the parameters.

Comparing models for income

Banks incomes are often modelled in two ways, through net interest margin (NIM) and net fee and commission margin (NFCM). NIM consists of incomes from interest rates on loans, where the interest rates expenditures on bank deposits are deducted (Buncic et al., 2019). NFCM consists of incomes connected to different fees. For instance, the fee for a credit card, the commission banks take for transactions for securities, or fees connected to consulting services. All expenses connected to these activities are deducted from the income to create NFCM. The most common way to model banks' income is through a dynamic panel regression. For instance, the Swedish Riksbank, the German Bundesbank and ECB all perform dynamic panel regression (Buncic et al., 2019; ECB, 2017; The German Bundesbank, 2015). The Norwegian Central Bank performs a similar panel regression (Dyre Syversten et al., 2015). ECB (2017) also conducts a second model, which incorporates the interest spread for different assets and liabilities for new business. From this, ECB creates an output with a path for the interest spread,

given the macroeconomic scenario. Together with the loan stock, this creates an estimation of NIM. However, ECB mentions that the first model, the dynamic panel regression, requires less data and is more suitable for analysing macroeconomic paths.

The modelling of incomes with dynamic panel regressions follows the same structure for the Swedish Riksbank, the German Bundesbank and ECB. It consists of NIM or NFCM, y_{it}, for bank i in time t, the lagged dependent variables, y_{it-1}, bank-specific effects, μ_i, a matrix of macroeconomic variables, X_t, and an error term, ε_{it}.

$$y_{it} = \mu_i + \alpha y_{it-1} + \beta X_t + \varepsilon_{it} \quad (2)$$

The Norwegian Central Bank's models do not include a lagged dependent variable, but are similar to equation (2), apart from this. The main difference between the central banks is the macroeconomic variables. Different central banks use different macroeconomic variables. For instance, the Norwegian Central Bank (Dyre Syversten et al., 2015) includes the oil price in its model, due to its importance for the Norwegian economy, while the Swedish Riksbank does not. The Swedish Riksbank and ECB use a least-angle regression to find which variables to include. Least-angle regression is an algorithm that is used to choose variables to include in a regression, where the idea is to create a parsimonious model (Efron et al., 2004). Neither the German Bundesbank or the Norwegian Central Bank use the least-angle regression.

To sum up, there are several ways to perform top-down stress tests. Which models that are used, and how the models are constructed, depends on several things. For instance, data availability, historical events and the country's economy. Since our study analyses Swedish banks, we follow the Swedish Riksbank's top-down approach.

4 The Swedish Riksbank's top-down approach

In this chapter, we start by presenting our approach, where the main focus is on modelling credit losses and income. Thereafter, the data in the models is described. Lastly, we present our estimation of the parameters for credit losses and income.

4.1 Our top-down approach

This paper aims to examine if banks have improved their capital resilience, with the implementation of Basel III, and how banks manage Covid-19. We perform five scenarios to examine this. Two scenarios are connected to historical crises, to observe if Basel III has made banks more resilient. Three scenarios are connected to Covid-19. In order to examine how banks are affected by the scenarios, we conduct stress tests. Stress testing banks' capital levels consist of four major steps, regardless if a top-down or a bottom-up approach is performed. In this paper, we perform a top-down approach, since the focus of our study is towards macroeconomic consequences. By using this approach, we are able to incorporate dispersion effects. Moreover, a bottom-up approach is not plausible to perform, since it requires confidential bank data.

Figure 1 shows a simplified timeline of a stress test, where the first step is creating a scenario of adverse events. A scenario can be that the economy is in a deep recession, with high unemployment, falling housing price and negative GDP growth. It could be a historical event, or it could be an entirely new scenario. In our case, we perform five scenarios: the financial crises at the beginning of the 1990s and in 2008, in light of today's market conditions, and three scenarios of Covid-19. The scenarios are selected for two reasons. First, to observe how banks handle a historical crisis, with the implementation of Basel III. Second, to test how different versions of Covid-19 affect banks. We test the following banks: Handelsbanken, Nordea[4], SEB and Swedbank.

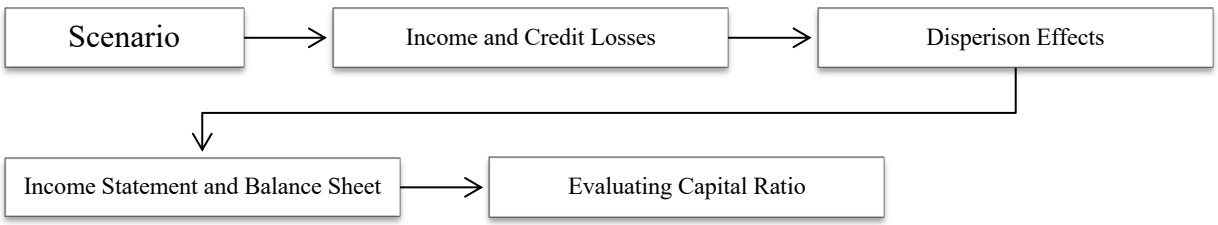

Figure 1. Simplified timeline of a stress test

The second step is creating models where the impact of the scenario affects banks' capital level. Three different models are created, one model for credit losses and two models for banks' incomes. The models depend on macroeconomic, financial and bank-specific variables. The variables capture changes in the state of the economy, which affect banks. For the model for

[4] Today Nordea is a Finnish bank. Nevertheless, Nordea still holds a significant market share in the Swedish bank sector.

credit losses, these variables are the *change in the unemployment rate, the 5-year government bond*, *the difference between the rate that non-financial corporates borrow to and the 6-month sovereign yield*, *the credit ratio*, *the share of banks' lending to non-financial corporates in relation to loans to the public* and lastly, *the growth rate of real housing prices.* The first model for banks' income is net interest margin (NIM). NIM depends on the *growth rate of the real GDP*, the *inflation rate*, *the 3-month sovereign yield*, *the slope of the yield curve*, i.e. the difference between the 10-year government bond and the 3-month sovereign yield, and *banks' equity ratio*, i.e. the ratio of book equity to total assets. The second model for banks' income is net fee and commission income margin (NFCM). NFCM depends on the *growth rate of the real GDP, the inflation rate*, *the return of OMX30* and *banks' equity ratio*.

The third step is to insert each scenario in the models for credit losses, net income margin and net fee and commission margin. Combining the scenarios with the three models creates incomes and credit losses for each of the four banks. In figure 1, this step is denoted as Income and Credit Losses. Adding dispersion effects to the estimated incomes and credit losses creates an income statement for each bank for each scenario. If the incomes are larger than the costs and the credit losses, banks' incomes statements experience a profit for the period. Profits increase banks' capital levels, while losses decreases banks' capital levels since banks use parts of their capital to cover losses. The result from the income statement affects banks' level of capital and the balance sheet. This is denoted as Income Statement and Balance Sheet in figure 1. The fourth, and last, step is using a measure for capital requirements to evaluate banks' capacity to withstand the scenarios. The ratio common equity tier one to risk-weighted assets is used.

Creating Scenarios

The first step in stress testing banks is creating a scenario where the economy is stressed. The idea with scenarios is to test how banks are affected today, given specific circumstances. For historical scenarios, e.g. the financial crises, the key macroeconomic variables are already known. With these known macroeconomic variables, we predict how banks manage the same events again, with today's market conditions. This shows whether banks handle the crises better today, compared with the actual crises.

For events that have not occurred, we can create hypothetical scenarios. With Covid-19, we do not know the economic consequences, even though there are many reports where negative consequences are reported. For instance, high unemployment, a significant drop in GDP and

decreases in housing prices. Since there are no known values for the outcome of Covid-19, we create three different scenarios for possible consequences of Covid-19. The first scenario is mild and short-lasting. It is based on forecasts from the National Institute of Economic Research[5] (KI) and the Swedish Government. The forecasts are published on the 1st April, and the 15th of April. The second scenario is tougher and last longer. This is based on forecasts as well, but adjusted to capture the uncertainty in forecasts for the time being. The last scenario is a scenario with severe and long-lasting consequences. This is based on statements from experts and adjusted forecasts. All scenarios last for three years.

For the scenarios, we do not consider any policy interventions. During a financial crisis, policy interventions would occur. Instead, the simulations show how banks handle the scenarios themselves.

Modelling of income statement

A bank's income statement consists of several different variables, see table 1. The Swedish Riksbank models three of them: *credit losses*, *net interest margin* and *net fee and commission margin* (Buncic et al., 2019). Credit losses are low during normal times, but increases significantly during turbulent times. For the fourth quarter of 2019, both Nordea (2020) and Swedbank's (2020a) share of NIM and NFCM to total incomes are roughly 80 per cent. Apart from the three variables, banks' income statement consists of other variables, e.g. *staff costs* and *depreciation*. These are assumed to be constant throughout the scenario, table 1 shows which variables from the income statement that are constant in the stress tests. For the constant variables, the last reported value is the used value throughout the scenarios.

Income		Expenses	
Net interest margin	Modelled	Credit losses	Modelled
Net fee and commission margin	Modelled	Depreciations, amortisations and impairments	Constant
Net gains and losses on financial items	Constant	Staff costs	Constant
Other operating income	Constant	Other expenses	Constant

Table 1. Which variables on the income statement that is modelled in the Swedish Riksbank's models
Source: Swedbank quarterly report Q1 2020

[5] Konjunkturinstitutet in Swedish.

Modelling of credit losses

During turbulent times banks' credit losses increase (Buncic et al., 2019). This comes from the increased risk that the counterparty is not able to repay its debt obligations. In the model for credit losses, the dependent variable is banks' credit losses divided by banks' loans to the public. The credit losses are the expected and incurred credit losses, instead of only write-offs. This is the measure banks use on their income statement. By using this measure rather than actual credit losses, the estimation of the income statement is similar to actual income statements. The credit loss model consists of six independent variables: *growth rate in real housing prices*, *change of unemployment rate*, *the five-year government bond*, *the credit to GDP ratio*, *the share of loans to non-financial corporates* and *the difference between the interest rate that non-financial corporates borrow to and the 6-month sovereign yield*. The change of the unemployment rate, the interest rates and the credit ratio are used to capture the state of the economy. Housing prices enter the model nonlinearly. During normal times the growth rate of housing has no, or little, effect on credit losses, but during turbulent times decreasing housing prices increase credit losses. Lastly, the share of loans to non-financial corporates is included since credit losses often emerge from credit to non-financial corporates. We estimate the credit loss model by using ordinary least square (OLS):

$$Y_t = \alpha + \beta X_t + \varepsilon_t \tag{3}$$

In the model, Y_t is the aggregated credit losses for all banks in period t, where the credit losses are calculated as the rolling sum of the last four quarters and are normalised by the average of total loans to the public for the last four quarters. X_t is a vector of six independent variables that affect credit losses. The growth rate in real housing prices is the average of the last two years and is multiplied with a dummy variable that is one if the growth rate is negative and zero if positive. This is done in order to create a non-linear relation between credit losses and housing prices. The 5-year government bond, the unemployment rate and the difference between the interest rate that non-financial corporates lend to and the 6-month sovereign yield are all measured as the moving average of the last four quarters. Lastly, the share of loans to non-financial corporates is lagged one quarter. See Appendix A for our estimation of the historical credit losses.

From the model for credit losses, the OLS regression estimates values for the parameters. These values are used together with the different scenarios. For each scenario, we insert a value for

each parameter from the OLS estimation. This results in a prediction for the credit loss ratio. The next step is to transform the credit loss ratio to credit losses in SEK, for the four banks. This is done by multiplying the estimated credit loss ratio from the model with loans to the public for each bank. For the second period in the scenarios, loans to the public are the value of loans to the public in period one, where the credit losses for period one are subtracted.

Modelling of net income margin and net fee and commission margin

During turbulent times banks do not only lose capital through credit losses, their incomes are affected as well. The two main sources of income for banks are *net interest margin* and *net fee and commission margin*, they consist of roughly 80 per cent of total incomes. The two sources of income are dependent on the current state of the economy and are modelled in two ways. Both of the models are estimated through a dynamic panel regression:

$$y_{it} = \mu_i + \alpha y_{it-1} + \gamma z_{it-1} + \beta X_t + \varepsilon_{it} \quad (4)$$

In equation (4) y_{it} stands for NIM or NFCM for bank i during period t, $y_{it-1}$is NIM or NFCM lagged one period, μ_i is a bank-specific fixed effect, X_t is a vector of macroeconomic variables, z_{it-1} is a bank-specific variable, and lastly, ε_{it} is an error term. For both NIM and NFCM, the equation is estimated with a generalised method of moment estimator, in order to avoid biased results due to correlation between the lagged dependent variable and the error term. Both NIM and NFCM are summed over the last four quarters, in order to remove seasonal effects, and divided by the average of the last four quarters assets to normalise. See Appendix B for our historical estimation of NIM and NFCM.

For the net interest margin, the macroeconomic variables in equation (4) consist of *the growth rate of GDP*, *the inflation rate*, *the interest rate for the 3-month sovereign yield*, and *the difference between the 10-year government bond and the 3-month sovereign yield*. GDP and inflation capture the current state of the economy, and the interest rate spread captures the income connected to interest rates. When the economy is blooming, banks' incomes increase. A larger interest rate spread implies higher incomes through interest rates. The macroeconomic variables are lagged one quarter. The bank-specific variable is book equity divided by total assets. It is updated for every period in the scenario, since book equity and total assets changes throughout the scenario. Book equity changes since it is part of CET1. When banks make a profit or a loss, book equity changes. Total assets change as a result of credit losses. The ratio

is used to capture differences between banks. For instance, differences in how well-capitalised banks are, affect their funding cost. In order to get the net interest margin in SEK, the ratio of NIM and total assets are multiplied with the average of the last four quarter's total assets.

The *net fee and commission margin,* similar to NIM, is dependent on *the growth rate of GDP* and *the inflation rate* to incorporate the current state of the economy. Both variables are lagged one quarter. In addition to these two variables, NFCM depends on *the return on the OMX30 index* as a third macroeconomic variable. The idea of the usage of return of the OMX30 index is to capture incomes from commission on trade with securities since NFCM partly consists of this. When the economy is doing well, this increases the transactions on the stock market, on these transactions, banks earn a commission. The opposite occurs during turbulent times, banks' income through commissions decreases. Lastly, the model uses the equity ratio as bank-specific variable. To get NFCM in SEK, we perform the same procedure as with NIM.

A final aspect to take into consideration is dispersion effects. Banks are interlinked and frequently do business with each other. If a negative shock strikes one bank, this would likely spread to other banks. The Swedish Riksbank (Buncic et al., 2019) models this in two different ways: contagion and asset fire sale. The contagion effect is when one bank's failure to meet its obligations spread to another. The asset fire sale occurs when banks need to sell assets in order to create liquid assets. Banks hold similar assets, if several banks sell assets simultaneously, the market price of these assets decrease. This creates mark-to-market losses for all banks. The mark-to-market effect implies that banks that did not sell any assets lose from the new, lower, market value as well. When the Swedish Riksbank models this, they use confidential data, which does that we cannot model this. However, the Swedish Riksbank states that 12 per cent of the credit losses in their scenario comes from the dispersion effect (The Swedish Riksbank, 2019). Therefore, we make the simplifying assumption that the dispersion effect is 12 per cent of the credit losses.

The last aspect regarding the income statement is taxes and dividends. The steps we have done until now creates the operating profit. If this is positive, banks pay taxes on this, and if the profit after taxes is positive, banks pay dividends to its shareholders. The Swedish Riksbank sets the tax rate to 22 per cent in their model, as an average from the banks' tax expenditures the last years. This was the corporate tax before 2019. Today the tax rate is 21.4 per cent (Carlgren, 2019). We use the tax rate of 21.4 per cent if the operating profit is positive. For dividends,

banks have different dividends policies. For 2018 the payout policies were roughly 70 per cent of the profit after taxes for the four largest Swedish banks, which we use as well.

To sum up, when these steps are performed, we have estimated the credit losses, the net interest income margin and the net fee and commission margin. Together with the assumption that variables, such as staff costs and depreciation, are constant throughout the stressed scenario, we have estimated income statements for the banks.

Evaluating the stress test

The last step is to focus on a measure used for the regulation of banks: common equity tier one ratio, i.e. the ratio between common equity tier-one (CET1) and risk-weighted assets (RWA). The stressed scenario affects both the CET1 and RWA. The result of the income statements directly affects CET1. If banks suffer losses, CET1 is used to cover these losses. If banks make a profit, CET1 increases with the amount that is left after taxes and dividend is paid. For the RWA, we deduct the credit losses with the last observed value for RWA and assume that RWA increases by 7.5 per cent per year. This is a simplification that the Swedish Riksbank does, with the reasoning that during turbulent times some assets becomes riskier. Finally, this results in a ratio that is used as a measure of how well the banks handle the crisis. If the ratio is positive, it implies the banks would have enough capital to endure the scenario, a negative ratio implies that banks do not hold enough capital for the given scenario. Also, a large decrease in the ratio, indicates that the scenario has a significant negative impact on banks' capital level. If the ratio is moving towards to zero, the government needs to intervene to save the banking sector.

4.2 Data

We model three variables on the banks' income statement. The first variable is banks' credit losses, the second variable is the net interest margin (NIM), and the third variable is the net fee and commission margin (NFCM).

For credit losses, we use quarterly data between the years 1990-2018 where all data are collected from the Statistics of Sweden (SCB) and the Swedish Riksbank, except the credit ratio which is collected from the Bank of International Settlements (BIS). The data for the variable *loans to the public* is interpolated from yearly data to quarterly data between the years 1990-1995, see Appendix C for our interpolation. The reasoning behind the choice of the time horizon is that we want to include the financial crisis in the early 1990s.

The income variables, NIM and NFCM, are both modelled similarly. We use data between the years 2004-2018. The reason for this time horizon is the limitation of data availability for the years before 2004. The data for the independent variables is mainly from SCB and the Swedish Riksbank, except the OMX30 return. It is collected from Yahoo Finance. Book equity and the dependent variables, (NIM) and (NFCM) are gathered from banks' quarterly reports.

4.3 Estimation of parameters

Table 2 shows our estimations of the parameters for the credit losses. From the regression, the parameters are in line with our expectations[6]. The variables that fluctuate the most during turbulent times are the unemployment rate and the growth rate in real housing prices.

Variables	Credit losses
Change in Unemployment rate	0.1242507***
5-year government bond	0.1495429***
Difference between corporate lending rate and 6-month sovereign yield	0.5003795***
Debt ratio	0.0056976*
Share of loans to non-financial corporates	0.0258500
Growth in Real housing prices	-0.1416696***
Intercept	-0.0354775**
Observations	113
R-squared	0.907
Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1	

Table 2. Regression result for credit losses

For the income variables, *net income margin* and *net fee and commission margin*, table 3 shows the regression results. The table shows that the previous value for the dependent variables is the most important variable for both NIM and NFCM. Also, NIM depends more on the equity ratio in comparison to NFCM, while NFCM depends more on GDP. One variable does not follow our expectations, the difference between the 10-year government bond and the 3-month sovereign yield. The Swedish Riksbank (Buncic et al., 2019) gets the same negative correlation, which they partly connect to Swedish banks business models.

[6] The Swedish Riksbank does not publish their estimation of parameters. Thus, we cannot compare our estimations with theirs.

Variables	Net Income Margin (NIM)	Net Fee and Commission Margin (NFCM)
L. NIM	0.9498413***	
L. growth Real GDP	0.0005804	0.0019792***
L. Inflation Rate	0.0056827***	0.0035079***
L. 3-m sovereign yield	0.0041647***	
L. diff. 10-y gov.bond and 3-m sovereign yield	-0.0094360***	
L. equity ratio	0.0116261***	0.0036871***
L. NFCM		0.9503047***
OMX30 return		0.0006197***
Observations	240	240
Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1		

Table 3. Regression result for NIM and NFCM

5 Scenario results

To examine how banks handle different crises, this paper performs five scenarios. First, two scenarios are based on historical crises, the early 1990s, and 2008's financial crises. Second, three versions of Covid-19 follow after the historical crises. All scenarios have the same structure. First, the scenario with a scenario path is presented. Second, the results for credit losses, net income margin, net fee and commission margin, and the common equity tier one (CET1) to risk-weighted assets (RWA) ratio are presented.

For the historical crises, the scenario paths for the key variables, e.g., the growth rate of GDP and housing prices, follow the actual crises. To create the historical crises in light of today's market conditions, forecasts are used for the interest and inflation rates. These forecasts are performed by the Swedish government and the National Institute of Economic Research (KI) in the middle of April 2020 and include a broad set of key macroeconomic variables. For Covid-19, the scenario paths differ between the magnitude of the crisis. The first Covid-19 scenario is based on the same forecasts, as the historical crises, from the Swedish government and KI. However, additional variables, e.g. GDP and unemployment rate, are used from the forecasts. This scenario is denoted as a mild and short-lasting scenario. The second Covid-19 scenario uses the same forecasts, but adjusts the scenario paths to last longer and to be more challenging. This scenario is denoted as challenging and medium-term. The last Covid-19 scenario is based

on the forecasts and statements from experts. This is the toughest scenario, denoted as severe and long-lasting.

The models depend on both macroeconomic and financial variables to capture the changes in the scenarios. In all scenarios, the credit ratio and the ratio of loans to non-financial corporates to loans to the public are constant.

5.1 Two historical crises in light of today

The financial crises in the early 1990s and 2008 are the only times the Swedish economy has gone through major crises in the last 30 years. Especially the 1990s crisis created substantial consequences (Schück, 2017). Examining these two crises in light of today's market condition shows both how the banks handle a similar crisis today, and if banks' risk management has improved with the development of the Basel framework.

The most characteristic aspects differ for the two crises. For the 1990s crisis it is the significant drop in housing prices. While for the 2008 crisis, it is the sharp decrease in GDP and the development of OMX30. Regarding the interest and inflation rates, our scenarios for the historical crises use forecasted interest and inflation rates and not the actual historical rates. The last few years are characterised by low levels of inflation and interest rates. Using the historical values for these variables in a scenario is unrealistic in relation to today's low levels. For instance, the five years government bond was over 14 per cent in the first quarter in 1990; today, the bond is negative. In 2008 the three-month sovereign yield was over 4 per cent, the last five years the sovereign yield has been negative. It is highly unlikely that the levels of these variables from the two crises occur within the time frame of our scenarios. Therefore, in order to create the 1990s and the 2008 crises in light of today's conditions, the two scenarios use forecasted values for these variables[7]. The characteristic aspects from the crises are the same as for the actual crises, e.g. the values for unemployment rate, housing prices and GDP growth.

1990s crisis

The financial crisis in the early 1990s is the largest financial crisis in Sweden in modern time. The crisis emerged from the deregulation of the financial system in the 1980s and the change of the Swedish currency system (Schück, 2017). One of the most distinguishing characteristics of the crisis was the bust of the real estate market, where commercial real estates and housing

[7] The 3-month sovereign yield, the 5-year government bond, the 10-year government bond and the inflation rate

prices dropped rapidly. Table 4 shows the scenario path of our 1990s financial crisis, with the drop in housing prices. It also shows the increase in the unemployment rate and an initial decrease in GDP.

Variables	Year 1	Year 2	Year 3
Unemployment rate	5.51%	8.83%	10.73%
OMX30 return	-3.21%	15.23%	1.69%
Inflation rate	0.50%	-0.20%	-0.40%
GDP growth rate	-0.96%	-3.10%	4.21%
Difference lending rate non-financial corporates	3.15%	3.44%	2.73%
Housing prices growth rate	-2.69%	-12.47%	-0.31%

Table 4. The scenario path for key variables of our 1990s financial crisis.

Results, our 1990s crisis

The result from our 1990s crisis scenarios implies that the banking sector is significantly affected, but it endures. Figure 2 shows that the credit losses are lower in our scenario, compared with the actual 1990s crisis. In our scenario, the highest value for credit losses divided by loans to the public is 3.31 per cent, for the entire bank sector. The main driver for the credit losses in this scenario is the growth rate of the housing prices. For the actual crisis, the highest observed value is 4.37 per cent. The reason for the difference is partly due to the change in interest rate levels, but also from the fact that the banking sector has changed since the early 1990s. For instance, banks have decreased their ratio of loans to non-financial corporations to loans to the public, where loans to non-financial corporations are more likely to default compared to loans to the households.

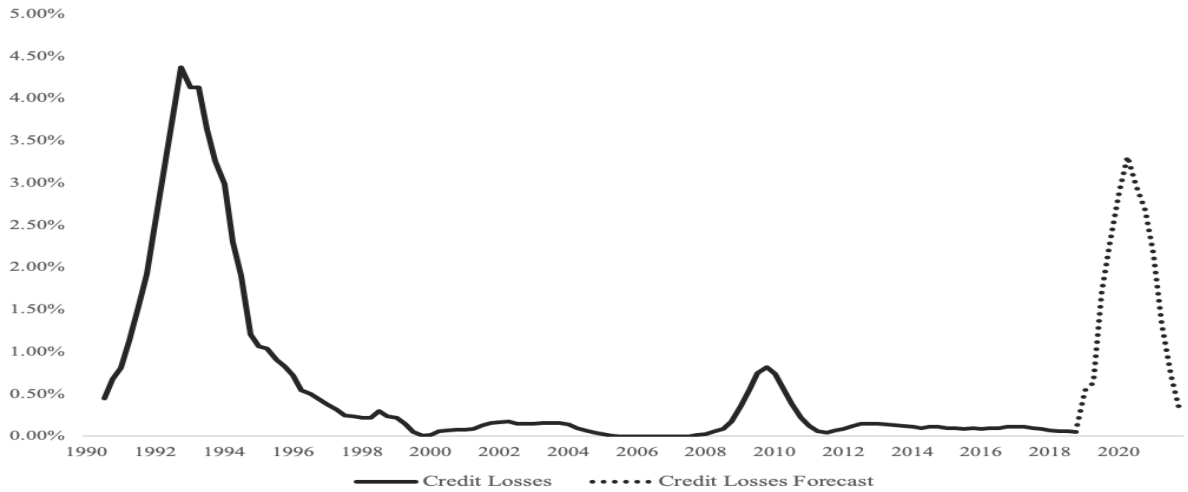

Figure 2. Forecast of Credit losses for scenario 1990s crisis for aggregated banks

Regarding incomes for banks, the net interest margin and the net fee and commission margin are estimated to decrease during the scenario, see figure 3 for the forecast of banks aggregated. NIM and NFCM decrease by 17.28 respectively 37.95 per cent in total in the scenario. NFCM is more sensitive than NIM for this setup. There are two main drivers in the models for NIM and NFCM: their previous value and total assets. When credit losses increase, this leads to a decrease in the sum of loans, which, in turn, decreases the total assets. This domino effect decrease banks' incomes. The variable that affects NIM most, apart from the previous value and total assets, is the equity ratio, i.e. the ratio book equity to total assets. Both book equity and total assets decrease when banks suffer losses, but the effect of book equity is stronger than for total assets. This decreases the equity ratios, which decreases NIM. A higher equity ratio signals that banks are well-funded, which decreases the funding costs. NFCM does not depend on the equity ratio to the same extent as NIM; instead, it relies relatively more on the state of the economy, i.e. on the growth rate of GDP and the inflation rate.

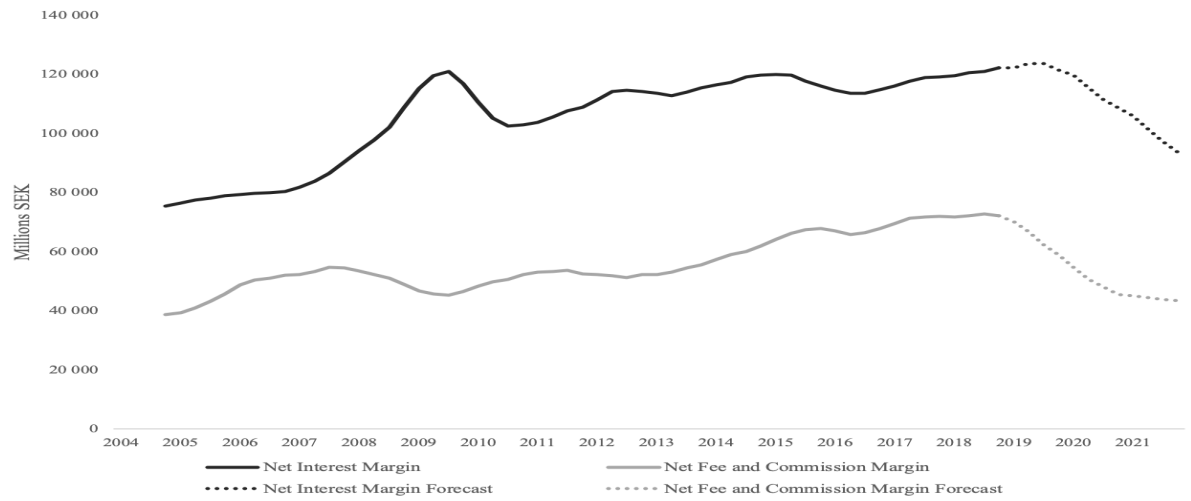

Figure 3. Forecast of NIM and NFCM for scenario 1990s crisis for aggregated banks

The changes in banks' capital depend on the income statement. Adding the dispersion effect, the constant aspects of the income statements, the tax rate and dividends to the credit losses and the estimated income creates an estimation of an income statement for the scenario. In this scenario, banks experience a negative result. Hence, the level of common equity tier one (CET1) decreases, since it is the capital that is used first to cover losses. The risk-weighted assets (RWA) decrease with the estimated credit loss at first. Second, the risk-weighted assets increase with 7.5 per cent. Table 5 shows that the ratio of CET1 to RWA decreases from its initial value for all banks. This implies that even though the ratios decrease, the banks endure

the scenario. SEB is the individual bank that suffers the most. This is because SEB has a higher share of NFCM relative to the other banks.

	Base year	Year 1	Year 2	Year 3
Aggregated banks	16.28%	15.27%	10.69%	9.67%
Handelsbanken	16.80%	15.95%	11.49%	10.48%
Nordea	15.45%	14.41%	10.36%	9.34%
SEB	17.60%	16.09%	9.81%	8.29%
Swedbank	16.30%	15.79%	11.62%	11.10%

Table 5. Estimation of the ratio CET1 to RWA for scenario financial crisis in the early 1990s

To sum up the scenario, banks suffer significant credit losses and losses of income. The key takeaway is, however, that banks endure our 1990s financial crisis. In comparison with the actual 1990s crisis, banks manage our 1990s scenario better, since no bank is close to becoming insolvent today. This result is not surprising. Since the 1990s crisis, comprehensive capital regulations, with the Basel framework, have been implemented and developed. In the aftermath of the actual financial crisis, the Swedish government acquired the banks Götabanken and Nordbanken. This is not the case for any bank in this scenario, which indicates that banks are better prepared today, than during the 1990s crisis.

The financial crisis of 2008

The financial crisis started in the US in 2007 with a collapse in the American housing market, together with the default of Lehman Brothers, the entire financial sector was affected. This spread to become a global financial crisis. In Sweden, the consequence was a decline in economic growth and some turbulent years. However, in comparison to several other countries (for instance, Spain, Italy and Greece), Sweden was not affected by the crisis to the same extent. For instance, the unemployment rate did not exceed 10 per cent during the crisis, the growth rate of GDP was negative for two years in a row, but housing prices continued to increase. Similar to the 1990s crisis, the inflation and the interest rates are adjusted to fit today's level, see table 6 for the path of the variables in the scenario.

The main characteristic from the crisis is the decrease in the growth rate of GDP and the return of OMX30. In comparison to the 1990s crisis, these values are higher in relation to the other variables' values. For example, the housing prices increased during the 2008 crisis, while it

decreased for the 1990s crisis. However, the growth rate of GDP follows almost the same path for both crises, and the OMX30 returns decreased more in the 2008 crisis. This shows the differences between the crises, and that the two crises have different characteristics.

Variables	Year 1	Year 2	Year 3
Unemployment rate	6.03%	7.51%	8.80%
OMX30 return	-12.50%	10.30%	4.30%
Inflation rate	0.50%	-0.20%	-0.40%
GDP growth rate	- 0.34%	-3.90%	5.92%
Difference lending rate non-financial corporates	3.25%	3.25%	3.00%
Housing prices growth rate	7.51%	0.24%	7.03%

Table 6. The scenario path for key variables of the financial crisis in 2008.

Result, our 2008 crisis

The results from the scenario of the financial crisis in 2008 indicate that the bank sector manages the same events without any significant problems. Figure 4 shows an increase to 0.90 per cent for the ratio of credit losses to loans to the public. In relation to the actual 2008 crisis, this is roughly 0.1 percentage point higher. However, banks do not have any problem with handling credit losses of this extent. In comparison to our 1990s scenario, the credit losses are substantially lower, even though several variables are similar. The most distinguishing variable is housing prices. This indicates that negative growth in housing prices affect credit losses significantly.

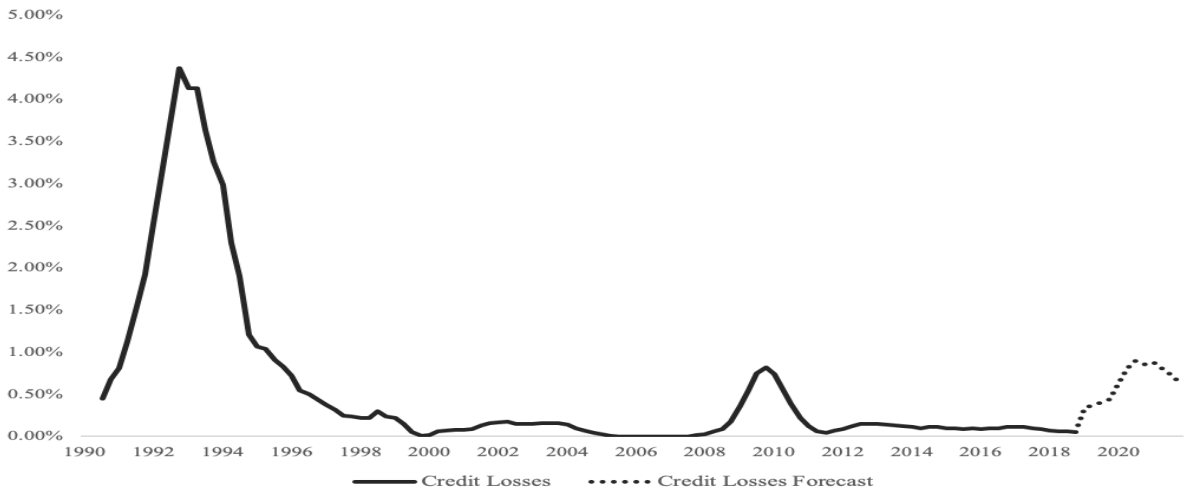

Figure 4. Forecast of Credit losses for scenario 2008 financial crisis for aggregated banks

For the estimation of net interest margin and net fee and commission margin, it predicts an initial increase for NIM and an immediate decrease for NFCM. In this scenario, NIM decreases by 5.17 per cent after the third year and NFCM decreases with 33.88 per cent. One explanation of NIM's path is that all banks' equity ratio increase. As a consequence of the scenario's low credit losses, banks generate a positive result, which increases the book equity. NIM is more sensitive to changes in the equity ratio than NFCM. For NFCM, it depends more on the state of the economy. When GDP starts to recover in the last year of the scenario, NFCM begins to recover as well.

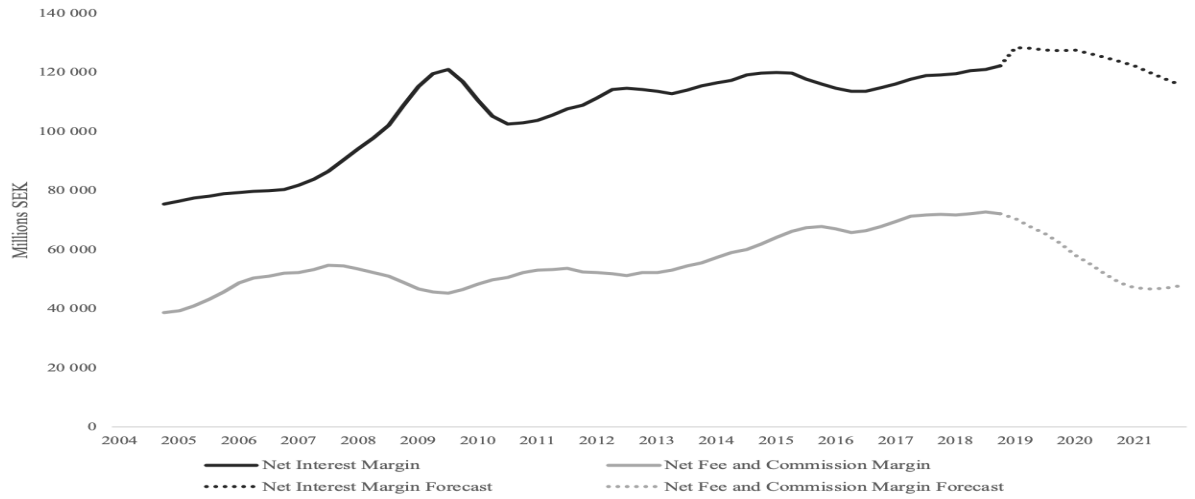

Figure 5. Forecast of NIM and NFCM for scenario 2008 crisis for aggregated banks

The estimations of credit losses and incomes are combined with the constant variables from the income statement and the dispersion effect to create the predicted income statement. The final result for the ratio of CET1 to RWA, for the banks aggregated, is a decrease from 16.28 per cent to 14.28 per cent, see table 7. This result implies that the bank sector stay solvent throughout the scenario. In this scenario, the banks' CET1 to RWA ratio are affected to the same extent, with a decrease by roughly 2 percentage points.

	Base year	Year 1	Year 2	Year 3
Aggregated banks	16.28%	15.74%	15.03%	14.28%
Handelsbanken	16.80%	16.25%	15.52%	14.75%
Nordea	15.45%	14.84%	14.10%	13.33%
SEB	17.60%	17.04%	16.28%	15.47%
Swedbank	16.30%	16.00%	15.48%	14.89%

Table 7. Estimation of the ratio CET1 to RWA for scenario financial crisis in 2008

To summarise the two historical crises, the banks manage the two scenarios well. Comparing our 1990s crisis with the actual 1990s crisis, banks handle our crisis better. For the 2008 scenario, banks do not face any significant problems. The results from these two scenarios indicate that Basel III tend to have improved banks' resilience.

5.2 Three Covid-19 scenarios

While the scenarios based on the historical crises show if the risk management in the banking sector has improved, the Covid-19 scenarios show something else. In addition to showing the level of risk management, these scenarios have a clear connection to the world's greatest problem for the time being: the consequences of Covid-19. The result of these kinds of scenarios can be used to determine if capital needs to be injected in the banking sector and if any bank tends to suffer more, compared to other banks, for a given scenario.

Covid-19 Mild and short-lasting

The current situation with the consequences of Covid-19 is uncertain. Experts and governments do not know how the pandemic will affect their population and the economy. In order to estimate how the bank sector is affected by Covid-19, we use the latest reports and forecasts from different institutes and experts. The idea is that these forecasts create one of the most plausible outcomes of Covid-19, at the time of these reports. Table 8 shows the path for this scenario. For the interest rates[8] we use a report from KI (2020). KI released its quarterly forecast for the economy on the first of April. In their report, they emphasise that their forecast should be seen as one possible scenario, rather than a usual forecast. KI's report also relies on several assumptions. One of the most important assumptions refers to that Covid-19 declines under the second part of 2020. For the unemployment rate, the inflation rate and the growth rate of GDP we use the Swedish Ministry of Finance's forecast from the 15th of April (KI, 2020). This forecast is constructed under the same premises as for KI.

The initial path for the variable housing prices growth rate is created from a statement from a housing market expert from Swedbank (Omni, 2020; Swedbank, 2020b). At the time being, there are no available forecasts for the housing market from any public authority. For the return of the OMX30 index, this is estimated in relation to GDP and the path of the index during the financial crisis. The last variable that is changed is the difference between the lending rate to

[8] The 10-year government bond, 5-year government bond and the 3-month sovereign yield

non-financial corporates and the 6-month sovereign yield. This is estimated from historical data. During turbulent times the difference increases from the current level, see Appendix C for a figure of the historical values and our estimation.

Variables	Year 1	Year 2	Year 3
Unemployment rate	9.00%	9.00%	8.40%
OMX30 return	-15.00%	1.00%	4.00%
Inflation rate	0.80%	1.20%	1.60%
GDP growth rate	-4.00%	3.50%	3.40%
Difference lending rate non-financial corporates	3.00%	3.00%	2.75%
Housing prices growth rate	-7.00%	-3.00%	0.00%

Table 8. The scenario path for key variables of a mild and short-lasting Covid-19 crisis.

The scenario indicates that the OMX30 decreases by 12.5 per cent after the third year. GDP increases by 2.3 per cent in total and housing prices decrease by roughly 10 per cent after the last year.

Results mild and short-lasting Covid-19

The results for a mild and short-lasting Covid-19 implies that the bank sector manages the situation well. Figure 6 shows that the credit losses increase to 1.76 per cent during the first year of the scenario before it declines during the second and third year. The value of 1.76 per cent is roughly one percentage point higher than during the financial crisis in 2008. This implies that even a mild and short-lasting Covid-19 creates large credit losses. In comparison to the financial crisis of 2008, one of the main differences in the scenarios is the path of the housing prices. During the financial crisis of 2008, the housing prices increased, while in this scenario, the housing prices decrease.

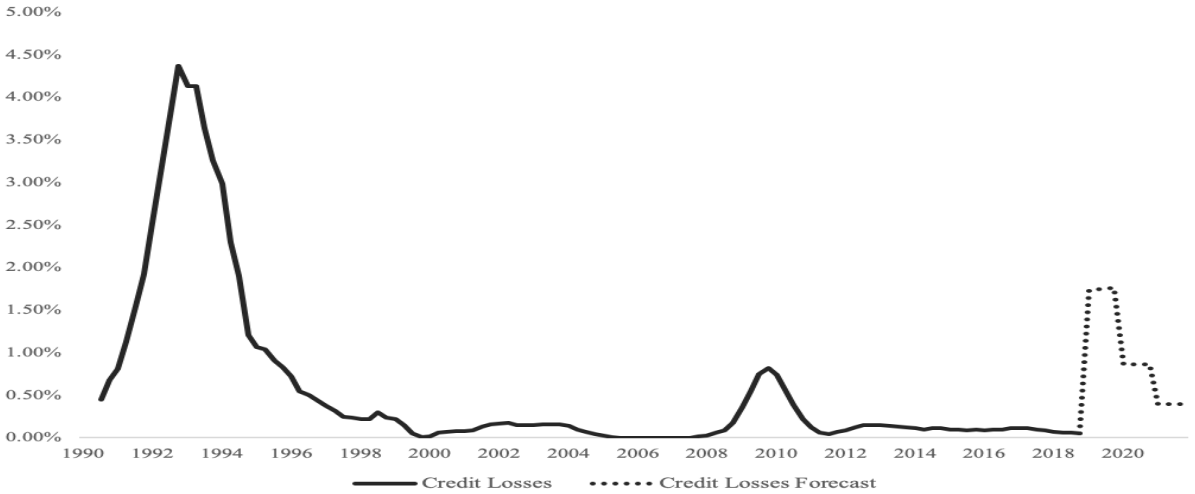

Figure 6. Forecast of Credit losses for scenario mild and short-lasting Covid-19 crisis for aggregated banks

For banks' incomes, the forecast is similar to the scenario for the financial crisis in 2008. The net income margin increases initially and ends the scenario with an increase of 2.53 per cent. Similar to the financial crisis in 2008, the equity ratio increases for all the banks in this scenario. The net fee and commission margin decrease rapidly, once again, before the decrease dampens when the economy recovers. In total NFCM decreases by 40.45 per cent.

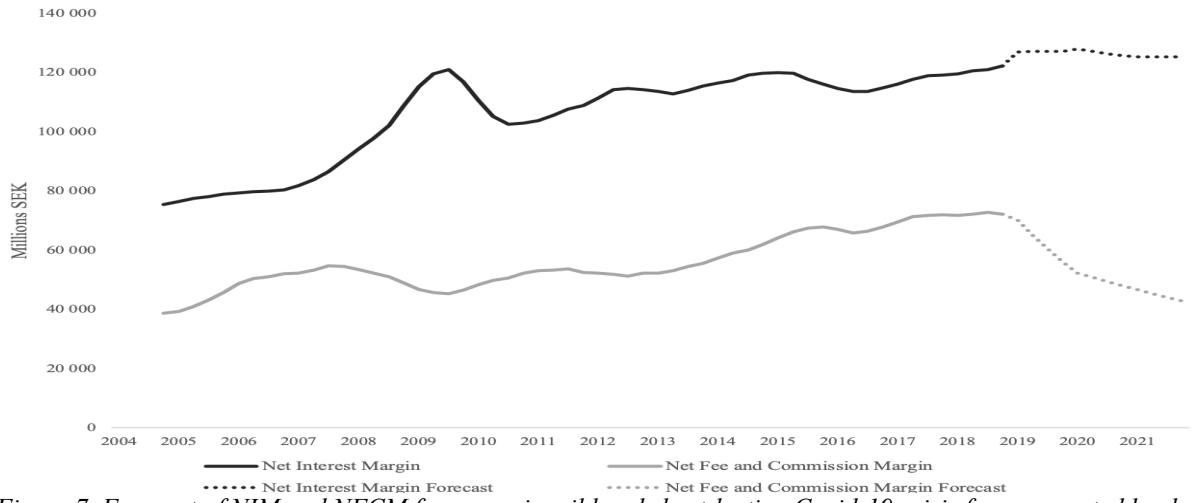

Figure 7. Forecast of NIM and NFCM for scenario mild and short-lasting Covid-19 crisis for aggregated banks.

The last aspect to examine for the scenarios is the ratio CET1 to RWA. This is calculated from the estimated income statements, as in the previous scenarios. Table 9 shows that all banks' capital ratio decrease. However, there is no significant problem for any individual bank. This implies that the banks endure a mild and short-lasting Covid-19. Even though banks suffer losses, they stay solid.

	Base year	Year 1	Year 2	Year 3
Aggregated banks	16.28%	14.32%	13.68%	13.09%
Handelsbanken	16.80%	14.94%	14.29%	13.71%
Nordea	15.45%	13.56%	12.88%	12.20%
SEB	17.60%	14.77%	14.10%	13.55%
Swedbank	16.30%	15.06%	14.59%	14.17%

Table 9. Estimation of the ratio CET1 to RWA for scenario mild and short-lasting Covid-19 crisis

The key takeaway from this scenario is that even a mild and short-lasting Covid-19 creates the most substantial credit losses since the 1990s crisis. However, banks handle this crisis well. No bank is close to having a problematic CET1 to RWA ratio.

Covid-19 challenging and medium-term

The first scenario of a mild and short-lasting Covid-19 is an uncertain scenario. It is plausible the pandemic will last longer and that the consequences are more adverse than previous beliefs. New reports and statements are frequently released regarding the consequences of the pandemic. For instance, the Swedish Public Employment Service estimates the unemployment rate to be 10 per cent by Summer 2020 (Petersson, 2020). In this scenario, we calculate the aftermath of Covid-19 to last longer and to be more adverse, in comparison to the first Covid-19 scenario. The scenario path is based on the same reports and forecasts as in the previous scenario. However, in this scenario, we make the state of the economy more adverse. For instance, an increase in the unemployment rate and a slower recovery of the economy. Table 10 shows the scenario path for a tougher and longer-lasting Covid-19.

Variables	Year 1	Year 2	Year 3
Unemployment rate	10.00%	12.00%	14.00%
OMX30 return	-20.00%	-2.00%	5.00%
Inflation rate	0.50%	-0.20%	-0.40%
GDP growth rate	-7.00%	0.00%	1.00%
Difference lending rate non-financial corporates	3.25%	3.25%	3.00%
Housing prices growth rate	-10.00%	-4.00%	-4.00%

Table 10. The scenario path for key variables of a challenging and medium-term Covid-19 crisis.

This scenario implies that the OMX30 falls with roughly 18 per cent in the three-year period. GDP and housing prices fall with approximately 6 respectively 17 per cent for the same period.

Results Covid-19 Challenging and medium-term

The results from the challenging and medium-term Covid-19 scenario differs from the first Covid-19 scenario. Figure 8 shows credit losses of 2.44 per cent, in relation to the first scenario, where the highest observed value for credit losses is 1.76 per cent. Already in the first mild and short-lasting Covid-19 scenario, the credit losses are the highest observed values since the 1990s crisis. In this scenario, the consequences are more challenging, in comparison to the previous Covid-19 scenario.

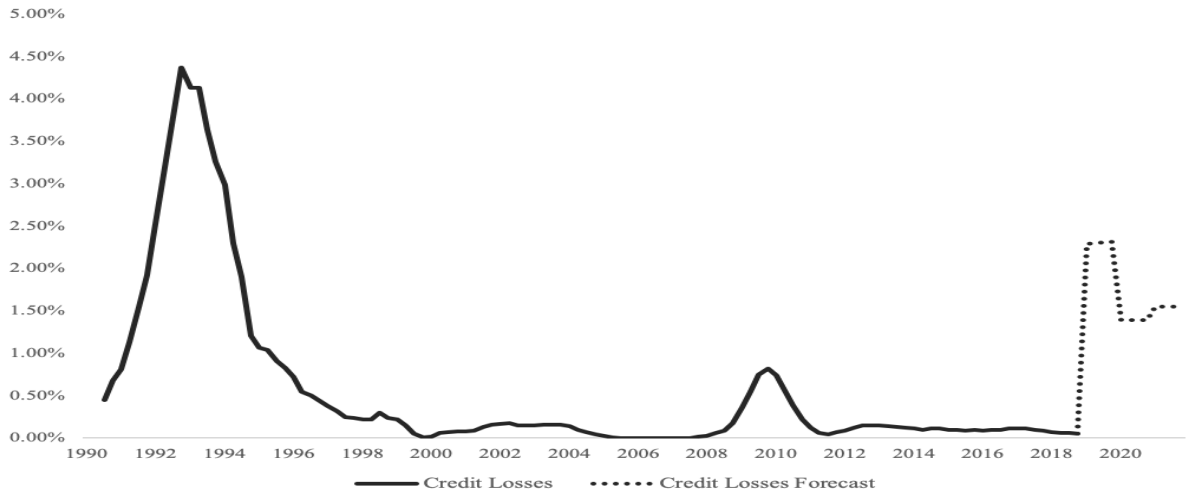

Figure 8. Forecast of Credit losses for a challenging and medium-term Covid-19.

Regarding the banks' income, the net interest margin and the net fee and commission margin decrease during this Covid-19 scenario, see figure 9. NIM decreases shortly after the scenario is implemented, and continues on the same trajectory during the remainder of the scenario. NIM decreases with 19.66 per cent in total, compared with the first Covid-19 scenario, NIM decreases with roughly 22 percentage points. This development arises mainly from two variables: The increase in the slope of the yield curve, i.e. the difference between the 10-year government bond and the 3-month sovereign yield, and the decrease in the equity ratio. NIM is more sensitive to a decrease in the equity ratio than NFCM. For NFCM, there is a rapid initial decrease during the first half of the scenario, which transcends to a slowly decreasing rate for the second half. In total, NFCM decreases by 45.79 per cent.

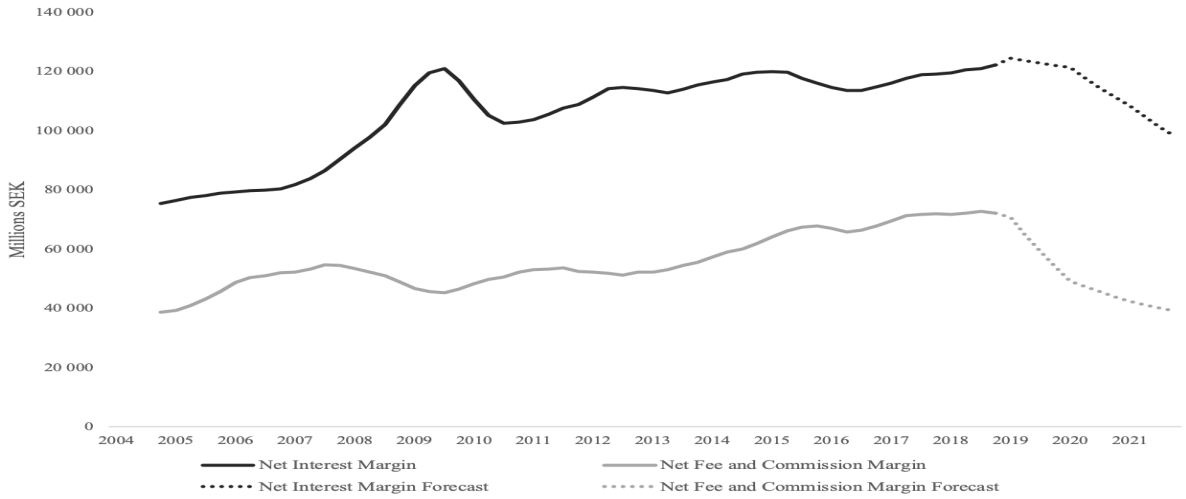

Figure 9. Forecast of NIM and NFCM for a challenging and medium-term Covid-19.

For the CET1 to RWA ratio, banks are more challenged than in the first Covid-19 scenario, see table 11. This scenario implies that the banks suffer significant credit losses and losses of income, but all of them endure. Once again, SEB is affected the most, because of their higher dependence of NFCM, compared to the other banks.

	Base year	Year 1	Year 2	Year 3
Aggregated bank	16.28%	12.70%	10.94%	8.91%
Handelsbanken	16.80%	13.44%	11.79%	9.86%
Nordea	15.45%	12.06%	10.29%	8.35%
SEB	17.60%	12.77%	10.32%	7.40%
Swedbank	16.30%	13.40%	12.36%	10.97%

Table 11. Estimation of the ratio CET1 to RWA for a challenging and medium-term Covid-19.

To sum up the scenario, banks are significantly affected by this scenario. The key takeaway is that when the equity ratio starts to decrease, NIM is more affected by this than NFCM. This results in a similar trajectory for the two income variables. For the first Covid-19 scenario and our 2008 scenario, the equity ratio increases. In these two scenarios, NIM is doing well. This shows, once again, the importance of the equity ratio for NIM.

Covid-19: severe and long-lasting

The last scenario for Covid-19 is when the consequences from the pandemic are severe and last for an extended period. All over the world, the world demand is set on hold, production in factories is paused, and global production chains are interrupted. In the world's largest

economy, the United States, the number of newly unemployed people has reached a new all-time high for a single week (Wallnor, 2020). The Swedish economy depends significantly on the state of the global economy, like all small and open economies. When the global demand for goods rapidly decreases (Fjellström, 2020), the Swedish export is affected by the new state. The reports of decreased global demand are connected to the ongoing volatility concerning oil prices. For the first time in history, the price for the WTI oil has reached negative values (Jones & Svahn, 2020). This affects the global economy, as well. The global economy is in a critical state and faces many challenges.

The scenario path for our severe and long-lasting scenario is based on statements from experts, historical paths during crises, and the forecasts used in the previous scenarios, see table 12 for values. The unemployment rate reaches 24 per cent the last year in the scenario. Kerstin Hessius, a former vice-governor of the Swedish Riksbank, states that there is a risk of mass unemployment, with unemployment rates between 20 to 40 per cent (Bengtsson, 2020). The OMX30 index decreases with 25 per cent the first year, followed by a 2 per cent decrease the second year, before it recovers. The path for the index follows the financial crisis of 2008, to some extent, and the state of the economy. For the inflation rate, there is a deflation throughout the scenario. During turbulent times the inflation decreases. Today the inflation level is already on a low level, with a new crisis, there is a risk of deflation (Andersson et al., 2015).

Regarding the interest rates, the growth rate of GDP and housing prices, this is estimated in light of previous scenarios. This scenario is more severe and long-lasting than the previous Covid-19 scenarios. The scenario paths for these variables are adjusted to take this into account, in order to follow the same pattern as the other variables.

Variables	Year 1	Year 2	Year 3
Unemployment rate	13.00%	20.00%	24.00%
OMX30 return	-25.00%	-2.00%	6.00%
Inflation rate	-1.50%	-1.00%	-0.20%
GDP growth rate	-12.00%	0.00%	1.00%
Difference lending rate non-financial corporates	3.50%	3.50%	3.50%
Housing prices growth rate	-20.00%	-16.00%	-3.00%

Table 12. The scenario path for key variables of a severe and long-lasting Covid-19.

Results severe and long-lasting Covid-19

The consequences for a severe and long-lasting Covid-19 scenario are significant. Figure 10 shows the credit losses for the aggregated banks. This implies that the banks' credit losses are on the same level as during the financial crisis in the early 1990s and for an extended period. The high level of unemployment and the large drop in housing prices creates a problematic scenario for the banks.

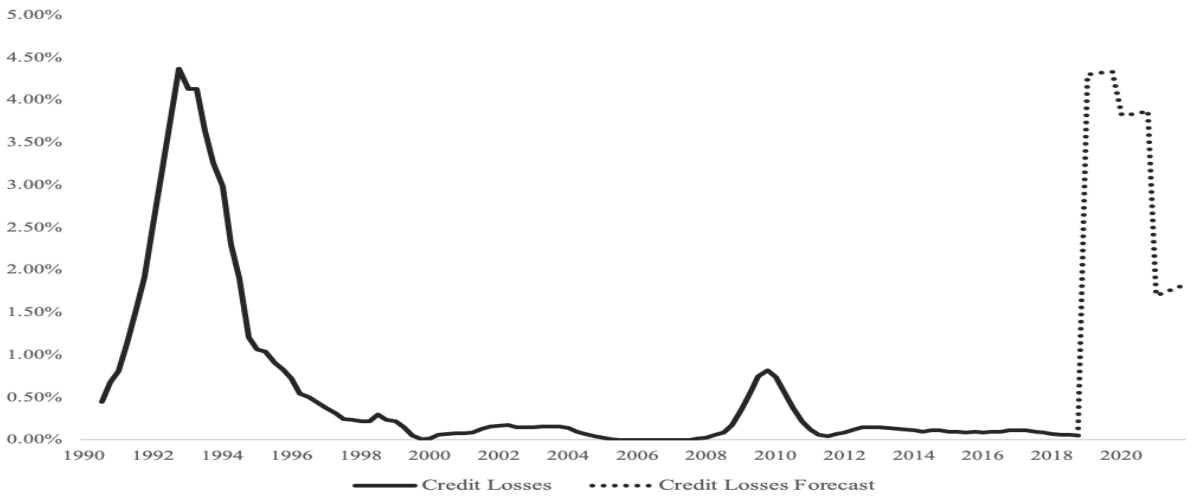

Figure 10. Forecast of Credit losses for scenario severe and long-lasting Covid-19 for aggregated banks.

The banks' incomes drop rapidly and significantly with a severe and long-lasting Covid-19. Figure 11 shows the development of the net interest margin and the net fee and commission margin. In total, NIM decreases by 43.89 per cent and NFCM with 51.13 per cent. This scenario creates the most significant loss of income for NIM. The explanation comes from the equity ratio. It decreases for all banks from its initial value of roughly 5 per cent to a final value between 0.2 and 3.7 per cent. In relation to the challenging Covid-19 scenario, the equity ratio has decreased further, which increases the losses of incomes. For NFCM, the trajectory is in line with the previous scenario. However, it decreases further, following the more adverse scenario path.

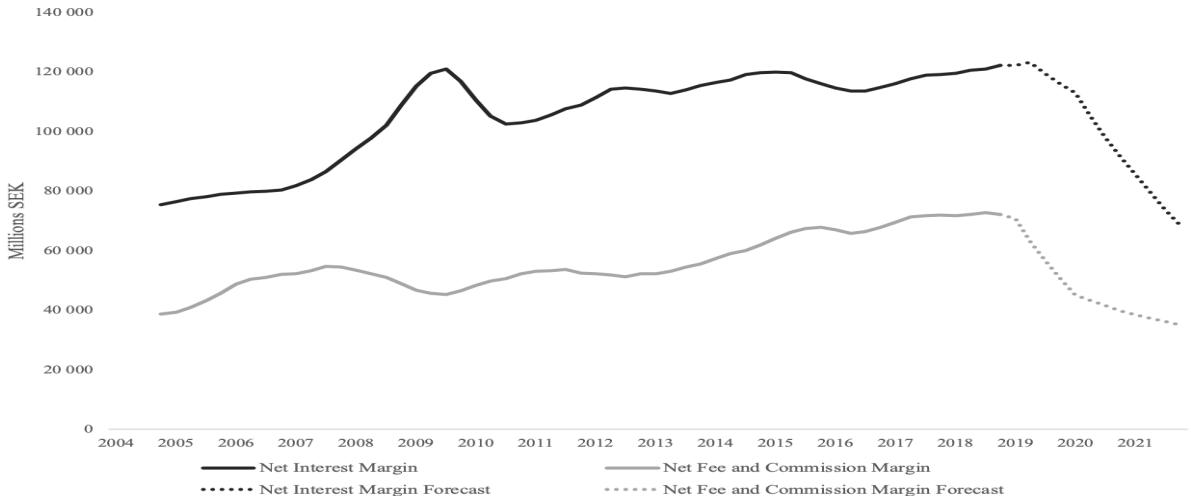

Figure 11. Forecast of NIM and NFCM for scenario severe and long-lasting Covid-19 for aggregated banks.

For the estimation of the ratio common equity one to risk-weighted assets, it is unambiguous that the banks face problems in this scenario, see table 13. All banks suffer significant losses. SEB has a negative capital ratio if no interventions from the Swedish government is implemented. The combination of a large decrease in NFCM and significant credit losses generates a negative result for SEB. The banks that depend less on NFCM tend to manage a severe Covid-19 crisis better. However, if the consequences of Covid-19 are severe and long-lasting, the banking sector is significantly affected.

	Base year	Year 1	Year 2	Year 3
Aggregated bank	16.28%	8.49%	3.89%	1.40%
Handelsbanken	16.80%	9.23%	4.64%	2.10%
Nordea	15.45%	8.70%	5.01%	2.80%
SEB	17.60%	7.02%	0.04%	-3.67%
Swedbank	16.30%	8.72%	4.20%	2.30%

Table 13. Estimation of the ratio CET1 to RWA for scenario severe and long-lasting Covid-19.

The key takeaway from the severe Covid-19 scenario is that it requires an exceptional adverse scenario in order to conflict substantial problems for the banks. The capital regulations in place appear to function well. It is important to highlight that if these events occur, it is not guaranteed that SEB is the individual bank that suffers the most. The models are sensitive to which variables that are included. Nevertheless, the development in regards to capital regulations appears to have been well implemented.

Final remarks

To sum up the scenarios, it is unambiguous that the banks are better prepared for a crisis today in relation to previous historical crises. Basel III tend to have improved banks' resilience. For instance, our 1990s scenario does not stress the banks to the same extent as it did during the actual crisis, see table 14. The consequences of the 1990s were substantial. Table 14 also shows the different Covid-19 estimation of the CET1 to RWA ratios, for the mild and challenging scenario the banks endure the crisis. For the last Covid-19 scenario, the banks need support from the government to survive.

	Base year	Year 1	Year 2	Year 3
1990s Crisis	16.28%	15.27%	10.69%	9.67%
2008 Crisis	16.28%	15.74%	15.03%	14.28%
Mild Covid-19	16.28%	14.32%	13.68%	13.09%
Challenging Covid-19	16.28%	12.70%	10.94%	8.91%
Severe Covid-19	16.28%	8.49%	3.89%	1.40%

Table 14. Summary of the five scenarios' estimation of the ratio CET1 to RWA for the banks aggregated.

The variables that affect the credit losses, the net income margin and the net fee and commission income most, differs between the models. For the development of credit losses, the main drivers are the unemployment rate and the growth rate of the housing prices. Hence, the credit losses increase during financial crises, where the unemployment rate increases and the housing prices decrease. For the net income margin, the main drivers are the previous value, total assets and the equity ratio. Lastly, for the net fee and commission income, the main drivers are the previous value, total assets, the equity ratio and the growth rate of GDP, where NFCM depends less on the equity ratio in comparison to NIM. This implies that banks' incomes are procyclical. In addition to the state of the economy, banks' incomes also depend on total assets. When financial crises occur, credit losses increase. This, in turn, decreases total assets.

6 Discussion

The first part of the aim is to examine if the banking regulations in Basel III have improved the four largest Swedish banks' risk management for capital resilience. The results from the stress tests indicate that the banks endure these crises. From the two historical simulations, the scenario of our 1990s crisis creates significantly larger credit losses in comparison to our 2008

crisis. This is not surprising since the 1990s crisis was more comprehensive than the 2008 crisis. However, the banking sector does not have any struggles managing these scenarios. When the actual 1990s crisis hit the Swedish economy, Götabanken and Nordbanken were saved by the government. Our result implies that no bank is close to becoming insolvent. Since the 1990s, the financial markets have changed substantially. The ratio lending to non-financial corporates to lending to the public is lower for banks today. Lending to non-financial corporates has a higher risk level than lending to the public. This implies that banks' risk level has decreased in that regard.

Moreover, another important change is the interest rates. They are on a completely different level today than during the historical financial crises. This changes the outcome of the scenario. As a result of this, our result for the credit losses 1990s crisis is lower than for the actual crisis. Nevertheless, banks handle the scenario well. This indicates that the new regulations conducted by the Basel Committee concerning capital requirements have improved banks' risk management.

The second part of the aim is to examine how banks manage the consequences of Covid-19. For the mild and short-lasting Covid-19 scenario, the banks handle the aftermath well. Even though the credit losses are substantially larger during this scenario compared to the financial crisis of 2008. However, it is essential to highlight that the forecasts the scenario is based upon are uncertain.

For the challenging and medium-term Covid-19 scenario, the banks are more affected than in the first Covid-19 scenario. The scenario generates more substantial credit losses and lower incomes. The outcome is similar to the simulation of the financial crisis in the early 1990s, regarding the CET1 to RWA ratio. In this scenario, the banks endure. Nonetheless, the banks are significantly affected by this and lose a large amount of capital.

The two first Covid-19 scenarios are in line with forecasts at this time. If the consequences of the pandemic do not get worse than these forecasts, our result imply that banks manage the pandemic without governmental intervention.

The last Covid-19 scenario, severe and long-lasting, creates devastating consequences for the banks. For instance, the credit losses, in this scenario, exceed the credit losses from the actual 1990s crisis. Our results indicate that without governmental interventions, one of the four major Swedish banks become insolvent. Even if the scenario is unlikely, it is plausible. Suppose that the restrictions governments have implemented continue to apply for an extended period, then several vital variables may reach the same levels as this scenario. This would be critical for the economy. The key takeaway from this scenario is that the Swedish government needs to inject capital in the banking sector if this scenario comes true. Otherwise, the consequences could be devastating.

Combining all five scenarios show that the banks handle the scenarios well. It requires a profoundly severe scenario to conflict serious damage on the banks. The Basel Committee's actions tend to have improved how banks manage financial crises. Stricter capital requirements tend to have made banks more resilient. Nevertheless, the last scenario shows that banks could be even more resilient with stricter regulations. However, everything comes with a cost. By applying stricter capital requirements, banks are not able to operate as before. Two common ways to adjust to higher capital requirements is to reduce risk-weighted assets and to increase the lending spread (Cohen & Scatigna, 2016). This change in behaviour would result in a dampening of economic activity and growth. Angelini et al. (2015) find a negative correlation between higher capital requirements and economic growth. Allen et al. (2012) also find a negative correlation between higher capital requirements and economic growth, but only in the short run. The authors state that in the long run, the negative correlation almost disappears. Higher capital requirements may, therefore, be seen as an "insurance" for the banking sectors sustainability. As with all insurances, it comes with a cost.

Finally, the model could be developed further. For instance, the assumptions that some variables in the model are constant, e.g. staff cost, might not reflect the development of a crisis. During turbulent times staff costs are likely to decrease. Furthermore, there are some uncertainty regarding our scenarios for Covid-19. The actual path likely differs from our scenarios. In addition to this, stress tests have their shortcomings. Therefore, it could be beneficial to include another analysis together with our, for instance, a bottom-up approach. By using a bottom-up approach, new aspects are taken into consideration. For instance, the approach uses the probability of default (PD) and loss given default (LGD) to model credit losses. This is beneficial since it includes specific information for different sectors. For instance, if one

specific sector has a higher risk level than a second sector, the first sector has a higher level of predicted credit losses than the other sector. Combining our top-down approach with a bottom-up approach would include both second-round effects and sector-specific risks. This would create a more comprehensive analysis. However, it is beyond the scope of this thesis.

7 Conclusion

The purpose of this study is to examine if the implementation of Basel III has improved Swedish banks preparation for a financial crisis and to examine how banks are affected by different Covid-19 scenarios. To accomplish this, we conduct five stress tests on the four major banks in Sweden to see how the banks' capital levels change. Two stress tests of historical crises in light of today's market conditions, the early 1990s crisis and the 2008 crisis, and three stress tests with different versions of Covid-19. Our method consists of a top-down approach for the stress tests. We model banks' credit losses, net interest margin (NIM) and net fee commission margin (NFCM). In addition to this, we assume that some variables on banks' income statement, e.g. staff costs, are constant throughout the scenarios. By combining our models of credit losses, NIM and NFCM with the constant variables from the income statement, we estimate income statements for our different scenarios. The result from the estimation of the income statement affects the banks' capital levels. By looking at the ratio common equity tier one (CET1) to risk-weighted assets (RWA), we evaluate if banks' capital resilience has improved and how banks handle different scenarios of Covid-19.

The results of our study imply that banks' risk management and capital resilience has improved. By stress testing historical crises in light of today's market conditions, we observe that banks CET1 to RWA ratio decreases, but the banks endure. This indicates that Basel III has improved banks' resilience. For the Covid-19 scenarios, banks handle two of the scenarios well. These scenarios are in line with the current forecasts of the aftermath Covid-19. If the aftermath does not get worse than these forecasts, banks endure the Covid-19 without governmental intervention. The last, and most severe, scenario creates problems for banks. If this scenario occurs, the government needs to intervene and inject capital in the bank sector. Otherwise, the consequences could be devastating.

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Appendix A

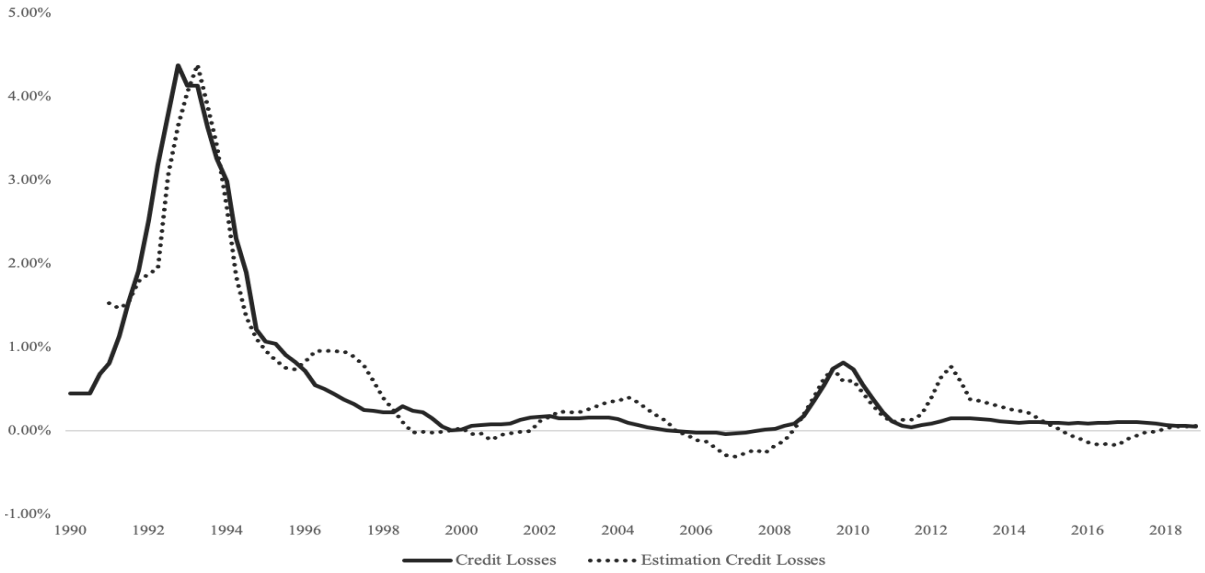

Figure 1A. Estimation of historical credit losses

Appendix B

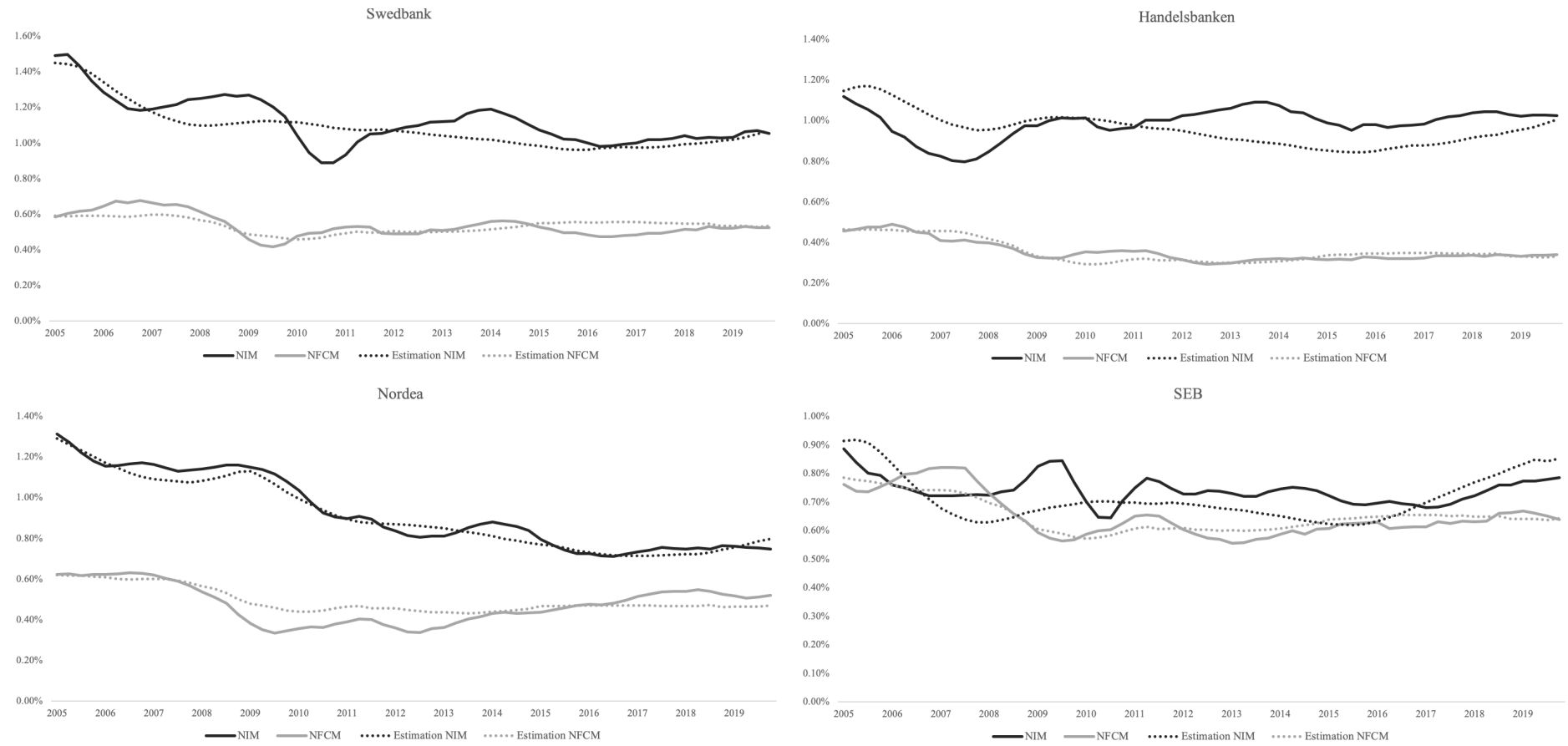

Figure 1B. Estimation of historical NIM and NFCM for the four banks

Appendix C

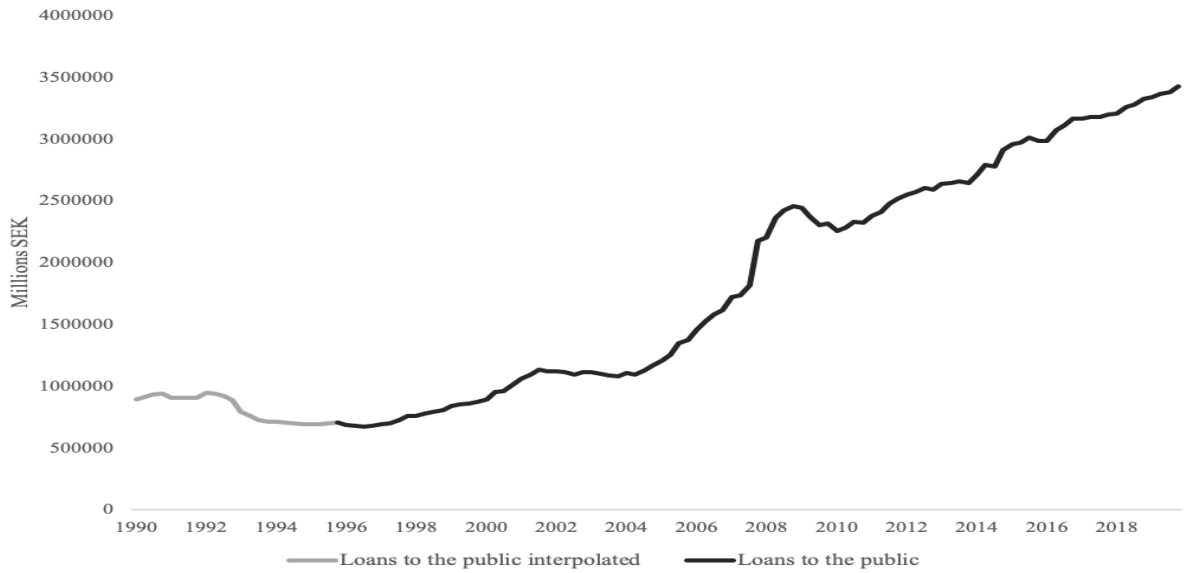

Figure 1C. Interpolation of loans to the public for 1990-1995

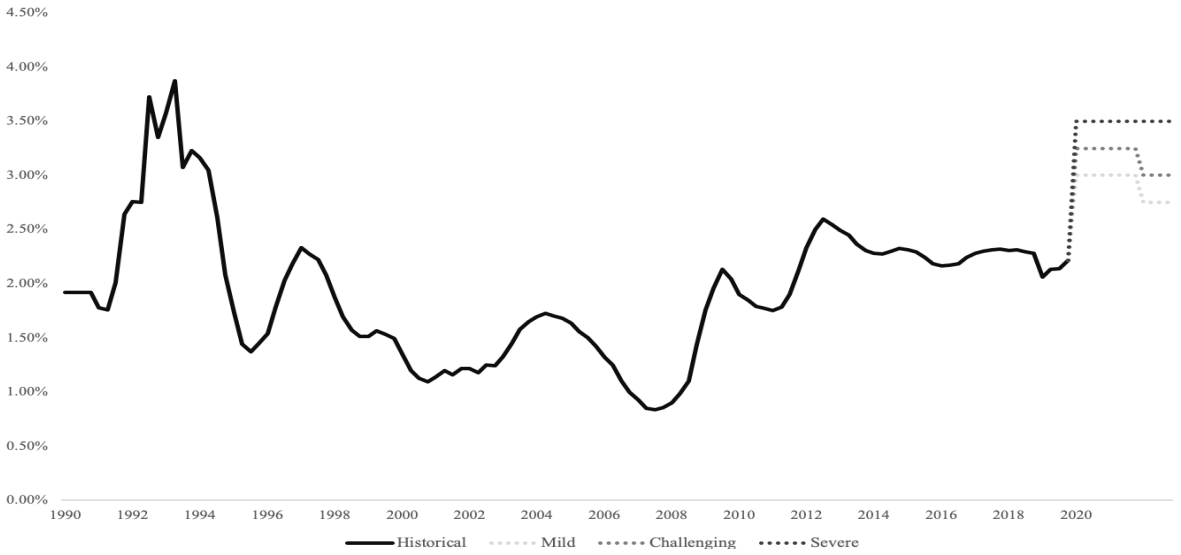

Figure 2C. Scenario paths for the variable difference in lending rate to non-financial corporate and the and the 6-month sovereign yield