A system-wide scenario analysis of large-scale corporate bond downgrades

An ESRB technical note

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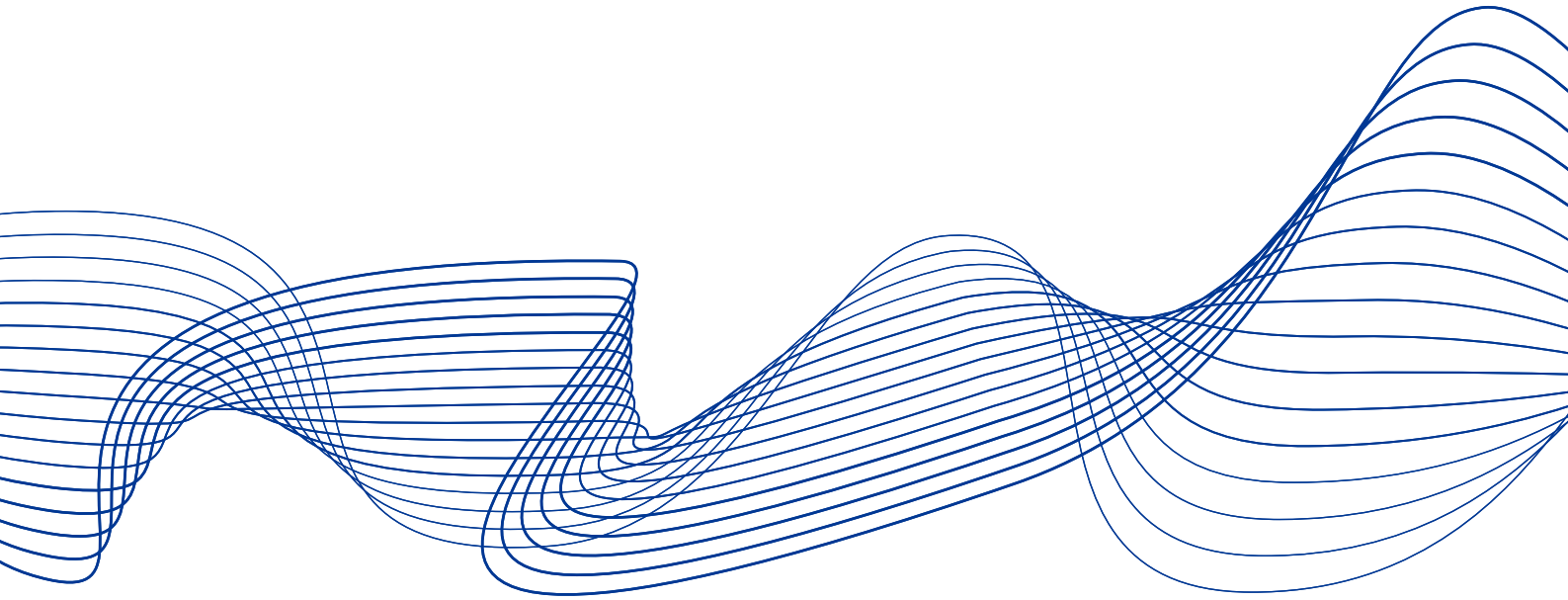

ESRB
European Systemic Risk Board
European System of Financial Supervision

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1 Executive summary

Background

The coronavirus (COVID-19) pandemic has inflicted a severe and unprecedented shock on the economies of Europe and the world. Against this background, the General Board of the European Systemic Risk Board (ESRB) decided at its meeting on 2 April 2020 to focus its attention on five priority areas where coordination among authorities or across the EU is likely to be particularly important in order to safeguard financial stability.[1] One of those five priority areas was the procyclical impact that downgrades of corporate bonds might have on markets and entities across the financial system.

Following an issues note on the topic which describes the main issues[2], this report summarises the findings of a top-down analysis that attempts to quantify the impact of a mass bond downgrade scenario on the financial system. While the report focuses on European financial institutions when considering the impact of forced bond sales, the estimates of forced sale volumes include global (non-European) passive investment funds, given that sales of their holdings would also have an impact on European institutions holding the same assets. The main focus is on the potential sales of "fallen angels" (corporate bonds which were formerly investment grade but have been downgraded to high yield) and covers only "plain vanilla" financial and non-financial corporate bonds (thus excluding unrated financial and non-financial corporate bonds, sovereign bonds, securitisations[3] and covered bonds, among others). The report uses data and models from the European Supervisory Authorities (ESAs), the European Central Bank (ECB), the ESRB Secretariat and the Bank of England. The results have not been validated in a bottom-up exercise involving any individual financial institution.

Analysis

The report considers two scenarios that are characterised by an increasingly large percentage of bonds being downgraded (see scenarios 1 and 2 in Table 5), both accompanied by the same severe yield shock.[4] Using these two scenarios, the report then analyses (i) direct losses occurring owing to increases in yields, (ii) the amount of forced sales of fallen angels that could potentially result from these downgrades, and (iii) the possible extent of the price impact (and hence additional losses) of these forced sales on all bond holders. The analysis applies three different behavioural scenarios regarding how financial institutions might react, as well as two regimes of potential price

1 See ESRB (2020a).

2 See ESRB (2020b).

3 Note: many collateralised loan obligations have recently been put on negative watch or downgraded.

4 These increases in yields and downgrades are assumed to materialise simultaneously as a consequence of the increase in credit risk owing to the pandemic. Indeed, as the market usually prices in downgrades before they occur, yields are not assumed to increase entirely "because of" the downgrades. Nevertheless, downgrades can have an additional "trigger" effect, for example affecting the behaviour of funds that follow investment-grade indices and may therefore be forced to rebalance their portfolios by selling fallen angels once the downgrade has materialised.

impacts (“low market liquidity and high price impact” and “high market liquidity and low price impact”). As the variation in the estimates set out in Tables 1 and 2 below shows, the assumptions and modelling parameters are key drivers of the results and produce considerable uncertainty around the estimated losses. For this reason, the report presents estimated losses and results as “ranges” under various assumptions, rather than providing single point estimates. Moreover, the volume of sales presented herein should be read as a “what if” analysis, rather than an evidence-based estimate of what amounts various sectors might realistically choose to – or be forced to – sell in such scenarios. In particular, while downgrades have historically taken place over a longer time horizon, the shock from the Coronavirus pandemic is an unprecedented far-reaching and exogenous shock, and more downgrades may consequently appear over a shorter time period. While this has not occurred before, the analysis asks the question “What if a large number of downgrades and forced sales were to occur at the same time?”

Recent estimates by the ECB and the ESRB place the likely amount of BBB-rated non-financial corporate bonds that could be downgraded at between €110 billion and €132 billion.[5] In this context, it is important to recognise both (i) the “what if” nature of the present analysis using higher downgrade percentages and multiple-notch downgrades (for example from A to BB), and (ii) the difference in coverage (i.e. financial corporate bonds and non-euro area bonds are included in the present analysis), which therefore complements the analysis of likely downgrades by the ECB and ESRB with two hypothetical scenarios.

Holdings

Chart 1 below provides an overview of the total corporate bond holdings and the subset of BBB-rated and A-rated corporate bonds, as captured in the ECB’s Securities Holdings Statistics (SHS) database. The data cover the global holdings of the reporting institutions (which comprise euro area institutions and some selected European countries that report voluntarily). These data can be seen in relation to several benchmark figures:

- The total assets of the banks included in the data amount to roughly €27 trillion and total equity amounts to €1.9 trillion (€1.65 trillion in terms of CET1).
- For the insurance sector, total investments stand at approximately €8.9 trillion.
- The Total Assets held by EU passive investment-grade corporate bond funds is €155 billion.
- EU active investment-grade corporate bond funds hold Total Assets of €480 billion.

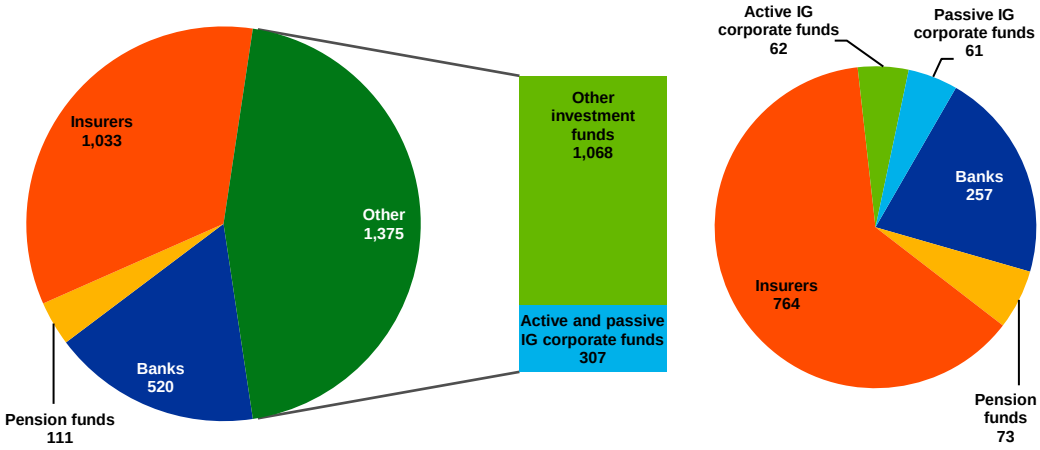
The total value of the EU investment-grade and high-yield corporate bond markets stands at around €3 trillion.

[5] See Chart 2.11 in the **ECB Financial Stability Review**, May 2011, and the ESRB **issues note on liquidity in the corporate bond and commercial paper markets, the procyclical impact of downgrades and implications for asset managers and insurers**, May 2020.

Chart 1

Overview of corporate bond holdings by sector (left-panel) and BBB-rated and A-rated bond holdings by sector (right-panel)

(EUR billions)



Sources: ECB SHS database and ESAs.
Notes: The insurance sector holdings comprise corporate bonds for which the credit quality step was reported. See Section 2.3 for further details on geographic and institutional coverage.

Main findings

Table 1 shows that under the first downgrade scenario (which assumes that approximately 25% of downgrades are from BBB to below investment grade), the system-wide initial losses would amount to €146 billion.[6] Depending on the behavioural assumption regarding institutional reactions, these losses may trigger forced sales of fallen angels amounting to between €30 billion and €198 billion. In turn, these sales – also called "fire sales" – which reflect the assumed stressed market conditions in which they take place, could trigger additional fire sale[7] losses, owing to the high-yield corporate bond market's assumed limited capacity to absorb such sales. These additional losses would range from between €2 billion and €18 billion under the "mild" behavioural assumption which considers forced sales by index-tracking funds only, to between €10 billion and €64 billion under the hypothetical extreme behavioural assumption. Under the second downgrade scenario (which assumes that around 45% of downgrades are fallen angels), the initial losses could climb to €213 billion across the financial system, triggering up to €373 billion of forced sales of fallen angels, which, under the severely stressed assumptions, could produce up to €85 billion of additional losses.

6 The analysis in this report assumes that the downgrades occur instantaneously, rather than over a longer time horizon. As mentioned above, the assumed downgrade percentages considered in this report take a "what if" approach and therefore differ from recent estimates by the ECB and ESRB.

7 Unlike sales under normal circumstances, "fire sales" entail distressed values and occur in the context of low to very low market liquidity: "a fire sale is essentially a forced sale of an asset at a dislocated price" (Shleifer and Vishny, 2011).

While it would be expected that the price impact of forced sales would not be permanent and prices would revert to their fundamental value over a longer time horizon, capital may not be available fast enough to prevent price dislocations (see Duffie 2010). Institutions that have sufficient balance sheet capacity and a long-term investment perspective, enabling them to hold on to the assets, would therefore suffer only accounting losses, which would subsequently be reversed. Conversely, institutions that did sell some of the bonds would "lock in" the loss.

Table 1

Initial losses from downgrades (in all rating categories), volume of fallen angels, volume of sales and lower and upper bounds for losses resulting from fire sales

(EUR billions)

	Scenario 1					Scenario 2				
	Initial losses	Fallen angels	Volume of sales	Lower bound fire sales	Upper bound fire sales	Initial losses	Fallen angels	Volume of sales	Lower bound fire sales	Upper bound fire sales
Mild behavioural assumption	145.9	231.8	30.3	1.7	18.0	212.7	443.1	64.6	3.3	33.0
Severe behavioural assumption	145.9	231.8	68.6	4.0	36.9	212.7	443.1	135.2	7.3	58.7
Extreme behavioural assumption	145.9	231.8	198.1	9.8	64.1	212.7	443.1	373.1	15.7	84.6

Sources: ESAs, Bank of England and ESRB Secretariat calculations.
Note: Owing to data aggregation issues, it was not possible to provide a breakdown of the losses into those on bonds issued by non-financial corporations and those on bonds issued by banks.

Table 2 shows the additional market value losses (as a percentage of initial losses) corresponding to additional fire sale losses triggered by the estimated forced sales. Under the less severe scenario, i.e. scenario 1, and the mild behavioural assumption, these additional fire sale losses would add only 1.2% to the initial losses, while under the hypothetical most extreme behavioural assumption these additional fire sale losses could increase the initial losses by approximatively 44% in the first downgrade scenario and by up to 40% in the second downgrade scenario.

Table 2

Fire sale losses as a percentage of initial losses

	Scenario 1			Scenario 2		
	Initial losses	Lower bound fire sales	Upper bound fire sales	Initial losses	Lower bound fire sales	Upper bound fire sales
Mild behavioural assumption	-	1.2	12.3	-	1.6	15.5
Severe behavioural assumption	-	2.7	25.3	-	3.5	27.6
Extreme behavioural assumption	-	6.7	44.0	-	7.4	39.8

Sources: ESAs, Bank of England and ESRB Secretariat calculations.

Overall, the analysis shows that in a severe mass downgrade scenario with a corresponding yield shock, initial losses from repricing could amount to €150 billion – €200 billion across the entire financial system, and that fire sale losses stemming from distressed market reactions might add another 20% – 30% to these losses, depending how much of their holdings it is assumed that institutions would sell and how (il)liquid markets would turn out to be. These fire sale losses result from estimated price impacts, which are notoriously difficult to model and depend on the size of the sale and the underlying market liquidity assumptions (see Annex 5.4). In the analysis below, depending on the scenario, they range, on average, between 0.3% and 7.9% for an individual bond and thus cover a realistic range, observed both from anecdotal market intelligence and academic empirical studies of the US corporate bond market.

Furthermore, a portfolio overlap analysis (see Figure 2 in Section 4.2) reveals considerable overlap between the portfolios of investment funds and insurers. This implies, for instance, that a forced sale by one of these sectors would potentially affect the other sector more severely through mark-to-market losses than would be the case with the less significant overlap between the holdings of the banking and pension fund sectors.

Finally, the report does not assess the impact and consequences of increased funding costs for the companies whose bond yields have increased. These effects could be a sizeable addition to the losses described in the report.

2 Introduction

2.1 Background and main goals of the analysis

In the context of the coronavirus (COVID-19) pandemic and the ESRB's priority work streams, the present report summarises the results of a system-wide top-down impact assessment of a mass bond downgrade scenario carried out jointly by the ESAs (the European Banking Authority, the European Insurance and Occupational Pensions Authority and the European Securities and Markets Authority), the ECB, the Bank of England and the ESRB.

The economic disruptions caused by the coronavirus pandemic could trigger a wave of credit rating downgrades in the financial and non-financial corporate bond sector owing to the significant increase in credit risk.[8] These downgrades can be problematic, in particular when issuers lose their investment-grade status and the downgrades are concentrated within a short period. BBB-rated corporate bonds represent roughly 50% of the investment-grade universe. Index-tracking funds would need to sell those holdings quickly if the bonds fell out of the reference basket. Other investment funds, banks, pension funds and insurers may voluntarily decide – or be forced – to sell because of their risk limits or investment mandates, or in order to protect their solvency positions. Such sales could result in additional spread increases, given the expected limited absorption capacity of the high-yield market (which is three times smaller than the BBB corporate bond segment), leading to mark-to-market losses for investors and higher funding costs for corporates. From a macroprudential perspective, it is therefore important to ensure that the possible effects of these credit rating downgrades are well understood, so as to capture any risks to the proper functioning of financial markets and the real economy. The analysis below attempts to estimate the following:

1. The direct losses that could materialise from yield shocks in a "large-scale downgrade" scenario.
2. The potential volume of forced sales and the high-yield corporate bond market's capacity for absorption and potential price impacts of forced sales.
3. The additional losses from the price impact for financial institutions (investment funds, insurers, pension funds and banks).

[8] It is assumed that increases in yields and downgrades occur simultaneously owing to the increase in credit risk, rather than increases in yields occurring as a result of the downgrades. See also Footnotes 4 and 6.

2.2 Caveats

We stress several important caveats:

- **Behavioural assumptions underpinning the "what if" analysis:** Assumptions regarding the likely behaviour of financial institutions play an important role in driving the results. The analysis below therefore considers three hypothetical behavioural scenarios. These scenarios should be seen as "what if" analyses, rather than a judgement on likely behaviour. For instance, regarding behavioural assumptions, the present analysis has not taken into account liquidity management tools that help investment funds meet outflows and limit fire sales. Regarding the downgrade scenarios, the likelihood of the scenarios materialising is not considered, given the "what if" nature of the exercise. The present analysis therefore serves as a hypothetical complement to prior ECB and ESRB analyses on the topic.

- **System-wide perspective:** While the modelling of fire sales by individual sectors has received a lot of attention in the academic literature, the present analysis of forced sales attempts to model simultaneously almost the entire ecosystem (investment funds, pension funds, insurers and banks). It is therefore essential to specify who will be the buyers of assets that are sold off (e.g. distressed debt buyers, hedge funds or sovereign wealth funds). The system-wide perspective is particularly relevant when modelling the price impact of these forced sales. Given the considerable uncertainty regarding price impacts (owing to both the size of the potential sales and the number of sectors covered), a sensitivity analysis is conducted around this parameter. Furthermore, although dealing with the entire ecosystem, the present analysis does not assess where cash from investment fund redemptions would flow to elsewhere in the system, thereby potentially mitigating the impact on other actors (e.g. through increased bank deposits or purchases of higher-rated bonds).

- **Types of bond covered:** The analysis focuses on corporate bonds and does not consider securitisations, covered bonds or sovereign bonds. The repercussions of sovereign downgrades are likely to exceed those of corporate downgrades. Owing to the need to merge several databases, the analysis unfortunately does not allow a breakdown between corporate bonds issued by financial corporations and those issued by non-financial corporates, although the expected downgrades and their effects (including second-round effects) could vary considerably across these two types.

- **Geographic scope:** The analysis of potential sales of fallen angels focuses particularly on euro area corporate bonds and non-euro area assets reported by European institutions to the ECB's Securities Holding Statistics (SHS) database. Using detailed data on these assets, price impacts are also extrapolated to non-euro area bonds.

- **Indirect holdings and other effects:** The report does not consider and quantify the issue of "indirect holdings", i.e. funds holding corporate bonds with "fallen angel" risk and banks, insurance companies or other institutions holding shares in these funds in turn. As such, the estimates of losses for banks and insurers may be somewhat higher depending on their share of such indirect holdings. Other potential effects, such as the increase in funding costs for non-financial corporates or the impact on the liquidity coverage ratio for banks when bonds lose their high quality liquid asset status, are also not included in the analysis.

2.3 Overview of current holdings

Table 3 provides an overview of the different sectors' initial holdings, as at the end of 2019 (except for investment fund data provided by ESMA, which are refer to March 2020). The data on these holdings are database extracts that do not vary on the basis of the above-mentioned scenarios or assumptions and thus constitute fixed inputs into all scenario variants.

Three types of fund are exposed to corporate bonds:

1. Active investment-grade (IG) corporate bond funds use an IG corporate bond benchmark which they seek to outperform, and can invest in a range of other assets in addition to corporate bonds. The Total Assets of EU and UK active funds amount to €480 billion and these funds hold €152 billion of corporate bonds, including €52 billion of euro area corporate bonds.

2. Passive IG corporate bond funds replicate an IG corporate bond index and therefore invest almost exclusively in index constituents. EU passive funds hold Total Assets of €155 billion, and EU passive funds tracking euro IG corporate index hold Total Assets of €43 billion.

3. Finally, other funds invest in corporate bonds, such as mixed funds (which invest in both equities and bonds).

In the analysis, we focus on active and passive funds only, as their investment mandates are directly related to IG corporate bond benchmarks.

In Table 3, the data in the blue columns are extracted from the ECB's SHS database, which covers only euro area institutions and some selected countries that voluntarily report SHS data (currently Bulgaria, the Czech Republic, Denmark and Romania). The SHS data cover global holdings of these institutions. The green columns correspond to data provided by ESMA and EIOPA, which have global coverage. It is also important to note that passive funds constitute only a small portion of the investment funds included in SHS data, since active funds and especially other types of fund could also hold corporate bonds, as discussed in Section 3.2. It is therefore difficult to compare the global passive funds data from ESMA with the SHS investment fund data. Focusing only on SHS data, i.e. the global holdings of euro area institutions (plus institutions of some selected countries), these institutions hold approximatively €967 billion of BBB-rated bonds and €782 billion of A-rated bonds (as at the end of 2019), which are the two rating categories that are most important for considering fallen angel risk. Of these amounts, between 60% and 70% are euro area bonds, while 30% – 40% are non-euro area corporate bonds held by the euro area institutions reporting SHS data.

Table 3

Holdings of various sectors in selected rating categories in the EEA (excluding the United Kingdom)

(EUR billions)

Rating	Investment funds	Insurers	Banks	Pension funds	Total	Global passive funds	Insurers (EEA excluding UK)
AAA	53.6	40.2	106.2	7.0	207.0	11.0	59.8
AA	143.2	210.2	140.9	15.2	509.5	99.5	179.7
A	327.6	281.1	140.4	32.9	782.0	464.1	416.3
BBB	518.7	291.6	116.5	40.1	966.9	530.4	347.9
BB and below	331.4	24.2	16.4	15.8	387.8	NA	29.0
Total	1,374.5	847.3	520.4	111.0	2,853.2	1,105.0	1,032.7

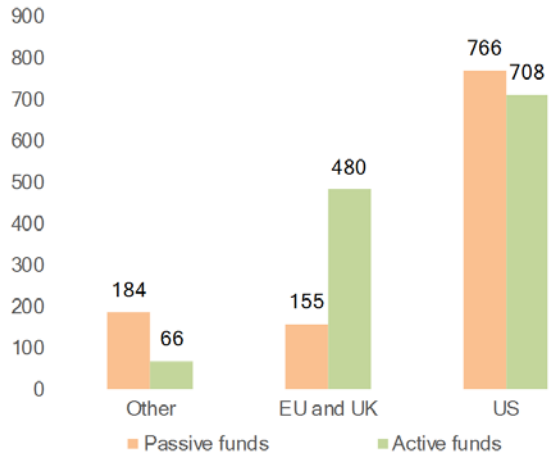
Sources: ESAs and ECB SHS database.
Notes: The left-hand columns in blue are based on SHS data, while the two right-hand columns in green are based on data provided by the ESAs. In general, it should be expected that the total based on SHS data would be smaller than the total collected by the ESAs, as SHS data cover only global assets of owners in the euro area and some other selected countries. The only exception is for AA holdings of insurers, possibly owing to different sources used for reporting the credit quality step. Similarly, "investment funds" in SHS data (blue columns) also include active funds and other investment funds, while global passive funds is an estimate of the global holdings of passive funds by ESMA. These differences have no impact on the results since the report only considers sales of fallen angels. EIOPA data contain CIC2-1 (corporate bonds, corporate bonds) with the reported credit quality step. The analysis below requires both data sources, as it seeks to quantify the impact of sales by global institutions on European institutions.

Active funds dominate the corporate bond fund sector in Europe, with a market share of roughly 75%. EU passive funds manage assets with a value of €155 billion (i.e. 25% of the market), which is significantly less than in the United States, where passive funds dominate (see Chart 2).

Chart 2

Size of passive and actie IG corporate bond funds

(EUR billions)



Sources: Morningstar Direct, ESMA.
Note: Total assets of open-ending fungs tracking IG corporate indice by domicile.

Passive funds, in the aggregate, are assumed to track the Bank of America Merrill Lynch (BoAML) global corporate bond index. Since passive funds can track a range of IG indices (including the Bloomberg Barclays Aggregate index where corporates only account for 25% of the index), the estimates can be interpreted as an upper bound. The composition of the index, as shown in Table 4, is used to map passive funds' exposures to rating categories in Table 3.

Table 4

Assumed composition of passive funds' corporate bond holdings

	Index composition	Eupassive funds total assets (EUR billions)	United States	Rest of the world	Total
AAA	1%	2	9	2	13
AA	9%	14	69	16	99
A	42%	65	321	77	463
BBB	48%	74	367	88	529
Total	100%	155	766	183	1,104

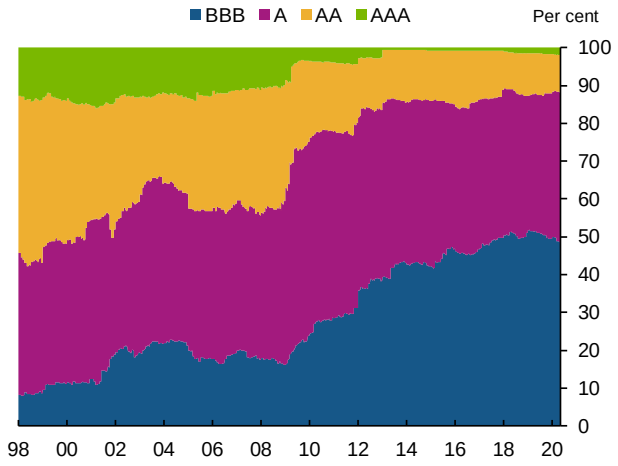
Sources: BoAML, Morningstar Direct, ESMA.

For active funds, the available data cover only €136 billion of holdings. All data are obtained from a commercial database (Morningstar Direct) where no harmonised definition of active funds exists. The sample of active funds has been constructed by selecting fixed income funds which mainly invest in corporate bonds and whose benchmark is an IG corporate bond index. Most bond funds investing in corporate and sovereign bonds are not included. Overall, active funds' Total Assets amount to €1.2 trillion, with €480 billion held by funds domiciled in the EU and the United Kingdom. Only a subsample (€139 billion) of those active funds was used in the analysis owing to data availability issues regarding portfolio composition and credit quality. The data are as at the end of March 2020. Of the €139 billion subsample, only €55 billion is held by EU-domiciled funds.

Regarding the United Kingdom, the size of the sterling investment-grade corporate bond market has increased six-fold since 1998 and currently stands at £430 billion. Over the same period, the share of BBB-rated bonds in the market has increased from 8% to 49% (see Chart 3). Thus the market value of the sterling BBB market is now four and a half times greater than it was in 2008 and nine times greater than in 2002.

Chart 3

Sterling investment-grade corporate bond index broken down by credit rating



Sources: ICE BoAML and Bank of England calculations.

3 Description of scenarios

3.1 Transition matrices and yield shocks

In contrast to recent estimates by the ECB and the ESRB that focused on estimating the likely amount of downgrades,[9] the present analysis focuses on two "what if" scenarios that consist of a large number of downgrades (Scenario 1) and a very large number of downgrades (Scenario 2), as summarised in Table 5. In each case, the shocks are assumed to materialise simultaneously. The scenarios have been calibrated by taking into account the projected contractions in GDP and the Purchasing Managers' Index (PMI) for 2020, assessing the link between GDP, the PMI and rating transitions, and applying additional expert judgement via benchmarking the model-based estimates to historical maxima. In addition, the transition probabilities from BBB to BB (or below) have been increased[10] to reflect (i) the substantial growth of the BBB segment in recent years, (ii) the fact that 60% of BBB-rated corporate bonds are now on "negative outlook",[11] and (iii) the fact that this rating is a key threshold in terms of investor and market behaviour.

Yield shocks to bonds

Three types of shock are applied to the bond holdings:

- First, as the data for insurers, pension funds and banks are as at the end of 2019 and do not include the price movements resulting from the market turmoil in March 2020, Table 6 adds yield shocks that correspond to the actual market moves between February and April 2020.[12] This brings all prices to the same "starting point". The losses from the application of these yield shocks are not counted in the analysis below.
- Second, Table 7 models a yield shock to all bonds, capturing a further deterioration in credit risk.
- Finally, those bonds that are downgraded in line with the percentages in Table 5, and thus face a larger increase in credit risk, receive an additional yield shock reflecting this relatively higher credit risk.[13] This element is captured in Table 8.

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9 See Chart 2.11 in the **ECB Financial Stability Review**, May 2011, and the ESRB **issues note on liquidity in the corporate bond and commercial paper markets, the procyclical impact of downgrades and implications for asset managers and insurers**, May 2020.

10 While pure model-based calibrations have resulted in downgrade percentages close to the observed historical maximum, they have been increased substantially for the BBB → BB and BBB → B downgrades for the reasons stated.

11 See ESRB (2020b) for details.

12 See the Annex for an overview of the various data sources.

13 As an example, consider an EU/EEA financial corporate bond, initially rated BBB. If the data capture its value in February 2020 or earlier and it is downgraded to B, it receives a shock of 221 (Table 6) + 143 (Table 7) + 210 + 340 (both Table 8) = 914 basis points.

To the extent that market prices may already have priced in forced sales, the impact once they occur might be smaller. This uncertainty is captured in the range between “low price impact” and “high price impact” in Section 4.1.4.

Table 5

Transition probabilities in both scenarios

EU-27 and EEA

Medium severe case – Scenario 1											Severe case – Scenario 2										
	AAA	AA	A	BBB	BB	B	CCC	CC	C	D		AAA	AA	A	BBB	BB	B	CCC	CC	C	D
AAA	80.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	AAA	20.0	65.0	10.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
AA	0.0	85.6	10.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	AA	0.0	40.5	45.0	13.4	1.0	0.0	0.0	0.0	0.0	0.1
A	0.0	0.0	86.9	10.0	2.0	1.1	0.0	0.0	0.0	0.0	A	0.0	0.0	52.7	35.0	10.0	2.1	0.0	0.0	0.0	0.2
BBB	0.0	0.0	0.0	74.9	20.0	5.0	0.0	0.0	0.0	0.2	BBB	0.0	0.0	0.0	54.7	40.0	5.0	0.0	0.0	0.0	0.3
BB	0.0	0.0	0.0	0.0	78.7	20.0	0.5	0.0	0.0	0.8	BB	0.0	0.0	0.0	0.0	50.1	35.0	13.3	0.0	0.0	1.6
B	0.0	0.0	0.0	0.0	0.0	76.7	15.0	5.0	0.0	3.3	B	0.0	0.0	0.0	0.0	0.0	63.0	25.0	0.3	5.0	6.7
CCC	0.0	0.0	0.0	0.0	0.0	0.0	86.7	5.0	5.0	3.3	CCC	0.0	0.0	0.0	0.0	0.0	0.0	53.3	30.0	10.0	6.7
CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	20.0	5.0	CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	30.0	10.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	20.0	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	40.0

United Kingdom

Medium severe case – Scenario 1											Severe case – Scenario 2										
	AAA	AA	A	BBB	BB	B	CCC	CC	C	D		AAA	AA	A	BBB	BB	B	CCC	CC	C	D
AAA	85.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	AAA	55.0	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AA	0.0	86.2	10.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	AA	0.0	47.4	40.0	11.6	0.9	0.0	0.0	0.0	0.0	0.1
A	0.0	0.0	80.2	14.1	5.0	0.7	0.0	0.0	0.0	0.0	A	0.0	0.0	58.2	30.0	10.3	1.3	0.0	0.0	0.0	0.2
BBB	0.0	0.0	0.0	77.9	18.0	4.0	0.0	0.0	0.0	0.2	BBB	0.0	0.0	0.0	59.7	35.0	5.0	0.0	0.0	0.0	0.3
BB	0.0	0.0	0.0	0.0	75.7	22.9	0.5	0.0	0.0	0.8	BB	0.0	0.0	0.0	0.0	56.9	30.0	11.5	0.0	0.0	1.6
B	0.0	0.0	0.0	0.0	0.0	75.1	16.6	5.0	0.0	3.3	B	0.0	0.0	0.0	0.0	0.0	68.0	20.0	0.3	5.0	6.7
CCC	0.0	0.0	0.0	0.0	0.0	0.0	87.0	4.7	5.0	3.3	CCC	0.0	0.0	0.0	0.0	0.0	0.0	58.3	25.0	10.0	6.7
CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	15.0	5.0	CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.0	35.0	10.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	20.0	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	40.0

United States and rest of the world

	Medium severe case – Scenario 1											Severe case – Scenario 2									
	AAA	AA	A	BBB	BB	B	CCC	CC	C	D		AAA	AA	A	BBB	BB	B	CCC	CC	C	D
AAA	90.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	AAA	75.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AA	0.0	90.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	AA	0.0	69.9	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
A	0.0	0.0	74.4	20.0	5.0	0.0	0.0	0.6	0.0	0.0	A	0.0	0.0	63.8	25.0	10.0	0.0	0.0	1.0	0.0	0.2
BBB	0.0	0.0	0.0	60.1	25.0	9.0	3.4	2.3	0.0	0.2	BBB	0.0	0.0	0.0	49.1	35.0	9.4	3.7	2.5	0.0	0.3
BB	0.0	0.0	0.0	0.0	89.2	10.0	0.0	0.0	0.0	0.8	BB	0.0	0.0	0.0	0.0	53.4	45.0	0.0	0.0	0.0	1.6
B	0.0	0.0	0.0	0.0	0.0	70.4	15.0	11.3	0.0	3.3	B	0.0	0.0	0.0	0.0	0.0	41.7	35.0	11.6	5.0	6.7
CCC	0.0	0.0	0.0	0.0	0.0	0.0	81.7	10.0	5.0	3.3	CCC	0.0	0.0	0.0	0.0	0.0	0.0	58.3	25.0	10.0	6.7
CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	20.0	5.0	CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	40.0	10.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	20.0	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	40.0

Sources: ESRB and ECB estimations.
Notes: Additional transition matrices for short-term ratings and historical maximum downgrades are provided in the Methodological annex. The rows denote the initial rating, while the columns denote the final rating. The orange shaded area covers all fallen angels. For instance, in Scenario 2, for the EU-27 and EEA, 40% of BBB bonds are assumed to migrate to BB, while 5% are assumed to migrate to B and 0.3% are assumed to default.

Table 6

Yield shocks to bonds reflecting market developments in March – April 2020

(absolute changes (basis points))

		Corporate bond yields			
Country	Type	AAA-AA	A	BBB	BB (and below)
United Kingdom	*Financial*	160	173	292	369
	Non-financial	172	181	207	262
EU and EEA	*Financial*	131	175	221	280
	Non-financial	117	125	179	226
United States and rest of the world	*Financial*	113	165	297	375
	Non-financial	113	129	211	267

Notes: These shocks have been applied only to bond holdings data for the period prior to February 2020. Losses from these yield shocks are not added to the loss estimates below. Observed during the March – April 2020 market turmoil.

Table 7

Yield shocks to all bonds owing to the increase in credit risk

(based on final ratings after transitions; absolute changes (basis points))

		Corporate bond yields			
Country	**Type**	**AAA-AA**	**A**	**BBB**	**BB (and below)**
United Kingdom	*Financial*	61	66	149	188
	Non-financial	73	80	105	133
EU and EEA	*Financial*	50	67	113	143
	Non-financial	49	56	90	114
United States and rest of the world	*Financial*	55	73	124	157
	Non-financial	54	61	100	126

Source: ECB calculations.

Table 8

Additional yield shocks to downgraded bonds only

(basis points)

Shocks on downgrade	**AAA → AA**	**AA→ A**	**A → BBB**	**BBB → BB**	**BB → B**	**B → CCC****
Financials	10	60	120	210	340	910
Non-financials	10	60	90	150	250	670

Source: ECB calculations.
*** And for each additional downgrade step.*

3.2 Behavioural and modelling assumption

The analysis below assumes that financial institutions respond to the instantaneous shocks calibrated in Section 3.1 partly mechanically (e.g. implementing fixed investment mandates) and partly through behavioural reactions (e.g. management actions or portfolio rebalancing). The forced sale analysis focuses only on the first month after the downgrade shock, as price impacts are unlikely to be of first-order importance over longer time horizons. The results are based on the behavioural assumptions below, which should be viewed as hypothetical "what if" reactions, rather than specifying an evidence-based expected or likely behaviour of different institutional sectors.

The simulations below analyse three different sets of "behavioural scenarios", which, as the estimated losses further below show, are important drivers of the results:

1. **Mild behavioural scenario:** Only passive funds are assumed to engage in forced sales; they are assumed to sell all of their fallen angels. All other institutions are assumed not to engage in any forced sales.

2. **Severe behavioural scenario:** Passive funds behave as under the mild behavioural scenario. In addition, active funds, insurers and pension funds are assumed to sell some of their fallen angels. Further details on the assumptions underlying this scenario are provided below.

3. **Extreme behavioural scenario:** Passive and active funds, pension funds and insurers sell all of their fallen angels.

"What if" assumptions regarding the selling behaviour of the various institutional sectors:

- **Passive IG corporate investment funds** tracking an IG index are assumed to sell all of their fallen angels in accordance with their investment mandate within the first month for the purposes of the analysis.[14] Additional potential volumes sold to meet potential redemptions have not been incorporated.[15] Such outflow-related sales have been estimated for active funds and are dwarfed by the direct sale assumption for fallen angels. This assumption for passive funds remains the same across all three behavioural scenarios.

- **Active IG corporate bond funds,**[16] following Aramonte and Eren (2019) and ESMA (2020), are assumed to sell 33.3% of the fallen angels in their portfolios to reflect some degree of investment mandate flexibility. Moreover, active funds are assumed to face outflows and are assumed to sell some assets to meet these redemptions. The redemptions are calibrated to historical return-flow relationships for EU funds (ESMA, 2019).[17] This assumption is relevant for the severe behavioural scenario.

- **Insurers'** reactions depend on their current portfolio composition, their asset-liability management and their risk appetite. Based on available information, it is difficult to assess how insurers would react in such a downgrade scenario. They might not sell their fallen angels immediately if prices are perceived as being "too low" and if they have sufficient balance sheet capacity and/or for instance choose to de-risk in other asset classes, such as equities. For the sake of simplicity, it is therefore assumed that, similarly to active funds, insurers would sell 20% of their fallen angels. This hypothetical assumption is relevant for the severe behavioural scenario below.

- **Pension funds**, depending on their risk appetite, may also choose to reduce risk exposures. While the EIOPA 2019 IORP stress test suggests that pension funds may take considerable time to rebalance their portfolios, for the sake of simplicity it is assumed here that pension funds would sell 10% of their fallen angels. Again, this assumption is relevant for the severe behavioural scenario.

Assumptions for other financial institutions:

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[14] In practice, passive funds replicate the index by using a set of sampling techniques (rather than holding all the index constituents) and have some flexibility regarding the timing of the rebalancing of their portfolios. This flexibility can however imply larger tracking errors.

[15] Given that it is already assumed that passive funds would sell all of their fallen angels.

[16] Excluding hedge funds, distressed debt funds and sovereign wealth funds.

[17] The flow-related sales are in the order of 1% compared with the assumption of selling 33.3% of the fallen angels.

- **Money Market Funds** (MMFs) invest in short-term bonds and adjust their portfolios to changes in credit risk. Although there is no automatic reliance on credit ratings in the regulation governing MMFs, a large share of MMFs receives money market fund ratings issued by credit rating agencies (CRAs) (around 95% of a sample of €750 billion of EU MMFs). AAAmmf ratings for MMFs prohibit them from investing in a short-term instrument from an issuer rated below P1/A1/F1. CRAs give MMF managers a short transition period to dispose of the assets following a downgrade ("grace" or "cure" periods). It is therefore assumed that MMFs refrain from rolling over these investments instead of selling these parts of their bond portfolios.

- **Banks** act as market-makers, and it is assumed that they are unlikely to sell off their existing bond holdings. They may in fact act as buyers and, balance sheet capacity allowing, increase their holdings. The recent measures taken by the ECB with regard to the collateral framework in order to alleviate the impact of rating downgrades on the availability of collateral should help banks to continue their activities of market-making. Marketable assets and issuers of those assets that were rated at least BBB- on 7 April 2020 will retain their eligibility in terms of the provision of collateral in the event of rating downgrades, as long as their rating remains at or above BB.[18] An analysis including banks as sellers is possible in principle. Nevertheless, banks suffer mark-to-market losses from the initial yield shocks in the scenarios and the price impact of the forced sales by other institutions. We assume that all bonds are held on a "fair value" accounting basis to estimate these mark-to-market losses.[19]

- **Hedge funds, distressed debt funds or sovereign wealth funds** may also act as potential buyers (however, see Duffie 2010 on "slow-moving capital"). These counterparties are not modelled directly in the analysis, but captured indirectly in the "price impact function" and in particular the price floors (i.e. levels below which prices are assumed not to drop, as fundamental value buyers are assumed to step in at this level).

- **Central counterparties** (CCPs) usually accept only assets with very low credit risk as collateral. At first sight, a fallen angel scenario is thus not likely to have a severe impact on CCPs, unless a substantial amount of their clients were using, for "collateral upgrades", bonds that became fallen angels, which their dealer banks would no longer be willing to transform into accepted collateral. Our data sources do not allow us to assess the relevance of this possibility. CCPs are therefore not modelled.

- **Central banks** are not modelled. While the ECB has recently taken policy actions to expand its collateral framework, no policy actions are modelled in the simulation exercise below.

Regarding the liquidation strategy, it is assumed that **assets are sold in proportion to current holdings** (pro-rata).[20]

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18 ECB (2020a) and (2020b).

19 This is a simplifying assumption because bonds held at amortised cost do not suffer mark-to-market-losses. However, the bonds held in the banking book would also have an impact on the balance sheet via increases in risk weights or migrations in credit stages (owing to deterioration in credit risk). The mark-to-market losses can thus be seen to approximate these effects.

20 A variant in which only bonds assigned a negative outlook are sold is in principle implementable, but this matching was not feasible within our timeline.

Simplified version of a potential timeline of events (in days)

T0:	Credit risk increases and downgrades
T+1:	Passive funds sell
T+2:	MMFs cut their exposures
T+7:	Active funds face outflows and sell
T+10 and later:	Pension funds and insurers sell

4 Results

Given both the uncertainty and importance surrounding some of the key parameters and modelling assumptions in this analysis, the results below are presented for different combinations of assumptions, which yield a range for the results rather than single point estimates. This approach attempts to quantify the uncertainty of the results and thereby to be "roughly right", rather than "precisely wrong". We consider:

1. **Two scenarios for the transition probabilities** which quantify the amount of downgrades. These scenarios are referred to as "Transition scenario 1" and "Transition scenario 2" below (see Table 5 in Section 3.1);

2. **A single scenario for the yield shocks** (see Tables 6, 7 and 8 in Section 3.1);

3. **Three behavioural scenarios** which specify the assumptions regarding the behavioural reactions of institutions in a "what if" approach. These scenarios are referred to as "mild behavioural scenario", "severe behavioural scenario" and "extreme behavioural scenario" below (see Section 3.2 for a description of the scenarios).

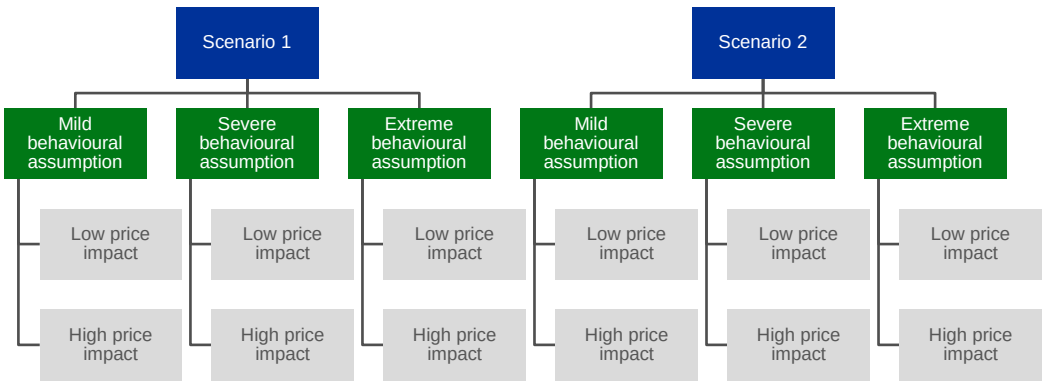
4. **A two-scenario sensitivity analysis on the price impact**, using a "low price impact" regime and a "high price impact" regime. The low price impact regime is characterised by price impacts that are usually below 50 basis points, which may be small for a distressed market condition, while in the high price impact regime, price impacts can reach 500 basis points or more.

Overall, these combinations thus yield:

- Two scenarios for both the amount of fallen angels and for the initial losses.
- Twelve scenarios for the final fire sale losses/price impact estimates.

The twelve grey boxes in the flow chart below illustrate these twelve combinations.

Figure 1
Overview of the combinations of scenarios and assumptions



4.1 Impact assessment of the scenarios

4.1.1 Losses from yield shocks

Table 9 shows the initial losses suffered by the various sectors under transition scenario 1, which amount to roughly €146 billion. For active funds, a small-sample approximation of their portfolio holdings has been used; data availability issues do not allow a more granular estimation of the impact. It is assumed that the duration of pension funds' and banks' portfolios is similar to that of insurers' portfolios; the losses for pension funds and banks are therefore derived by multiplying the pension fund and banking sectors' respective holdings with the percentage losses by rating category recorded by insurers.[21]

Table 9
Initial losses under transition scenario 1

(EUR billions)

Transition scenario 1	EEA			EEA excluding United Kingdom	Euro area	EEA	
Rating	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Banks	Total
AAA	0.0	0.1	0.1	2.3	0.3	4.1	**6.8**
AA	1.8	0.6	2.4	6.8	0.6	5.3	**15.2**
A	2.2	4.0	6.2	24.1	2.1	8.1	**40.5**
BBB	11.4	8.3	19.7	33.3	4.3	11.2	**68.4**
BB	3.2	0.0	3.2	1.8	1.3	1.4	**7.8**
B	3.2	0.0	3.2	0.6	0.0	0.0	**3.8**
CCC	0.8	0.0	0.8	0.1	0.0	0.0	**0.9**
Not rated	2.6	NA	NA	NA	NA	NA	**NA**
Total	25.2	13.0	38.2	69.0	8.6	30.1	**145.9**
In relation to initial holdings	6.4%	8.4%		7.3%	7.8%	5.8%	

Source: ESA and ESRB Secretariat calculations.

Table 10 below shows the estimated initial losses by sector in transition scenario 2. They total approximately €213 billion.

[21] In scenario 1, these losses correspond to 4% (AAA and AA), 6% (A), 10% (BBB) and 9% (BB and below). In scenario 2, these losses correspond to 6% (AAA and AA), 9% (A), 12% (BBB), 16% (BB), 13% (B) and 17% (CCC). The average duration of insurers' bond portfolios usually ranges between 8 and 10 years, while for banks it usually ranges between 5 and 6 years. As such the losses from yield shocks for banks will be slightly overestimated in the table below.

Table 10

Initial losses under transition scenario 2

(EUR billions)

Transition scenario 2	EEA			EEA excluding United Kingdom	Euro area	EEA	
Rating	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Banks	Total
AAA	0.0	0.1	0.1	3.3	0.4	5.9	9.7
AA	3.0	1.0	4.0	11.1	1.0	8.7	24.8
A	3.8	6.7	10.5	37.5	3.2	12.6	63.9
BBB	16.2	10.1	26.3	40.2	5.2	13.5	85.2
BB	7.1	0.0	7.1	3.3	2.5	2.6	15.5
B	5.3	0.0	5.3	0.9	0.0	0.0	6.2
CCC	1.8	0.0	1.8	0.2	0.0	0.0	2.0
Not rated	5.4	NA	NA	NA	NA	NA	NA
Total	42.6	18.0	60.6	96.5	12.3	43.3	212.7
In relation to initial holdings	10.8%	11.6%		10.3%	11.1%	8.3%	

Source: ESA and ESRB Secretariat calculations.

Initial portfolio losses from downgrades amount to 8.4% for passive funds and 6.4% for actively managed funds in scenario 1, and 11.6% and 10.8% respectively in scenario 2. In the scenarios tested, the European insurance sector, excluding the United Kingdom, could be faced with losses on their BBB holdings of 9.5% in scenario 1 and 11.5% in scenario 2. This corresponds to €33.3 billion in scenario 1 and €40.2 billion in scenario 2 and would account for about 2.5% of their initial holdings of corporate bonds in scenario 1 and 3.3% in scenario 2. As the scenarios assume the largest downgrade percentages in the A and BBB categories, the losses resulting from downgrades are, by design, also the largest in these categories, while the losses in other rating categories still amount to about €20 billion.

Overall, for the insurance sector, the losses from all downgrades amount to 4.9% in scenario 1 and 6.9% in scenario 2 in terms of pre-shock excess of assets over liabilities (EAOL). But such losses on the corporate bond portfolios would not be directly reflected in the own funds of insurers. In fact, the extent of this negative development in the own funds would depend on a series of factors not included in this assessment. In particular, there are many loss-absorbing mechanisms which would mitigate the actual impact of a downgrade on the insurers' balance sheets. Profit-sharing mechanisms would certainly alleviate pressure on own funds, and the volatility adjustment would also likely offer a substantial countercyclical effect. Overall, these figures should not be considered estimates of post-stress EAOL since they do not reflect any changes to liabilities offsetting the estimated asset-side decrease. Consequently, while the figures help to understand the order of magnitude of the shock, they cannot be considered a reliable estimate of the impact on the solvency of insurers.

For the banking sector, these losses should be seen in relation to approximately €1.65 trillion of CET1 capital. The losses may be concentrated within a smaller subset of banks, however, which the present analysis cannot disentangle.

4.1.2 Amount of fallen angels

Table 11 shows the amount of fallen angels by sector and rating category for transition scenarios 1 and 2 respectively. The figures for banks are shaded in grey, as they are not assumed to contribute to the sales volume. The estimates based on the above-mentioned transition matrices suggest that the EU financial sector could face amounts between €232 billion and €443 billion. These estimated amounts of fallen angels correspond almost directly to the figures obtained by multiplying the total amount of BBB and A holdings (€967 billion and €782 billion, as stated above) with the average percentage of downgrades (assumed to be, for EU assets, 3.1% for A-rated bonds and 25.2% for BBB-rated bonds in scenario 1, compared with 12.3% for A-rated bonds and 45.3% for BBB-rated bonds in scenario 2). A back-of-the-envelope estimate therefore implies that each percentage point of additional downgrades in A and BBB holdings generates €7.8 billion and €9.7 billion of fallen angels in each rating category respectively.

Table 11
Amount of fallen angels in transition scenarios 1 and 2

(EUR billions)

Scenario 1

	Global funds EU assets			EEA excluding United Kingdom		United Kingdom			
Rating	**Active funds**	**Passive funds**	**Funds – total**	**Insurers**	**Pension funds**	**Insurers**	**Banks**	**Total**	**MMF**
A	1.9	0.8	2.6	12.6	0.9	6.0	4.4	**26.4**	
BBB	40.6	29.5	70.1	79.9	8.1	18.0	29.4	**205.4**	
P1 (short term)								**0.0**	15.2
Total	**42.5**	**30.3**	**72.7**	**92.5**	**9.0**	**24.0**	**33.7**	**231.8**	15.2

Scenario 2

	Global funds EU assets			EEA excluding United Kingdom		United Kingdom			
Rating	**Active funds**	**Passive funds**	**Funds – total**	**Insurers**	**Pension funds**	**Insurers**	**Banks**	**Total**	**MMF**
A	7.5	12.8	20.3	38.8	3.5	12.3	17.3	**92.1**	
BBB	72.9	51.8	124.7	126.5	14.5	32.6	52.8	**351.0**	
P1 (short term)								**0.0**	30.4
Total	**80.4**	**64.5**	**144.9**	**165.3**	**18.0**	**44.9**	**70.0**	**443.1**	30.4

Source: ESA and ESRB Secretariat calculations.

4.1.3 Volume of estimated sales

The tables in the following subsections present estimates for the volume of assets that are sold under each of the three behavioural scenarios described above. There are multiple reasons for why institutions might choose (or be forced) to sell after a downgrade occurs, such as (i) discretionary management decisions, (ii) internal risk management benchmarks, (iii) a desire to shrink the balance sheet following a loss of equity, or (iv) regulatory restrictions or covenants. The mild behavioural scenario focuses on stricter investment mandates that passive funds follow under regulatory restrictions or conventions. The severe and extreme behavioural scenarios extend to further reasons, but without taking a clear stance as to why exactly the sale was triggered.

For AAA-rated MMFs, issuer downgrades below P1 force them either to sell the bond or to let it mature without rolling it over. MMFs are assumed to let short-term instruments mature (see Section 3.2) and are therefore not included in the estimation of the price impact from forced sales (see below). Overall, the reduction in short-term funding to issuers (mainly financial corporations) would range between €15 billion and €30 billion (see Table 11).

Mild behavioural scenario

Under the mild scenario, only passive investment funds sell all of their fallen angels. Table 12 provides estimates of the volume of forced sales (in EUR billions) in this scenario. We focus on the EU assets held by global funds, as the sales of EU corporate bonds by a US passive investment fund will obviously affect the price of that asset held by all other EU institutions. Our estimates suggest that in scenarios 1 and 2 an amount between €30.3 billion and €64.6 billion could be sold by passive investment funds.

Table 12

Estimated volume of forced sales under the mild behavioural assumption in transition scenarios 1 and 2

(EUR billions)

Scenario 1

Rating	Global funds EU assets			EEA excluding United Kingdom		United Kingdom	Banks	Total	MMF
	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Insurers			
A		0.8	0.8					**0.8**	
BBB		29.5	29.5					**29.5**	
P1 (short term)								**0.0**	15.2
Total			**30.3**					**30.3**	15.2

Scenario 2

Rating	Global funds EU assets			EEA excluding United Kingdom		United Kingdom	Banks	Total	MMF
	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Insurers			
A		12.8	12.8					**12.8**	
BBB		51.8	51.8					**51.8**	
P1 (short term)								**0.0**	30.4
Total		**64.5**	**64.5**					**64.5**	30.4

Source: ESA and ESRB Secretariat calculations.

Severe behavioural scenario

Under the severe behavioural scenario, passive investment funds sell all their fallen angels while active funds sell 33.3%, insurers 20% and pension funds 10% of their fallen angels (see Table 13). At a system level, this yields a total volume of assets sold of between €69 billion and €135 billion in scenarios 1 and 2 respectively.

Table 13

Estimated volume of forced sales under the severe behavioural assumption in transition scenarios 1 and 2

(EUR billions)

Scenario 1

Rating	Global funds EU assets			EEA excluding United Kingdom		United Kingdom	Banks	Total	MMF
	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Insurers			
A	0.6	0.8	1.4	2.5	0.1	1.2		**5.2**	
BBB	13.5	29.5	43.0	16.0	0.8	3.6		**63.4**	
P1 (short term)								**0.0**	15.2
Total	**14.2**	**30.3**	**44.4**	**18.5**	**0.9**	**4.8**	**0.0**	**68.6**	15.2

Scenario 2

Rating	Global funds EU assets			EEA excluding United Kingdom		United Kingdom	Banks	Total	MMF
	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Insurers			
A	2.5	12.8	15.3	7.8	0.3	2.5		**25.8**	
BBB	24.3	51.8	76.1	25.3	1.5	6.5		**109.4**	
P1 (short term)								**0.0**	30.4
Total	**26.8**	**64.5**	**91.3**	**33.1**	**1.9**	**9.0**	**0.0**	**135.2**	30.4

Source: ESA and ESRB Secretariat calculations.

Extreme behavioural scenario

Under this scenario, which is the most extreme hypothetical behavioural scenario in our framework, all financial institutions except for banks sell all their fallen angels (see Table 14). Table 14 is therefore, save for banks, identical to Table 11 in terms of the total amount of fallen angels under both scenarios. In this case, estimates suggest that the volume liquidated is between €198 billion and €313 billion. At these volumes of sales, which would reach almost 50% of the total initial BBB market and exceed the total value (€388 billion as recorded in the SHS data) of all bonds rated BB and below, we must again ask who the potential buyers of these distressed sold assets might be. It is uncertain whether hedge funds, distressed debt funds and sovereign wealth funds would be able or willing to absorb these volumes, especially if concentrated in time. In addition, in the light of the volume of such potential sales relative to the high-yield market, one might conjecture that markets could freeze or that forced sales of bonds would entail prices so severely depressed that institutions might hold on to their assets. Insurers and pension funds with long-term business and with no immediate liquidity pressure are likely to opt for the latter.

Table 14

Estimated volume of forced sales under the extreme behavioural assumption in transition scenarios 1 and 2

(EUR billions)

Scenario 1

Rating	Global funds EU assets			EEA excluding United Kingdom		United Kingdom	Banks	Total	MMF
	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Insurers			
A	1.9	0.8	2.6	12.6	0.9	6.0		**22.0**	
BBB	40.6	29.5	70.1	79.9	8.1	18.0		**176.1**	
P1 (short term)								**0.0**	15.2
Total	**42.5**	**30.3**	**72.7**	**92.5**	**9.0**	**24.0**	**0.0**	**198.1**	15.2

Scenario 2

Rating	Global funds EU assets			EEA excluding United Kingdom		United Kingdom	Banks	Total	MMF
	Active funds	Passive funds	Funds – total	Insurers	Pension funds	Insurers			
A	7.5	12.8	20.3	38.8	3.5	12.3		**74.8**	
BBB	72.9	51.8	124.7	126.5	14.5	32.6		**298.3**	
P1 (short term)								**0.0**	30.4
Total	**80.4**	**64.5**	**144.9**	**165.3**	**18.0**	**44.9**	**0.0**	**373.1**	30.4

Source: ESA and ESRB Secretariat calculations.

4.1.4 Price impact from forced sales

The price impact refers to the return resulting from a system-wide forced sale. A large order imbalance with temporarily more sellers than buyers can depress prices and move them below fundamental value. For the estimates below, price impact functions, which quantify how much the price of a bond will fall as a function of the size of the distressed sale, have been calibrated at the individual bond level (for more than 20,000 bonds); see Annex 5.4, Kaijser et al (2020) and Cont and Schaanning (2017) for details. Because it is notoriously difficult to quantify how much the price of a bond will drop for a forced sale of €100 million in distressed markets, for example, we attempt to provide upper and lower bounds for these impacts, rather than giving a single point estimate.[22] Empirical studies on the US corporate bond market (see Ellul et al. 2011) have shown that median cumulative abnormal returns can reach up to 10% for forced sales, while anecdotal market intelligence suggests that impacts in the order of 100 basis points for a €100 million sale can also

[22] While there is a rich academic literature on the relative liquidity of assets (see Schestag et al. (2016), Bao et al. (2011) and references therein), this literature is of little help for the problem at hand, i.e. estimating the impact of a hypothetical sale of size x on the price of a given bond. Indeed, such an exercise requires absolute estimates of liquidity, which has received relatively little attention in the academic literature to date (see Kyle and Obizhaeva (2016), Bouchaud (2010), Kaijser et al. (2020), Cont and Schaanning (2017) and references therein).

be realistic. These different snapshots of price impacts span a rather wide range, which our sensitivity analysis attempts to cover. Taking an alternative, less micro-focused modelling approach, one could attempt to infer from estimated macro-elasticities the resulting price changes from sales (see Koijen and Yogo (2020) or Koijen et al. (2020)).[23]

To derive price impacts, the sales volumes above are used by rating category, and it is assumed that institutions sell bonds in proportion to their holdings. It would in principle be possible to conduct the analysis by assuming that institutions sell only the downgraded bonds. This would, however, require specifying which of the more than 20,000 bonds in the SHS data are the fallen angels and which are not, and would therefore require more time than was available for conducting the present analysis. We expect that such a detailed analysis would not significantly modify the system-wide losses, however, because the impact, which is larger for the smaller subset of bonds that are sold, is averaged with a zero-impact on other bonds that are not sold, thus leading to a similar system-wide average. Nevertheless, the distribution of losses across individual institutions would likely differ substantially, depending on how the individual portfolios are composed (i.e. a BBB portfolio with more fallen angels would thus be affected more severely than a BBB portfolio containing just a small number of fallen angels).

For instance, in scenario 2, in the severe behavioural scenario, the average price impact ranges:

- Between 0.3% and 2.7% for sales between €10 million and €50 million per individual bond;
- Between 0.8% and 5.7% for sales between €50 million and €100 million per individual bond;
- Between 1.7% and 7.9% for sales exceeding €100 million per individual bond.

In scenario 1, price impacts are somewhat lower (owing to smaller volumes). The distributions of price impacts show similar patterns across the three behavioural scenarios, although price impacts become larger for larger sales and less liquid market assumptions. Overall, it might be expected that, as long as markets function and do not freeze, the actual price impact would lie within the ranges modelled below.

4.1.4.1 Mild behavioural scenario

The two panels in Chart 4 show the distribution of price impacts under:

- The mild behavioural assumption, under transition scenario 1, using the “lower bound” of price impacts, in the left-hand panel.
- The mild behavioural assumption, under transition scenario 2, using the “upper bound” of price impacts, in the right-hand panel.

As such, these two panels on the left and right provide a lower and upper bound for the price impacts under the mild behavioural assumption. On the left, we see that most price impacts are

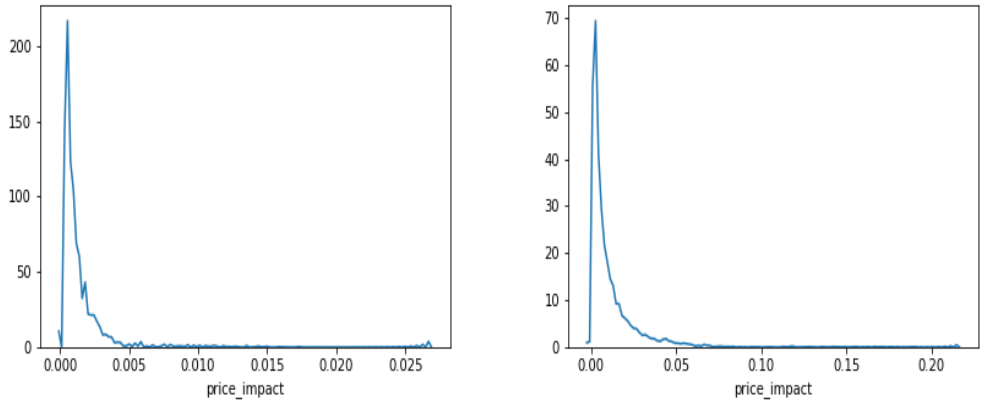
[23] In a similar vein, equilibrium models are being developed that could also be used to model fire sales in an equilibrium setting (see Aikman et Al. (2019) or di Iasio et al. (2020)).

below 0.5%, with some assets experiencing drops of 2.5%. In the right-hand panel, we see that the price impacts are substantially larger, by an order of magnitude roughly, lying between 0% and 5% for most assets, and some assets reach a price decline of 20%.

Chart 4

Distribution of price impact ratios for all bonds under the mild behavioural scenario

(left-hand panel: distribution of price impact ratios under transition scenario 1 with lower price impact bounds; right-hand panel: distribution of price impact ratios under transition scenario 2 with upper price impact bounds)



Source: ESRB Secretariat calculations.
Note: Values expressed as ratios, i.e. multiply by 100 to obtain percentages.

The forced sales under the mild behavioural scenario, which lead to the price declines shown in Chart 4, thus lead to losses that are broken down by institutional sector in Chart 5. The models suggest that:

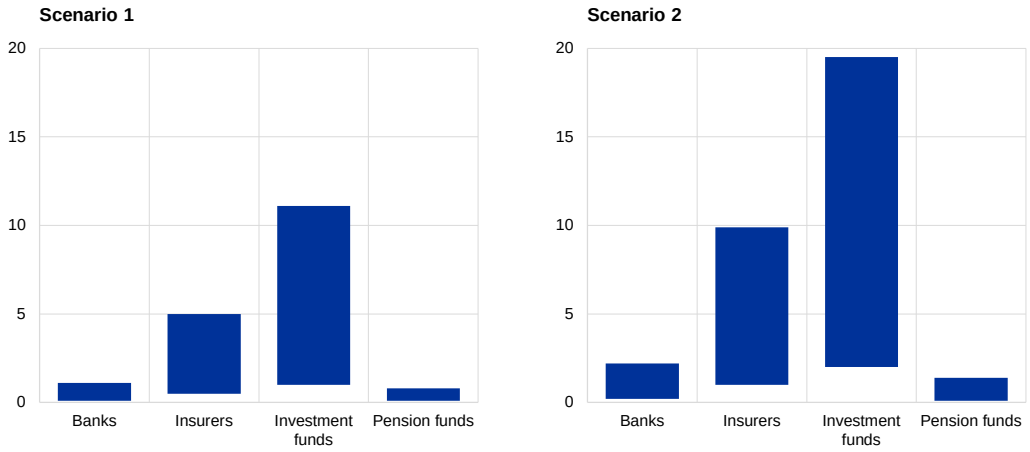
- In scenario 1, losses would lie between
  - €0.1 billion – €1.1 billion for banks,
  - €0.5 billion – €5 billion for insurers,
  - €1 billion – €11.1 billion for active and passive investment funds, and
  - €0.1 billion – €0.8 billion for pension funds.
- In scenario 2, losses are estimated to be more elevated ranging between
  - €0.2 billion – €2.2 billion for banks,
  - €1 billion – €9.9 billion for insurers,
  - €2 billion – €19.5 billion for investment funds and
  - €0.1 billion – €1.4 billion for pension funds.

Overall, the system-wide estimated fire sale losses from forced sales would thus range between €1.7 billion and €18 billion in scenario 1, while in scenario 2 they would lie between €3.3 billion and €33 billion. While these ranges are very large, they are a reflection of the uncertainty attached to hypothetically large sales in hypothetically distressed markets.

Chart 5

Estimated range of fire sale losses for the mild behavioural scenario and transition scenarios 1 and 2

(EUR billions)



Source: ESRB Secretariat calculations.
Note: The bars show the ranges of potential fire sale losses by sector.

4.1.4.2 Severe behavioural scenario

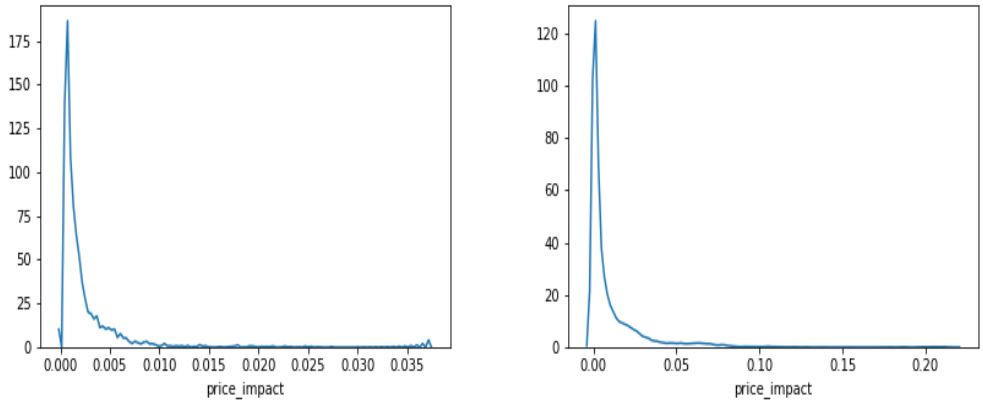
A briefer description will be provided of the remaining scenarios. For a detailed description of the charts, see the previous sub-section 4.2.4.1.

Chart 6 shows that in the severe behavioural scenario, price impacts would be similar to those in the mild behavioural scenario, lying mostly below 0.5% in the “lower bound” while lying mostly below 5% in the “upper bound”. Some illiquid assets would see potential drops in the order of 20%.

Chart 6

Distribution of price impact ratios for all bonds under the severe behavioural scenario

(left-hand panel: distribution of price impact ratios under transition scenario 1 with lower price impact bounds; right-hand panel: distribution of price impact ratios under transition scenario 2 with upper price impact bounds)



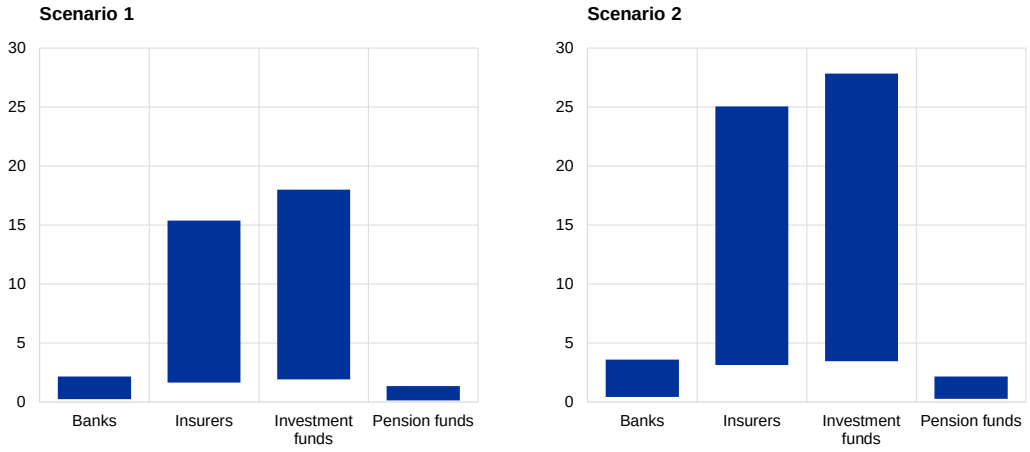
Source: ESRB Secretariat calculations.
Note: Values expressed as ratios, i.e. multiply by 100 to obtain percentages.

In the severe behavioural scenario, it is estimated that losses could lie between €4 billion and €37 billion in scenario 1 and between €7 billion and €59 billion in scenario 2. The estimated ranges of losses by institutional sector are shown in the two panels of Chart 7.

Chart 7

Estimated range of fire sale losses for the severe behavioural assumption and transition scenarios 1 and 2

(EUR billions)



Source: ESRB Secretariat calculations.
Note: The bars show the ranges of potential fire sale losses by sector.

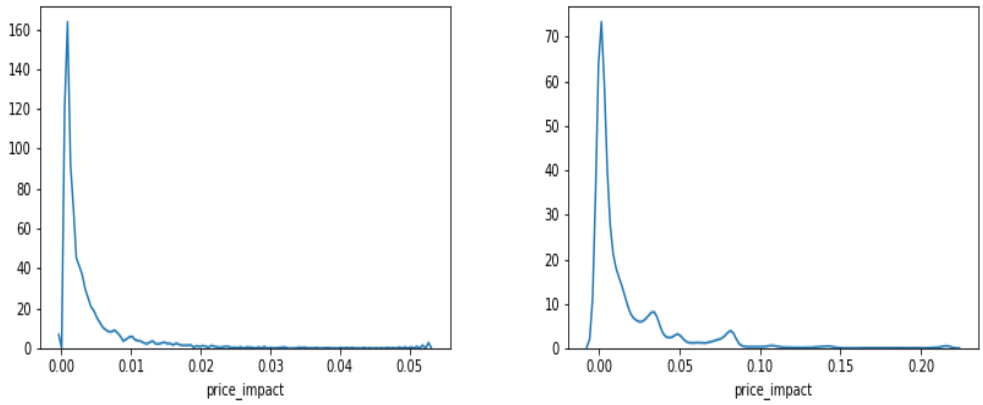
4.1.4.3 Extreme behvaioural scenario

Finally, we consider the results under the extreme behavioural scenario. Chart 8 shows the distributions of price impacts, where in scenario 1 (left-hand panel) most impacts lie below 2%, while in scenario 2 price drops can reach up to 7.5% for a substantial amount of assets. A small portion suffers 20% drops in this case.

Chart 8

Distribution of price impact ratios for all bonds under the extreme behavioural scenario

(left-hand panel: distribution of price impact ratios under transition scenario 1 with lower price impact bounds; right-hand panel: distribution of price impact ratios under transition scenario 2 with upper price impact bounds)



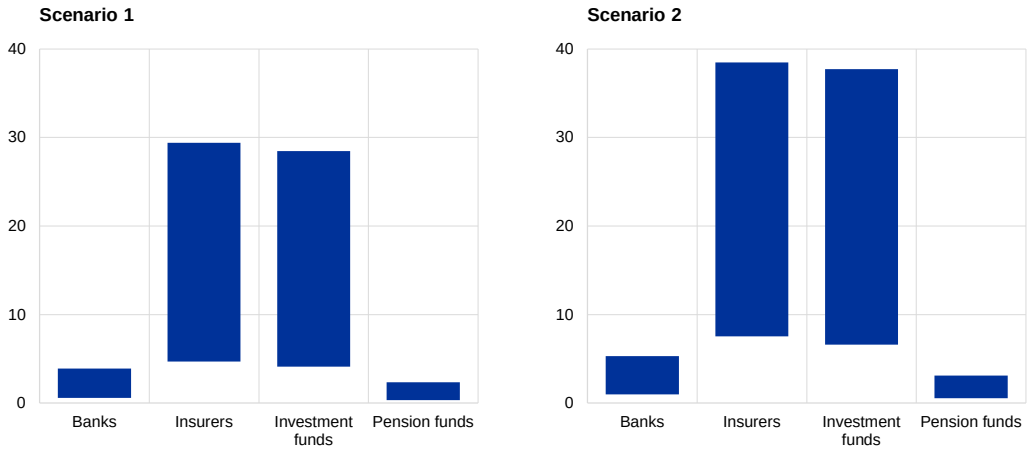
Source: ESRB Secretariat calculations.
Note: Values expressed as ratios, i.e. multiply by 100 to obtain percentages.

In the extreme behavioural scenario, total fire sale losses are estimated to lie between €10 billion and €64 billion for scenario 1 and between €16 billion and €85 billion for scenario 2 (see Chart 9).

Chart 9

Estimated range of fire sale losses for the extreme behavioural assumption and transition scenarios 1 and 2

(EUR billions)



Source: ESRB Secretariat calculations.
Note: The bars show the ranges of potential fire sale losses by sector.

4.2 Overlap analysis

In this final subsection, we analyse the cross-sectoral portfolio overlaps in the European corporate bond market. This can shed light on concentrated holdings and key nodes in the financial network that could generate spillover losses, if agents were to engage in forced selling.

Figure 2 shows the "portfolio overlaps" in corporate bonds between the sectors of different European countries.[24] The banking sector is coloured in blue, the investment fund sector in light green, the insurance sector in dark green and the pension fund sector in orange. Node sizes are proportional to the size of the sector's holdings, while edge widths are proportional to the overlap between sectors. The network has been "pruned", i.e. only the largest overlaps are displayed. The ten largest links are highlighted in red.

If a sector engages in a forced sale, under the assumption that the forced sale is roughly proportional to the sector's holdings[25] (i.e. without too much individual bond picking), the portfolio overlap network indicates which other sectors are likely to suffer mark-to-market losses from this

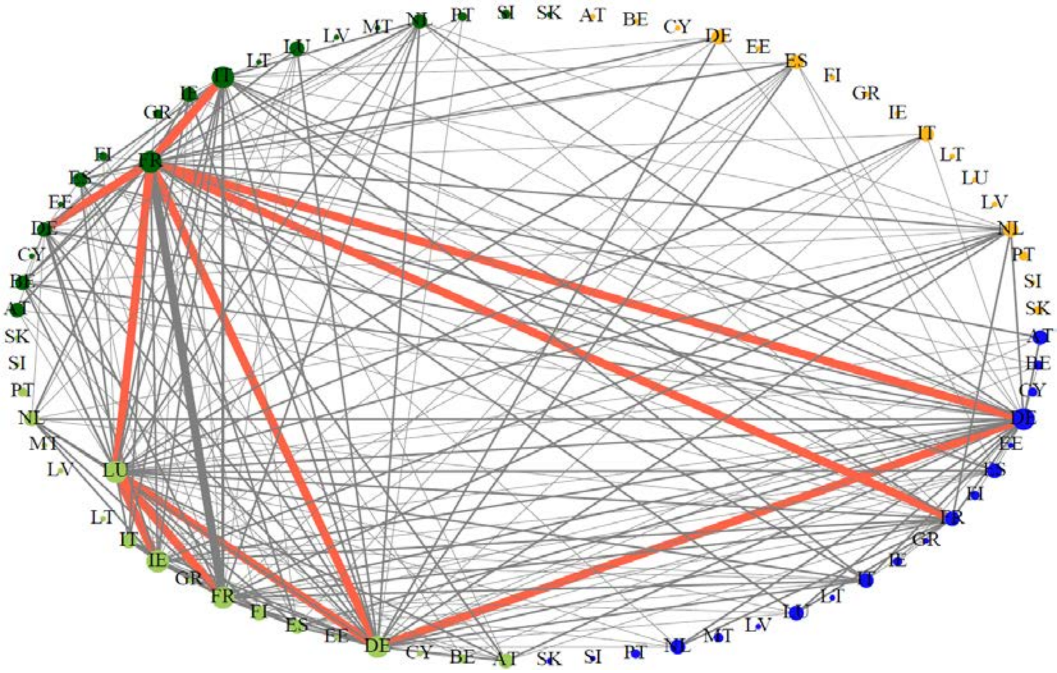
[24] We quantify the amount of overlap between two portfolios *i* and *j* by the "nominal overlap": $\omega_{i,j} = \sum_{k=1}^{N} \pi_{i,k}\, \pi_{j,k}$, where $\pi_{i,k}$ is portfolio *i*'s holding of asset *k* (in euro), and similarly $\pi_{j,k}$ is portfolio *j*'s holding of asset *k*. The overlap is computed over all *N* (approximatively 25,000 bonds) in the SHS data. For simplicity, we focused on the nominal overlap. We could consider more complex variants where less liquid holdings contribute more to the overlap and more liquid holdings contribute less to the overlap, see Cont and Schaanning (2019).

[25] It should be noted that this approach offers only a partial view of how financial institutions may manage their liquidity, which should be balanced by the possibility that specific sectors may act in a different way owing to their specificities. For instance, insurers manage their assets according to the nature of their liabilities; and such asset and liability management may not imply forced sales in the same way as considered above.

sale because they hold a portfolio that is similar to the portfolio that is undergoing the potentially distressed sale.

Figure 2

The European cross-sectoral portfolio overlap network



Sources: SHS data and ESRB Secretariat calculations.

While providing a static view of the current portfolio overlaps, these portfolio similarities do not necessarily reveal fragilities, especially if these similar portfolios remain liquid or if other sales of more liquid assets can be realised in order to compensate for the forced sales of corporate assets (for instance public or government bonds).

The overlap network also reveals that the investment fund and insurance sectors are relatively more connected.[26] At the same time there are fewer connections of lower strength to, and among, the pension fund sector and the banking sector. The relatively small overlap between the pension fund and banking sectors with the rest of the financial system also helps explain why, as discussed in the previous sections, potential fire sale losses do not affect these sectors as strongly.

[26] See also **EIOPA advice on short termism**, December 2019.

5 Methodological annex

5.1 Short-term transition matrices and historical maximum downgrades

Table A.1

Historical maximum downgrades in various regions

(historical maxima)

EU-27 and EEA

	AAA	AA	A	BBB	BB	B	CCC	CC	C
AAA		66.7	12.5	7.1	0.0	0.0	0.0	0.0	0.0
AA			41.7	2.8	1.2	0.0	0.0	0.6	0.0
A				16.8	1.6	2.8	0.7	0.5	0.2
BBB					7.4	3.4	1.8	2.2	0.2
BB						27.6	3.3	2.9	1.0
B							21.7	15.5	3.6
CCC								31.6	10.5
CC									33.3
C									

United Kingdom

	AAA	AA	A	BBB	BB	B	CCC	CC	C
AAA		18.8	4.6	0.0	0.0	0.0	0.0	0.0	0.0
AA			20.8	2.9	0.0	0.0	0.0	0.0	0.0
A				12.0	1.9	0.5	1.0	0.5	0.0
BBB					9.2	3.6	2.2	1.0	0.0
BB						14.7	2.4	1.3	0.6
B							19.7	4.0	0.6
CCC								10.1	6.1
CC									33.3
C									

United States and the rest of the world									
	AAA	AA	A	BBB	BB	B	CCC	CC	C
AAA		66.7	12.5	7.1	0.0	0.0	0.0	0.0	0.0
AA			41.7	2.8	1.2	0.0	0.0	0.6	0.0
A				16.8	1.6	2.8	0.7	0.5	0.2
BBB					7.4	3.4	1.8	2.2	0.2
BB						27.6	3.3	2.9	1.0
B							21.7	15.5	3.6
CCC								31.6	10.5
CC									33.3
C									

Source: ESRB Secretariat calculations.

Table A.2

Scenario 1: Short-term ratings

Rating transitions	EU-27 and EEA downgrades (%)	United Kingdom downgrades (%)	United States and rest of the world downgrades (%)
P1 → P2	5	5	5
P2 → P3	20	20	20
P3 → Default	80	80	80

Table A.3

Scenario 2: Short-term ratings

Rating transitions	EU-27 and EEA downgrades (%)	United Kingdom downgrades (%)	United States and rest of the world downgrades (%)
P1 → P2	10	10	10
P2 → P3	20	20	20
P3 → Default	100	100	100

5.2 Estimation of transition matrices

Empirical Model

A base case and a severe case model are designed separately for the EU, United Kingdom and the United States. Both use country-specific rating migration matrices for training the model. The base case scenario considers the historical ratings of non-financial corporates, while in the severe case

ratings of financial entities are also included in recognition of their extensive downgrades during the great financial crisis.

Downgrades of each rating segment are modelled as a function of lagged GDP and the PMI to account for their ability to forecast rating changes.[27] To address downgrades, both exogenous variables are censored to values related to recessions.[28] For GDP, only negative observations are included and their variable is set to zero otherwise. For the PMI, only values below 50 are considered in the regression:[29]

$$Transition_t^{A \to B} = \alpha + \beta_1 GDP_{<0,t-1} + \beta_2 PMI_{<50,t-1} + \varepsilon_t$$

with $Transition_t^{A \to B}$ representing the transition probability of bonds from rating A to rating B at year t, α being the intercept term and β_1 (β_2) as the regression coefficient of the variable GDP (PMI) as described above.

For the sake of brevity, Tables A.4 and A.5 report only regression results for EU non-financial corporates (base case scenario) and all corporates (severe case scenario) for transitions of BBB-rated bonds to lower rating categories. Here and in all other cases, regression explanatory power (R-squared) is highest for one notch downgrades. In the case of EU bond downgrades from BBB to BB, the explanatory power amounts to 27.6% for non-financial corporate bonds and 57.5% for all bonds. The R-squares of all one notch downgrades range from 3.9% (from CC to C) to 80% (from A to BBB) and are on average 46.3%. For all non-financial corporate bond downgrades, the average R-square is slightly lower at 28.6%.

Table A.4

Regression coefficients for rating transition matrices of EU non-financial corporate bonds

	From BBB to				
Variable	**BB**	**B**	**CCC**	**CC**	**C**
GDP	-0.714 (-0.99)	0.0455 (0.12)	0.0427 (0.67)	0.0645 (0.34)	0 (.)
PMI	-0.279 (-2.21)	-0.0355 (-0.53)	-0.0035 (-0.31)	-0.034 (-1.04)	0 (.)
const	2.476 (4.34)	0.443 (1.47)	0.0795 (1.58)	0.0836 (0.56)	0 (.)
Rsqr	0.276	0.0199	0.0366	0.0759	.

Source: ESRB Secretariat calculations.
Notes: Regression coefficients are reported in the upper rows and t-statistics in the brackets. The variable const refers to the intercept term and Rsqr reports the R-squares. Downgrades from rating category BBB to C are zero in most years, which impede the regression estimates.

[27] Results are robust to the inclusion of other variables. Other measures of economic activity as well as market stress, proxied by the Composite Indicator of Systemic Stress, did not reveal a significant impact on ratings.

[28] Technically, the variables are interacted with dummy variables which take a value of one if the respective variable indicates a recession.

[29] Kilinc and Yücel (2016), PMI Thresholds for GDP Growth.

Table A.5

Regression coefficients for rating transition matrices of all EU corporate bonds

	From BBB to				
Variable	**BB**	**B**	**CCC**	**CC**	**C**
GDP	-2.244 (-3.64)	-0.466 (-1.36)	0.0335 (0.65)	0.055 (0.34)	0 (.)
PMI	-0.304 (-2.81)	-0.0259 (-0.43)	-0.00359 (-0.40)	-0.029 (-1.04)	0 (.)
const	2.325 (4.76)	0.454 (1.67)	0.0613 (1.51)	0.0712 (0.56)	0 (.)
Rsqr	0.5750	0.1170	0.0390	0.0759	.

Source: ESRB Secretariat calculations.
Note: For further explanations, see Table A.4.

Results: Expected downgrades

Expected downgrades are computed under the assumptions of GDP declines as projected by the International Monetary Fund (IMF) and recent PMI developments. For each rating category, only statistically significant effects are taken into account by multiplying the estimated coefficient with the assumed economic variable. 0-values refer to non-significant effects. In cases of implausible values, for example if severe case estimates are lower than in the base case, expert judgment was applied.

The model-based expected amount of fallen angels in Europe amounts to €111 billion in the base case and €190 billion in the severe case, both of which are close to S&P's expectations (€165 billion). The downgrade of the full AA-segment in the severe case seems an extreme scenario but reflects the segment's strong correlation with GDP.

Data

Rating migrations matrices are collected from ESMA. The matrices provide the historical migrations of bonds into another rating class based on upgrades or downgrades over the period from 2000. Rating migrations are provided for each rating class separately and thus allow tracing of the likelihood of single or multiple notch downgrades. Matrices are provided individually for the United States and EU. Owing to unavailability of data, the UK matrix is approximated by the EU dataset.

Economic activity is captured by EU GDP growth, which is published quarterly, and its projections are updated regularly by public and private institutions. For example, after the IMF announced its forecast that EU GDP would fall by 7.5%, year on year, S&P updated its GDP forecast with only a short delay.[30]

[30] IMF (2020), Global Economic Outlook and S&P (2020) Economic Research: COVID-19 Deals A Larger, Longer Hit To Global GDP.

The PMI leads not only economic activity but also rating downgrades.[31] Historically, net downgrades have been reasonably well correlated, with a lag, with euro area PMIs, worsening just before downgrades start to rise. Downgrades peak 22 months after significant falls in the PMI index.[32]

5.3 Estimation of the yield shocks on prices

The yield shocks in Table 6 correspond to the average market evolution of the corresponding rating categories between February and April 2020.

The yield shocks in Table 7 have been calibrated using the ECB's financial shock simulator tool. A detailed description of the model is available **here**.

The yield shocks in Table 8 have been calibrated by considering average historical spreads between different rating categories. In the light of the fact that spreads for financial corporate bonds have been higher relative to non-financial corporate bonds, as well as the nature of the Covid-19 shock to the real economy, the spread shocks to non-financial corporate bonds have been adjusted manually (by adding 50% of the financial corporate bond historical spread).

5.4 Estimation of price impacts from forced sales

It is notoriously difficult to estimate the price impact as a function of the sold volume for hypothetical sales, in particular under stressed market conditions. The approach taken in the analysis has been used in studies such as ESMA (2019) and was initially developed in Cont and Schaanning (2017).

When a forced sale of size qi takes place in bond i, this will result in a negative return

$$R^{i}{}_{t+1} = B_i \left(1 - \exp\left(-\frac{q_i}{D_i}\right)\right)$$

where

- $B_i \in [0,1]$ denotes the lowest value (as a percentage of the initial value) to which the price can drop. The rationale is that at the level Bi, the price has deviated to such an extent from its fundamental value that deep-pocketed investors will step in as buyers, so the price will stabilise here and not fall further.
- Di denotes the "market depth" of the bond, which models the price impact (i.e., unit decrease of the price per unit of forced sale) for smaller volumes. Di can be calibrated reasonably well from market data and observed trades. The larger Di, the more liquid the asset and the smaller the impact.

[31] See Citi (2020), European Credit Focus: Downgrades happening faster than ever – and more to come.

[32] Barclays (2020), Reviewing downgrade and fallen angel risk. This crisis is not, however, a standard cyclical downturn, and the lag is likely to be much shorter.

As it is unlikely that the large sales considered in our analysis would take place during the course of a single day, the time horizon is expanded from one day to one month (20 trading days), so the final formula employed to estimate price impacts is:

$$\mathrm{R}^{i}{}_{\tau} = \max\left\{ Floor_i\ , B_i \tau^{\xi} \left(1 - e^{-\frac{q_i}{D_i B_i \tau^{\xi}}}\right)\right\},$$

Where Floori is an absolute lower price floor, calibrated to the 95th percentile over the entire history of bond prices of similar bonds, and $\xi = 0.2397$ is a scaling factor, which has been calibrated using a power-law.

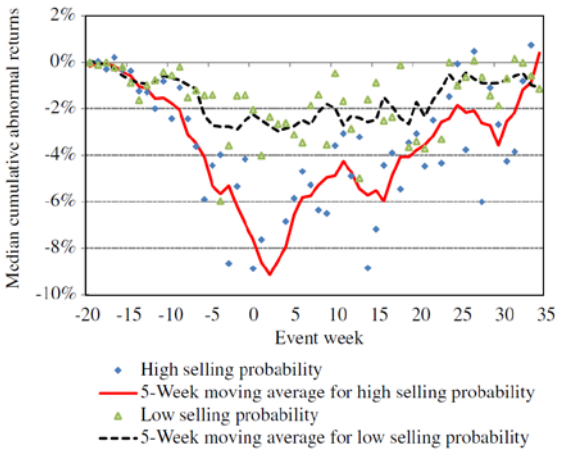
The parameters Bi , Di, ξ and Floori have been estimated by a project team in the ECB's DG Macroprudential Policy and Financial Stability – Stress Test Modeling division based on historical data – see M. Kaijser et al. (2020) for details – and kindly shared with the ESRB. For each bond market, depth is calibrated on a historical set of daily trading volume and day-to-day bond return observations. A sample of ten thousand of the largest securities are selected which covers an aggregated market value of €5.62 trillion or 30% of the observed valuation from the SHS-S data. Bonds with market depth information include all of the non-financial corporate bond holdings of euro area financial intermediaries in the SHS data.

It is assumed that the assets held by each sector as reported in the SHS data are representative for the securities to be liquidated. Equal-weighted (pro-rata) security liquidations of each sector are aggregated across sectors at the individual security level. This total liquidation amount q is inserted into the price impact equation above to derive the asset return. The resulting asset returns generate portfolio losses by multiplying the corresponding bond returns with the holdings of the portfolios. These portfolio-level losses are finally summed up to the sector-level.

Chart A.1 shows the median cumulative abnormal return for bonds that have been downgraded, grouped by "high" and "low" selling probability.

Chart A.1

Median cumulative abnormal return for downgraded bonds in an academic study on US corporate bonds



Source: Figure 2 from A. Ellul et al. "Regulatory pressure and fire sales in the corporate bond market" (2011), Journal of Financial Economics.

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