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A MODEL OF SYSTEM-WIDE STRESS SIMULATION: MARKET-BASED FINANCE AND THE COVID-19 EVENT

by Giovanni di Iasio*, Spyridon Alogoskoufis§, Simon Kordel§, Dominika Kryczka§, Giulio Nicoletti§ and Nicholas Vause†

Abstract

We build a model to simulate how the euro-area market-based financial system may function under stressed conditions, such as the Covid-19 turmoil. The core of the model is a set of representative agents reflecting key economic sectors, which interact in asset, funding and derivatives markets and face solvency and liquidity constraints on their behaviour. We illustrate the model's behaviour with a two-layer approach. In Layer 1, we consider the deterioration in the outlook for the nonfinancial corporate sector. Agents reallocate their portfolios and risky asset prices fall. Layer 2 adds a rating downgrade shock to Layer 1, where a fraction of investment grade nonfinancial corporate bonds is downgraded to high yield. The additional shock creates further rebalancing pressure and price movements. For both layers we present asset flows (i.e. buying and selling marketable securities) across agents and balance sheet losses. The model provides quantitative support to the equilibrium effects of the macroprudential regulation of investment funds, which we illustrate by varying their liquidity buffers.

JEL Classification: G17, G21, G22, G23.
Keywords: Systemic risk, market-based finance, stress testing, Covid-19.
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Contents

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Non technical summary[1]

This paper builds a system-wide stress simulation model to estimate the effects of some COVID19-related shocks to the euro area nonfinancial corporate sector. As the financial system becomes progressively more reliant on markets and nonbanks, this type of analyses aims at capturing amplification effects emerging from market interactions among bank and nonbank intermediaries in times of stress.

The core of the model is a set of six representative agents representing aggregate euro area sectors: banks, insurance companies, pension funds, investment funds, hedge funds and a central bank. They interact in asset, funding, and derivatives markets and face solvency and liquidity constraints on their behaviour. We consider three representative marketable euro area asset classes: sovereign bonds, corporate bonds and equities. Agents react to shocks and seek their optimal portfolio allocation, in some cases amplifying asset price movements. Although stylised and based on representative agents, the framework is rich enough to be simulated on real data for the euro area financial system. The model is calibrated to end-2019 data and exploits several datasets.

The COVID-19 crisis put the market-based financial system under severe stress. We capture this crisis by considering a two-layer approach. First, a broad-based macro shock hit the nonfinancial corporate sector (Layer 1 simulation). On top of that, much attention was devoted to credit rating agencies and their decisions to update rating of companies according to deteriorating macro fundamentals. Because of possible cliff-effects, main concerns were related to 'fallen angel' companies, i.e. those downgraded from investment grade (IG) to high yield (HY). Indeed, many investors in the corporate bond market are restricted by mandates to invest only in IG assets. In Q2 2020, it was estimated that potential downgrades of euro area NFC BBB-rated bonds to HY could have reached euro 110bn, euro 68bn of which were held by model's private agents (i.e. when excluding the Eurosystem and non-euro area investors). This is reflected in our Layer 2 simulations, where holders of fallen angels are also hit by the rating downgrade shock.

Marked-to-market losses and forced portfolio rebalancing trigger further endogenous reactions in the model. We find that yields of euro area IG NFC bonds increase by 265bps

[1]This paper should not be reported as representing the views of Banca d'Italia (BdI), the Bank of England (BoE) or the European Central Bank (ECB). The views expressed are those of the authors and do not necessarily reflect those of BdI, BoE or ECB. We thank David Aikman, Lorenzo Cappiello, Sujit Kapadia, Arianna Miglietta and Benjamin King for useful comments and suggestions.

in Layer 1 and by more than 430bps in Layer 2. The model converges towards new equilibrium allocations and we calculate equilibrium asset flows, i.e. buying and selling by different agents in tradable assets. We find that endogenous fund investor redemptions are very important driver of net sales of corporate bonds. Insurance companies and (to a lesser extent and in Layer 2 only) pension funds take the other side of the market and engage in net purchases, in order to meet their targeted optimal portfolio weights.

Balance sheet losses for euro area financial sectors resulting from shocks and agents' reactions that drive the system towards the new equilibrium are substantial. System-wide losses due to the deterioration of the corporate outlook shock amount to euro 690bn (Layer 1). These are driven by a large drop in the valuation of equities and nonfinancial corporate bonds. The estimated rating downgrade shock results in additional losses of euro 240bn (Layer 2). For this case also, losses are concentrated in the investment fund sector, while those hitting banks, insurance companies and pension funds are quite limited.

The model has implications in terms of financial stability surveillance framework as it captures amplification effects stemming from agents' interactions and the role of occasionally binding constraints that affect agents' behaviour. In an extension, we explore the role of higher liquidity buffers of investment funds and show that these can reduce amplification effects and price dislocation. This is an example on how the model can be used to test different possible regulatory tools, especially those under discussion for the asset management industry.

1 Introduction

Following the 2008-09 financial crisis, the global financial system has changed profoundly. The relevance of non-bank intermediaries and sectors has grown quickly, especially in Europe where, traditionally, banks had the lion's share of firms' financing. Nonbanks are an integral part of the financial ecosystem: entities such as insurance companies, pension funds and investment funds are key investors in capital markets, while money market funds - important lenders in commercial paper and repo markets - issue shares that are often perceived by retail and institutional clients as substitutes of bank deposits. The financial ecosystem and the real economy are now more reliant on market-based intermediaries. The question of how the changing structure of the financial system could affect financial stability is more relevant than ever before. Policymakers are concerned that the new environment may come with new vulnerabilities. More specifically, investment funds and other institutional investors such as insurance companies and pension funds may exhibit pro-cyclical behaviour: buying assets as prices rise and selling them as they fall. Such behaviour would amplify financial cycles and structurally increase demand for market liquidity.

The aim of this paper is twofold. The paper provides a new framework to track and study relevant interactions in the market-based financial system of the euro area. The core of our model is a set of representative agents which correspond to key sectors of the financial system. We model the behaviour of five financial sectors that interact in asset, funding and derivatives markets. Sectors are banks, insurance companies, pension funds, investment and hedge funds. We also introduce a central bank as the ultimate funding provider in the repo market. Traded assets are equities, government and corporate bonds. Agents face a range of solvency and liquidity constraints on their behaviour. Agents have specific net demand functions for assets, derived from fundamentals and calibrated on real data, and react to exogenous shocks. Given the shocks, the demand functions and the constraints, the model computes the prices of financial assets that clear the markets. The focus is financial amplification in the short-run (i.e. one month time) driven by agents' behaviour and constraints. More specifically, when shocks are large, or agents have poor capital or liquidity ratios, the model can generate adverse feedback loops in which lower asset prices cause solvency and/or liquidity constraints to bind. Agents such as insurance companies, pension and investment funds endogenously react and reallocate portfolios according to their investment horizon and assumed behaviour. This leads intermediaries such as banks to pull funding, which creates greater forced deleveraging, pushing asset prices lower still. In this respect, the model is similar to Aikman et al. (2019), although accounting for a different set of agents, amplification mechanisms and a different (euro area) calibration. Section 2 explains the structure of the model.

In addition, the paper is used to study the short-term effects of the COVID-19 crisis on the market-based financial system. Although stylised and based on representative agents, the framework is rich enough to be simulated on real data for the euro area financial system. We capture the COVID-19 crisis by considering a two-layer approach. In Layer 1 we consider the broad-based macro shock hitting the nonfinancial corporate sector (see below for more details). The deterioration in corporate fundamentals translates into higher probability of default and lower expected dividends, thereby reducing the value of corporate bonds and equities. The change in fundamentals ultimately induces agents to rebalance their portfolios. Trading takes place and agents arrive at their new desired portfolio holdings, at the new market prices. In our Layer 2 we consider that new fundamentals are progressively reflected in credit rating agencies' downgrade decisions. We focus on 'fallen angels' companies, i.e. those issuers that lose the investment grade (IG) status and are downgraded to high yield (HY). Many investors in the corporate bond market are indeed restricted by mandates to invest only in IG assets and large-scale downgrades can generate cliff edge effects. We assume that the insurer and the pension fund must sell fallen angels. According to the ECB (2020), in an adverse scenario potential downgrades of euro area NFC BBB-rated bonds to HY would increase to €110bn.[2] We calculate that €68bn of them are held by the model's private agents (i.e. when excluding the Eurosystem and non-euro area investors).[3] In our Layer 2 simulations, holders of fallen angels are also hit by the rating downgrade shock and rebalancing is more pronounced.

In both layers, marked-to-market losses and forced portfolio rebalancing trigger endogenous reactions in the model. We find that yields of euro area IG NFC bonds increase by 265bps in Layer 1 and by more than 430bps in Layer 2. The model converges towards new equilibrium allocations and we calculate equilibrium asset flows i.e. buying and selling by different agents in tradable assets. We find that endogenous fund investor redemptions are an important driver of net sales of corporate bonds. Insurance companies and, to a lesser extent and in Layer 2 only, pension funds take the other side of the market and engage in net

[2]These estimates were revised downward in subsequent months, as various support measures were introduced by public authorities and credit rating agencies decided to take a gradual approach in their decisions on rating revisions.

[3]BBB is the lowest bucket before being downgraded to HY.

purchases, in order to meet their targeted optimal portfolio weights. Balance sheet losses for euro area financial sectors resulting from shocks and agents' reactions that drive the system towards the new equilibrium are substantial. System-wide losses due to the deterioration of the corporate outlook shock amount to €690bn (Layer 1). These are driven by a large drop in the valuation of equities and bonds of nonfinancial corporates. The estimated rating downgrade shock results in additional losses of €240bn (Layer 2). Our results focus on short-term financial amplification between sectors, with the relevant time horizon for agents' reaction and price adjustments being one month. Therefore, we do not consider additional intra-sector contagion mechanisms and macroeconomic amplification effects that would arise in the medium and long term from higher credit spreads and stock market volatility.

Literature. This work builds upon a number of strands of the existing literature. In line with Shleifer and Vishny (1992), Greenwood et al. (2015), Brunnermeier and Pedersen (2008), the first one examines the role of different constraints and frictions in generating fire sales of assets. Similar to these contributions, balance sheet, regulatory and behavioural constraints contribute to amplifying changes in equilibrium asset prices when some agents are forced to liquidate. Di Iasio and Kryczka (2021) provide a theoretical model to frame market interactions between bankers, insurance companies and pension funds, and investment funds. A second strand of literature focuses on how financial institutions respond to changes in asset prices, and how such responses vary with their business models and balance sheet structures. Braouezec and Wagalath (2016) show that, as a result of capital and liquidity constraints, banks may choose to deleverage in response to certain shocks. Douglas et al. (2017), Douglas and Roberts-Sklar (2018) and Fache Rousová and Giuzio (2019) study the response of insurance companies and pension funds to different shocks, highlighting the potential for pro-cyclical behaviour. Chevalier and Ellison (1997) and Goldstein et al. (2017) and other papers outline the channels through which investors in open-ended investment funds might act pro-cyclically, causing asset management firms to initiate sales of assets as their prices fall. A third strand of literature seeks to combine these insights to simulate stress across the financial system. Baranova et al. (2017) build a representative agent model in which broker-dealers and hedge funds supply liquidity in corporate bond markets. They assess the degree to which redemptions and subsequent sales of assets by open-ended investment funds could have a destabilising effect on market prices. Our approach is similar to Aikman et al. (2019). With respect to that contribution, we introduce several novelties, all described in Section 2. Sydow et al. (2021) have model with banks and investment funds where contagion operates through liquidity and solvency risk. This approach, which does not include key players in the market-based financial system - such as insurance companies and pension funds, is more in line with bank stress testing. It assumes price impact functions to calculate the effects of asset sales. In our model, instead, we have equilibrium prices emerging from the market interaction between buyers and sellers of securities, both modeled.

2 The model

In this section we describe the markets and the agents included in the model.

2.1 Assets

The model shows the effect of economic shocks on prices and quantities in asset, funding and derivative markets. A representative government bond, an investment-grade (IG) non-financial corporate bond and an equity instrument are traded in the three asset markets. These should be thought of as the average IG corporate bond and equity issued by euro area non-financial firms and the average government bond issued by authorities in the bloc. Before shocks, these markets are in equilibrium, with prices normalised to one. Funding is available in a single repo market, where agents can borrow cash against government bond collateral. Shocks then affect the demand for securities and funding from different agents, and we find new equilibrium prices at which a) aggregate purchases and sales balance in each asset market; and b) funding market quantities clear.[4] Finally, there is a derivative market, where agents can hedge or increase their interest rate risk by trading interest rate swaps. Agents can trade any volume of swaps without affecting their price, as we assume that rest-of-world investors will take on positions that balance those of the seven explicitly modelled agents at prevailing prices. However, agents must post collateral to participate in the interest rate swaps market, providing government bonds as initial margin, and cash as variation margin, against their swap positions.[5] Euro area investors also hold high-yield (HY) non-financial corporate bonds. We do not explicitly model buying and selling of HY corporate bonds because the segment is quite small in the euro area. Moreover, many participants in the segment are non-euro area investors. Therefore we model the HY corporate bond yield by applying a (constant) spread over IG yields. The spread is estimated using iBOXX granular data, i.e. ISIN by ISIN information, allowing us to control for the duration and other bond

[4] That is, at the new prices funding quantities equal the minimum of desired repo (cash borrowing) and reverse repo (cash lending) transactions.

[5] For a detailed description of the derivative market please refer to Aikman et al. (2019).

characteristics.[6]

2.2 Agents

This section describes the behaviour and the relevant constraints of each agent. Agents are grouped into four categories. Long-term investors are the pension fund, life insurer and four types of investment funds (a mixed-asset fund and three single-asset funds, one per each marketable asset class). There is a hedge fund that behaves as an arbitrageur, while the bank intermediates the markets for repos and fixed-income instruments. Finally there is a Central Bank that provides funding to the bank against eligible collateral.

2.2.1 Long-term investors

Portfolio optimisation problem. The pension fund, the life insurer and investment funds choose their optimal asset allocations by solving a Markowitz problem and choose a vector ω of portfolio allocation weights to maximise:

$$E(r_p) - \frac{1}{2}\lambda^i Var^i(r_p) \tag{1}$$

where $E(r_p)$ is the perceived expected return of the portfolio and $r_p = \sum_j \omega_j r_j$, $Var^i(r_p)$ is the perceived variance of the portfolio return, λ^i is the risk aversion coefficient, i denotes the investor type and j the asset class. We assume investors have the same information about expected returns on each asset class, but their perceptions of the variance of some asset classes differ, as does their risk aversion parameter. These parameters are calibrated to match agents' initial asset allocation weights, while risk aversion and perceived asset volatility parameters remain unchanged during simulations. Long-term investors differ with respect to the speed they adjust their portfolio to shocks to fundamentals. Similar to Aikman et al. (2019) the pension fund and the insurer adjust in full after six and three months respectively. The mixed investment fund adjusts fully after one month and a half. Portfolio rebalancing interacts with market prices in our general equilibrium setting. Long-term investors that target their desired portfolio allocation may end up buying an asset in a situation where the price of this asset is falling. After addressing any liquidity need stemming from their exposure to IRS, long-term investors solve their portfolio optimisation problem and update their desired portfolio allocation given new fundamentals. Then they assess whether the

[6] Given historical averages, the procedure corresponds to having a difference between IG and HY yields of about 250bps

allocation satisfies all constraints and internal targets. If not, they react and sell tradable assets to deleverage.

The insurance company. The insurer is active in the IRS market but does not participate in the repo market. It holds cash (deposits), government and corporate bonds, equities and other assets. These are matched by liabilities to households and other institutions. The insurer holds equity capital that also reflects Solvency II requirements (see below). The present value of the insurer's obligations to households L^I_{HH} varies with the interest rate on the government bond:

$$L^I_{HH} = \frac{V^I_{HH,t_0} + \epsilon^I_{HH}}{(1 + r_{GB})^{(T^I)}}$$

where $V^I_{HH,t_0} = L^I_{HH,t_0}(1 + r_{GB,t_0})^{T^I}$ is the future value of insurance obligations to households at the initial time t_0; T^I is the average duration of insurance obligations and ϵ^I_{HH} is an exogenous shock to the value of insurer's obligations to households. After meeting any liquidity outflows from IRS margin needs, the insurer chooses its asset holdings solving the portfolio optimisation problem. This optimal portfolio is then checked against solvency constraints that are intended to capture the Solvency II regulation. Specifically the solvency ratio, the ratio of equity capital to risk-weighted assets, must remain above a minimum level $\bar{k}^I$:

$$k^I \equiv \frac{K^I}{\kappa^I_{nm} + (p_{CB}A^I_{CB} + p_E A^I_E + A^I_O)\kappa^I_m} \geq \bar{k}^I \tag{2}$$

where A_{CB}, A_E and A_O denote holdings of corporate bonds, equities and other assets, respectively. K^I is the insurer's capital level ($K^I = A^I - L^I_{HH} - L^I_O$), κ^I_{nm} is the capital that the insurer is required to maintain against non-market risks (e.g. longevity risk), κ^I_m is the average capital charge on risky assets, and p_{CB} and p_E denote the prices of commercial bonds and equities respectively. Price dynamics change the proximity of the solvency ratio to the regulatory minimum. When the solvency constraint binds, the insurer sells assets with positive risk weights and buys government bonds which carry a zero risk weight. More specifically, the insurer sells corporate bonds, equities and other assets in proportion to its initial holdings.

The pension fund. The pension fund has a similar business model to the life insurer. It receives cash from households that it uses to purchase financial assets, the returns on which allow it to meet future obligations to the household sector.

To stabilise the sensitivity of its solvency position to changes in interest rates, the pension fund holds a levered portfolio of government bonds. This levered exposure offsets the effect of changes in interest rates on its liabilities: when interest rates fall, the gains the pension fund makes on its levered portfolio partially offset the increase in the present value of its liabilities. In line with Aikman et al. (2019), the pension fund chooses its asset holdings $\{A^{PF}_{D,t}, A^{PF}_{GB,t}, A^{PF}_{CB,t}, A^{PF}_{E,t}, A^{PF}_{O,t}\}$ and repo borrowing $\{L^{PF}_{SR,t}\}$ as follows: after meeting any IRS initial and variation margins, the pension fund rebalances its asset portfolio to achieve its desired portfolio allocation. Finally, it adjusts its levered portfolio. This implies that the pension fund must post sufficient collateral to borrow in the repo market. Similar to its exposure to IRS, borrowing in the repo market creates liquidity risk. The pension fund's overall need for unencumbered government bonds resulting from its long-term repo borrowing and IRS initial margin IM^{PF} is given by:

$$p_{GB,t}\tilde{A}^{PF}_{GB,t} = \frac{1}{(1-h)}(IM^{PF} + L^{PF}_{LR}) \tag{3}$$

where $\tilde{A}^{PF}_{GB,t} \leq A^{PF}_{GB,t}$. IM^{PF} is set to 1% of pension fund's IRS gross notional exposure at the start of the simulation. In order to meet this collateral call, the pension fund first uses existing unencumbered government bonds. If the latter are not sufficient, it uses its cash holdings to purchase additional government bonds. If available cash is not sufficient, the pension fund sells risky assets in proportion to their initial portfolio weights, to purchase additional government bonds. If this step generates insufficient bonds to meet the call, the pension fund defaults. The pension fund relies on the bank to obtain repo funding. If the bank refuses to roll over short-term repos (see below) the pension fund uses available cash to cover any repo outflows. Similar to above, if this is insufficient, assets are liquidated in a proportional manner.

Investment funds. The model has a mixed-asset fund and three single-asset funds. The former invests in a portfolio of equities, government and corporate bonds with weights chosen to maximise risk-adjusted returns. The three single-asset funds invest individually in the three tradable assets. Funds do not participate in the repo market, consistent with available data, and hold other assets (e.g. non-euro area assets) and derivatives. All funds have liabilities that consist of investment shares owned by the household sector. These shares can be redeemed on a short notice. More specifically funds can be subject to redemption requests from the household sector Ξ^{IF}_{HH} that vary systematically with funds' performance, consistent with empirical evidence (e.g. Chevalier and Ellison (1997); Goldstein et al. (2017)). That is,

$$\Xi^{IF,j}_{HH,t} = \rho^{IF,j}(p^{IF,j}_t A^{IF,j}_t - p^{IF,j}_{t-1} A^{IF,j}_{t-1}) - \epsilon^{IF,j}_t \tag{4}$$

where j indexes the type of fund (mixed, single-asset), Ξ^{IF}_{HH} is the redemption from the fund in period t, $p^{IF,j}_t A^{IF,j}_t$ is the market value of fund type j at time t, $\rho^{IF,j}$ captures the flow-performance sensitivity of fund type j, and $\epsilon^{IF,j}_t$ is an exogenous shock. Single asset investment funds hold one type of traded security and do not react to shocks to asset returns. Instead, they either receive inflows from households that they channel into the asset class in question or they experience redemptions that they meet by selling the asset. All funds hold cash (deposits) to meet redemptions. These are made in cash and are met either by depleting the cash buffer (if available) or by selling assets in proportion to their original holdings ('vertical slicing'). In addition to the risk of redemption shocks, the mixed fund faces liquidity risks from its participation in the derivatives market that are analogous to those faced by insurers and pension funds. We assume an identical decision sequence as for those agents when initial margin or variation margin calls are made.

2.2.2 The hedge fund

The hedge fund represents the sum of all hedge funds managed in the euro area. It holds securities, deposits, 'other assets' and derivatives. It raises repo borrowings and has other long-term borrowing and derivative liabilities. The 'net asset value' of the hedge fund is owed to the household sector. Similar to Aikman et al. (2019), the hedge fund chooses its repo borrowing $\{L^{HF}_{SR,t}\}$ and asset holdings $\{A^{HF}_{D,t}, A^{HF}_{GB,t}, A^{HF}_{CB,t}, A^{HF}_{E,t}, A^{HF}_{O,t}\}$ to maximise the return of its portfolio by taking advantage of arbitraging opportunities in asset price valuations subject to satisfying its liquidity constraints arising from its participation in IRS and repo markets and self-imposed target leverage level. Furthermore, the hedge fund is subject to investor redemption outflows similar to other investment funds. After collateral and cash calls from repo and IRS initial and variation margins are met, the hedge fund sells assets to meet any investor redemptions. Then, it adjusts its repo and IRS positions to meet the target leverage ratio:

$$k^{HF} \equiv \frac{(A^{HF} + GNE^{HF}_{IRS})}{(K^{HF}_{HH} + L^{HF}_{O})} = \bar{k}^{HF} \tag{5}$$

where $\bar{k}^{HF}$ is the hedge fund's target leverage ratio and GNE^{HF}_{IRS} is the IRS derivatives gross notional exposure. When it deviates from this target, the hedge fund adjusts by varying its repo borrowing and, if the full adjustment cannot be carried out through repo, the hedge fund turns to the IRS market to adjust its exposures there. Finally, it purchases or sells assets based on the divergence between market prices and its internal asset price target. The hedge fund employs a 'value investment strategy', under which it seeks to profit from perceived divergences between the prevailing market prices of assets and its own estimates of the target prices of the assets.[7]

If market prices deviate from these targets, the hedge fund buys undervalued assets ($\hat{p}_i > p_i$) using its available cash holdings and sells overvalued assets ($\hat{p}_i < p_i$). The hedge fund's asset demand is a quadratic function of the gap to target:

$$\Delta A_{i,t}^{HF} = \Phi_{i,t} \left(min \left(1, \left(\frac{\hat{p}_i - p_i}{\alpha} \right)^2 \right) \right) \tag{9}$$

where α represents an uncertainty parameter. $\Phi_{i,t}$ is the maximum amount of a given asset that the hedge fund is able to buy or sell, defined as:

$$\Phi_{i,t} = \begin{cases} A_{D,t}^{HF} \left(\frac{A_{i,t}^{HF}}{A_t^{HF} - A_{D,t}^{HF}} \right) & \text{if } \hat{p}_i > p_i \\ -\tilde{A}_{i,t}^{HF} & \text{if } \hat{p}_i < p_i \end{cases} \tag{10}$$

When an asset is undervalued the hedge fund will purchase up to a limit of the share of its unused deposits assigned to that asset, which is simply the proportion of its non-deposit assets represented by that asset. When an asset is overvalued the hedge fund will sell up to its total unencumbered holdings of that asset - we do not incorporate the possibility of short selling in this version of the model.

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[7] The price target for government bonds is given by:

$$\hat{p}_{GB} = \frac{V_{GB,T}}{(1 + rf + \pi)^T} \tag{6}$$

where V_{GB} is the principal amount of the bond, rf is the long-term risk free real rate, π is the rate of inflation, and T is the maturity of the bond. Similarly, the price target for corporate bonds is:

$$\hat{p}_{CB} = \frac{V_{CB,T}}{(1 + rf + \pi + E[loss_{CB}] + \xi_{CB})^T} \tag{7}$$

where V_{CB} is the principal amount of the corporate bond, $E[loss_{CB}]$ is the hedge fund's expectation of credit losses from corporate defaults, and ξ_{CB} is the corporate bond risk premium, which we assume remains constant. Lastly, the equity price target is given by a simple dividend-discount relation:

$$\hat{p}_E = \frac{E[Div]}{(rf + \pi + \xi_E - g)} \tag{8}$$

where $E[Div]$ represents expected dividends in the next period, g is the expected long-term growth rate of dividends, and ξ_E is the equity risk premium.

2.2.3 The bank

The bank represents the euro area banking sector. It is the aggregate of traditional deposit-funded banks that extend finance to the real economy and global banks that intermediate capital and derivative markets. This is one major difference with respect to Aikman et al. (2019) where the banking sector is split between a traditional deposit-taking bank and a broker-dealer that only intermediates repo and derivatives markets. The balance sheet of our bank is comprised of loans to corporates and households, which we treat as exogenous, tradeable securities, reverse repo extended to the pension and the hedge funds, and reserves at the central bank. One other novelty of our model is that the bank is assumed to accumulate inventories when agents trade government and corporate bonds, reflecting its intermediation role in fixed-income markets. The bank is funded via cash deposits (including those of other agents in the model), repo funding from the central bank, longer-term bonds and equity capital. The bank's behaviour is not explicitly driven by profit maximisation. Instead, the bank simply accommodates the demand for repo and fixed-income market intermediation to the extent that it is able to, given the various solvency and liquidity constraints it faces.

The first role of the bank is to intermediate the repo and derivative markets. In the repo market, it borrows from the central bank and lends to the hedge fund and pension fund. This assumption reflects the current structure of euro money markets where the Eurosystem is a key ultimate provider of liquidity. Any change in this bank's activity is made on a matched-book basis: any increase or decrease in the demand of repo funding from the hedge or the pension fund is reflected in a symmetric position of the bank towards the central bank. The bank does not take proprietary positions in the derivatives market and the IRS positions it arranges for its clients do not appear on its balance sheet. The second role of the bank is to intermediate fixed-income markets and provide market liquidity. This represents another major deviation from Aikman et al. (2019). In some respects, it bridges a gap between the former and the mechanism at the core of the model of Baranova et al. (2017). When the initial equilibrium is shocked, agents rebalance their portfolios to meet their desired allocation. Among other things, this implies buying and selling of tradeable securities. While trading of equities usually takes place in stock exchanges, buying and selling government and corporate bonds typically requires a dealer bank to intermediate the market. We accommodate this market practice by assuming that trades in the fixed income universe absorb bank's balance sheet capacity. More specifically, although the model is not dynamic and the time dimension is not explicitly considered, we require that any trade in government and corporate bonds must be booked by the bank for a certain time period. This affects balance sheet ratios, such as the leverage ratio or risk-weighted assets to capital ratio. When shocks are very large and required portfolio adjustments of agents imply substantial flows (buying and selling), the bank's balance sheet capacity can fall short of the demand for market-making. In this case, the model generates a market breakdown.

The bank's repo and fixed-income intermediation provision are only limited by the regulatory constraints it faces. This is despite the bank being subject to a number of liquidity and solvency constraints, coming from both regulation and market dynamics. A source of liquidity risk is the need to post additional government bond collateral to meet haircuts on its repo funding. When the price of government bonds falls or haircuts increase, the bank is required to post additional collateral. If its existing holdings of government bonds are insufficient to cover the extra collateral required, the bank must buy additional collateral to meet the call. The purchase is funded by selling a vertical slice of other securities:

$$A^B_{i,t} = \begin{cases} A^B_{i,t-1} & \text{if } \frac{L^B_{R,t-1} - A^B_{R,t-1}}{1-h} \leq p_{GB,t} A^B_{GB,t-1} \\ \max[0, A^B_{i,t-1} - (\mu \frac{A^B_{i,t-1}}{\sum_i A^B_{i,t-1}}) \frac{1}{p_{i,t-1}}] & \text{otherwise} \end{cases} \tag{11}$$

where $i = CB, E, O$ and $\mu = \frac{L^B_{R,t-1} - A^B_{R,t-1}}{1-h} - p_{GB,t} A^B_{GB,t-1}$ is the collateral shortfall. Asset sales cannot be larger than asset holdings, of course. The bank is subject to a Liquidity Coverage Ratio (LCR) that limits its liquidity risk taking:

$$\frac{\sum_i \omega_i A^B_t}{\delta L^B_D} \geq \overline{lcr} \tag{12}$$

where ω_i are liquidity risk weights that define HQLA, L^B_D are the bank's deposit liabilities, δ is the 'run-off' rate on deposits in the LCR and $\overline{lcr}$ is the target LCR. Besides liquidity, the bank also faces two solvency constraints. The bank's risk-weighted asset capital constraint is:

$$k^{B,RW}_t \equiv \frac{K^B_t}{\sum_i \theta_i A^B_t} \geq \bar{k}^{B,RW} \tag{13}$$

where K^B is the bank's equity, A^B represents the total assets of the bank, and θ_i are risk weights. There is also a leverage constraint:

$$k^{B,LEV}_t \equiv \frac{K^B_t}{A^B_t} \geq \bar{k}^{B,LEV} \tag{14}$$

where $\bar{k}^B$ is the regulatory leverage ratio minimum. If the bank's leverage ratio falls below $\bar{k}^B$, the bank deleverages by first unwinding its short-term reverse repo position, then it sells a vertical slice of its other marketable assets. That is,

$$L^B_{SR,t} = \max(0, L^B_{SR,t-1} + \frac{K^B_{t-1}}{\bar{k}^B} - A^B_{t-1}) \tag{15}$$

and

$$A^B_{SR,t} = \max(0, A^B_{SR,t-1} + \frac{K^B_{t-1}}{\bar{k}^B} - A^B_{t-1}) \tag{16}$$

The bank operates in two regimes. It extends reverse repo to hedge fund and the pension fund and intermediate IRS and fixed-income markets if no constraints are breached. It pulls out of the repo market and liquidates assets if constraints are breached.

2.2.4 Other agents

The model includes a central bank which issues reserves to meet demand from the bank. Households and non financial firms hold assets passively. They post redemption requests to investment funds and hedge funds during stress. Finally, assets and liabilities of non-euro area investors are assumed to be exogenous and do not actively trade in the model.

2.3 Market clearing and equilibrium

The model assumes that initial balance sheets and prices represent an equilibrium allocation. Prices of the three traded securities are normalised to 1. The shocks trigger portfolio adjustments described in the previous section. Given the prevailing demand-supply imbalances, the algorithm posits a new price vector and checks whether securities and funding markets both simultaneously clear. We iterate this until an equilibrium price vector is found. The system finally converges to a new equilibrium allocation defined as a set of market prices $\{p_{GB,t}, p_{CB,t}, p_{E,t}\}$ at which asset and funding markets clear, and all agents satisfy their funding and solvency constraints. The asset market clearing condition is:

$$\Delta A^I_{i,t} + \Delta A^{PF}_{i,t} + \Delta A^{IF}_{i,t} + \Delta A^{HF}_{i,t} + \Delta A^B_{i,t} = 0 \tag{17}$$

for $i = GB, CB, E$. The funding market clearing conditions is:

$$A^B_{SR,t} = L^{PF}_{SR,t} + L^{HF}_{SR,t} \tag{18}$$

3 Data and calibration

One contribution of our paper is the creation of a new dataset covering Euro area financial institutions' balance sheets. This information is aggregated in a consistent manner by combining a range of regulatory, statistical and commercial sources (see Table 1).

Our dataset includes information on the balance sheets of each sector considered in the model. We use it to calibrate agents' initial balance sheets, i.e prior to the shock, as summarised in Tables 2 and 3. The dataset combines public and private balance sheet data for different sectors (see below). All data are as of end-2019 unless otherwise specified.

Balance sheets of the model's agents are calibrated from balance sheet and supervisory information for euro area entities. Information on asset holdings are mainly drawn from the ECB Security Holding Statistics (SHS). SHS collects security information for all institutional sectors (financial and non-financial) at individual security level (ISIN-by-ISIN). This ensures a consistent overview of asset holdings across different agents. The breakdown of corporate bonds between investment grade and high yield is gauged using a comprehensive database of ratings maintained by the Eurosystem. For the rating, we consider the average rating across the three major rating agencies (Fitch, Moodys' and S&Ps).

SHS information is then cross-checked and complemented with sector-specific sources on the liabilities of different sectors. More specifically, we use the ECB investment fund statistics (IVF), the EIOPA aggregate statistics for Insurance Companies and Pension Funds (IC and PF data) and confidential supervisory data on the portfolios of euro area banks. Further breakdowns from IVF on the type of funds, i.e. single asset versus mixed or hedge fund, are used to calibrate the model. Solvency II and ECB statistics on pension funds are used to build the balance sheets of the insurance company and the pension fund. Information on assets and liabilities of banks are taken from Banking Supervision statistics. Solvency information from COREP are used to calibrate regulatory ratios. Finally, the ECB money market statistical reporting (MMSR) have been used to estimate exposures in the repo market. Assets issued in the euro area but held by non-euro area investors are instead not considered.Assets issued outside the euro area and held by euro area financial institutions are considered in balance sheets as 'other assets'. Balance sheets of private sector agents are reported in tables 2 and 3, for assets and liabilities, respectively.[8]

[8]IC: Insurance Company; PF: Pension Fund; OEIF (mixed): balanced investment fund; OEIF (single): single-asset investment funds, i.e. equities, government and corporate bond funds; HF: Hedge Fund

Table 1: Statistical sources used in the paper and availability to the public

Data source	Description	Public
Securities Holdings Statistics	Holdings of securities, country-Sector holder	Not at ISIN level, but aggregates are available
Investment Fund Statistics	Liabilities and Assets of Investment Funds, broken down by type, i.e. Bond, Equity, Mixed and Hedge Funds	YES
Insurance Corporation and Pension Fund Statistics	Liabilities and Assets of ICPFs, also broken down by life and non-life insurers	YES
Money Market Statistical Reporting	Daily information on money markets, including˜repo transactions	NO
Lipper IM / Refinitiv	Balance sheets of Investment Funds	YES
EMIR	Daily information on derivatives	NO
Supervisory Information on banks	Used to calibrate regulatory information on banks' balance sheets	Aggregate version, Consolidated Banking Statistics generally available
Balance Sheet Items	Used to calibrate ˜the non regulatory parts of the banks' balance sheets	YES

Table 2: Balance sheet of financial institutions: Assets (end-2019 €bn)

	IC	PF	OEF (mixed)	OEF (single)	HF	Bank
Reserves	-	-	-	-	-	1044
Deposits	274	126	113	142	27	-
Short-term rev repo	-	-	-	-	-	50
Long-term rev repo	-	-	-	-	-	41
Gov't bonds	743	586	235	450	157	960
Corp bonds IG	215	177	143	287	73	212
Corp bonds HY	7	23	90	180	46	13
Equities	293	360	213	778	62	634
Loans	-	-	-	-	-	6843
Other assets	2204	2327	1965	1398	374	11478
Total Assets	3735	3600	2759	3235	739	21275

Notes: IC = Insurance Companies; PF = Pension Funds; OEF = Open Ended Funds, mixed and single assets; HF = Hedge Funds.

Table 3: Balance sheet of financial institutions: Liabilities (end-2019, €bn)

	IC	PF	OEF (mixed)	OEF (single)	HF	Bank
Short-term repo	-	9	-	-	41	-
Long-term repo	-	8	-	-	34	-
Other liab	889	915	-	-	234	6770
Pension liab	-	2668	-	-	-	-
Insurer liab	2000	-	-	-	-	-
Bank bonds	-	-	-	-	-	2409
Deposits	-	-	-	-	-	10877
Fund shares	-	-	2759	3235	431	-
Equity	846	-	-	-	-	1218
Total Liabilities	3735	3600	2759	3235	739	21275

Notes: IC = Insurance Companies; PF = Pension Funds; OEF = Open Ended Funds, mixed and single assets; HF = Hedge Funds.

Behavioural parameters of the different agents are calibrated according to existing literature. Whenever possible we rely on euro area specific figures, but in a few cases international literature, mainly the US and the UK, is used for the calibration. We make assumptions on the time horizon over which long-term investors adjust their portfolios towards their Markowitz allocations. The portfolios speed of adjustment regulates the degree of pro- or counter-cyclicality in the behaviour of different agents after shocks affecting fundamentals. For instance, faster agents will immediately sell securities after an increase of default probabilities, while slower agents will tend to maintain their portfolio weights, possibly resulting in counter-cyclical purchases. The speed of adjustment is calibrated at one month and a half for mixed funds, three months for the insurer and six months for pension funds. This means that - within the one-month time horizon of our simulations - the mixed fund, the insurer and the pension fund can adjust 0.67%, 0.34% and 0.17% of their portfolios, respectively. The speed of adjustment of investment funds is calibrated from Lipper IM-Refinitiv data.[9] According to SHS data, ICs and PFs have instead quite slower speeds of adjustment (see also Fache Rousová and Giuzio (2019) for a discussion).

We introduce a dampening factor in the mark-to-market adjustments of ICs' liabilities following interest rate changes. The dampening factor is 80% and reflects the current regulatory landscape (i.e. transitional measures of Solvency II) and the fact that market rates are not used to discount liabilities beyond the 10-year horizon. Without the dampening factor, the equity of ICs would tend to decrease abruptly even for small changes in interest rates.[10] Parameters governing the duration of assets are calibrated considering the duration of outstanding bonds in different markets in the euro area. The duration of liabilities is calibrated using EIOPA information. Granular information (i.e. ISIN-by-ISIN) from SHS, as well as reports from EIOPA, are used to estimate the duration of securities held by ICs and PFs. The duration gap is a key driver of the reaction of ICs and PFs to shocks. A more negative duration gap means that the equity of ICs declines more strongly when long term rates fall. While PFs are not subject to solvency capital regulation, they still try to limit asset-liability mismatches.

We exploit EIOPA and EBA information on equity capital of ICs and banks, respectively. More specifically, we consider the headroom (i.e. the gap between actual capital and the

[9] Our inquiry suggests that, even under very stressed conditions in 2008-2009, most euro area mixed funds did not adjust their portfolios within a month time window, but over a somewhat longer horizon.

[10] Admittedly, the calibration of the dampening factor is tentative at this stage as information on the impact of transitional measures is quite scant

regulatory thresholds) to calibrate equity buffers. Larger buffers imply that the agent can withstand larger shocks and/or not be forced to sell large amounts of securities. In the euro area, banks entered the COVID-19 crisis with large headroom and capital constraints are not binding in our simulations.

See Table 3 for our calibration of the parameters governing asset markets.

Market	**Parameter**	**Calibration**
Sovereign	σ_G	0.108
Sovereign	maturity	10 yrs
Sovereign	$corr_{G,CB}$	0.44
Sovereign	$corr_{G,S}$	-0.15
Corporate Bonds	σ_{CB}	0.084
Corporate Bonds	maturity	7 yrs
Corporate Bonds	$corr_{CB,S}$	0.22
Excess Return Sov-Corporate	$Exc_{CB,G}$	0.01%
Shares	σ_S	0.163
Shares	dividend growth	0.03
Shares	$corr_{S,O}$	0.5

Table 4: Asset market parameters

In relation to both investment and hedge funds, our model features a flow-performance relationship of investment funds, according to which funds' redemptions systematically vary with funds' performance. This is an important driver of asset sales and it is consistent with available empirical evidence (e.g. Chevalier and Ellison (1997); Goldstein et al. (2017)). Redemptions are made in cash, which is raised by funds by selling assets in proportion to their original holdings. Such so called vertical slicing has been used in several studies, e.g. see Cetorelli et al. (2016) for a recent one.

Finally, hedge funds are assumed to be macro funds, i.e. they have a view on fundamentals and buy or sell if they see a mispricing compared to such a view. This behaviour is very relevant when non-fundamental shocks hit the economy, as purchases from hedge funds contribute to push asset prices towards their fundamental values. However, in the euro area the size of the hedge fund sector is quite small, as gauged from ECB Investment Fund Statistics. Therefore their role in driving price dynamics is less prominent than in Aikman et al. (2019) on the UK.

4 Simulations and results

In this section we describe the simulation exercises and the key results of the model. We run two sets of simulations, each one reflecting one layer. The first layer simulates the effects of a fundamental deterioration in the corporate outlook (e.g. higher expected defaults). This deterioration leads long term investors (i.e. insurers, pension and investment funds) to re-optimise their portfolios based on mean-variance criteria (see Section 4.1). The second layer adds to the first one a rating downgrade shock. More specifically, additional market pressure is generated by the fact that some corporate bonds lose their IG status, also called fallen angels. Once the IG rating threshold is breached, institutional mandates force certain long-term investors to sell an amount of corporate bonds that is disproportionately higher than what could be predicted by the downgrade shock alone, based on mean-variance criteria. This excessive sale adds a non-fundamental component to the existing market pressure amid the corporate outlook deterioration (see Section 4.2).

We focus on three sets of results for each layer. The model calculates market clearing prices after the shocks. These prices are driven by asset flows, i.e. buying and selling of assets by each agent. Finally, we compare initial and final balance sheets of the model's agents and calculate the equity losses for each agent.

4.1 Layer 1: Deterioration of the corporate outlook

In Layer 1 we assume that the probability of default of euro area nonfinancial companies increases by 30bps. The shock reflects the change in Moodys' one-year-ahead expected default frequencies of euro area NFCs during the second and third week of March 2020. We also include a symmetric drop of 30bps in the expected dividends of euro area equities issued by nonfinancial corporations. Higher default probabilities and lower dividends reduce the fundamental expected returns on risky assets. Longer term investors rebalance their portfolios accordingly. In the final equilibrium allocation, yields of IG and HY bonds issued by euro area non financial firms increase by 265bps and 515bps, respectively; the drop in equity valuation is almost 20 per cent. Government bond yields drop by less than 30bps (Figure 1, left hand panel). Price changes reflect asset trading flows which lead to market clearing (Figure 1, right hand panel).

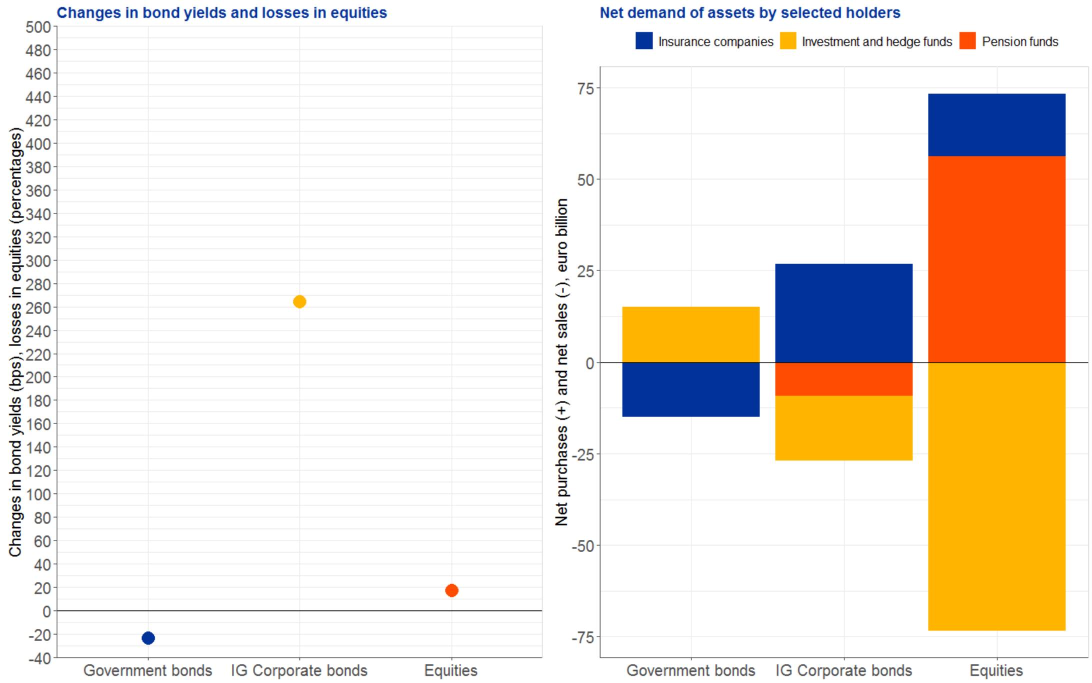

Figure 1: Layer 1: deterioration of the corporate outlook. Left-hand panel: bps changes in yields for government and IG corporate bonds, percentage change in return for equities. Right-hand panel: net demand for equities, government and IG corporate bonds by selected investors.

Long-term investors have different portfolio rebalancing speeds and risk aversions and therefore respond heterogeneously to the shock. Investment funds invested in equities and corporate bonds experience a negative valuation shock and face redemption requests from their clients, according to model's endogenous flow-performance relation. Thereby investment funds reduce their asset holdings quite substantially. The mixed investment fund slightly rotates from equities towards government and, to a lesser extent, corporate bonds. The pension fund and the insurer, which are assumed to react relatively more slowly, seek their new optimal portfolio weights. This leads the pension fund to gyrate from IG corporate bonds towards equities. The insurer purchases both IG corporate bonds and equities, whose yields and returns become more attractive, and sells government bonds. Sovereign yields are compressed by purchases from government bond funds that experience a relatively small amount of investor inflows driven by relative good fund performance.

4.2 Layer 2: Rating Downgrade shock

On top of the deterioration of the corporate outlook, Layer 2 considers a rating downgrade of €110bn euro area IG NFC bonds to HY[11]. According to Security Holdings Statistics data, only €68bn of these fallen angels were held by euro area banks, insurance companies, pension funds, investment and hedge funds at end-2019. The remaining part, held by non-euro area investors and the Eurosystem, is not directly considered in the analysis below. Holders of fallen angels are hit by mark-to-market losses, which eventually affect their portfolio choices. Additionally, we assume that the insurer and the pension fund operate under a mandate restriction and are forced to liquidate fallen angels. All this creates additional selling pressure in the corporate bond market.

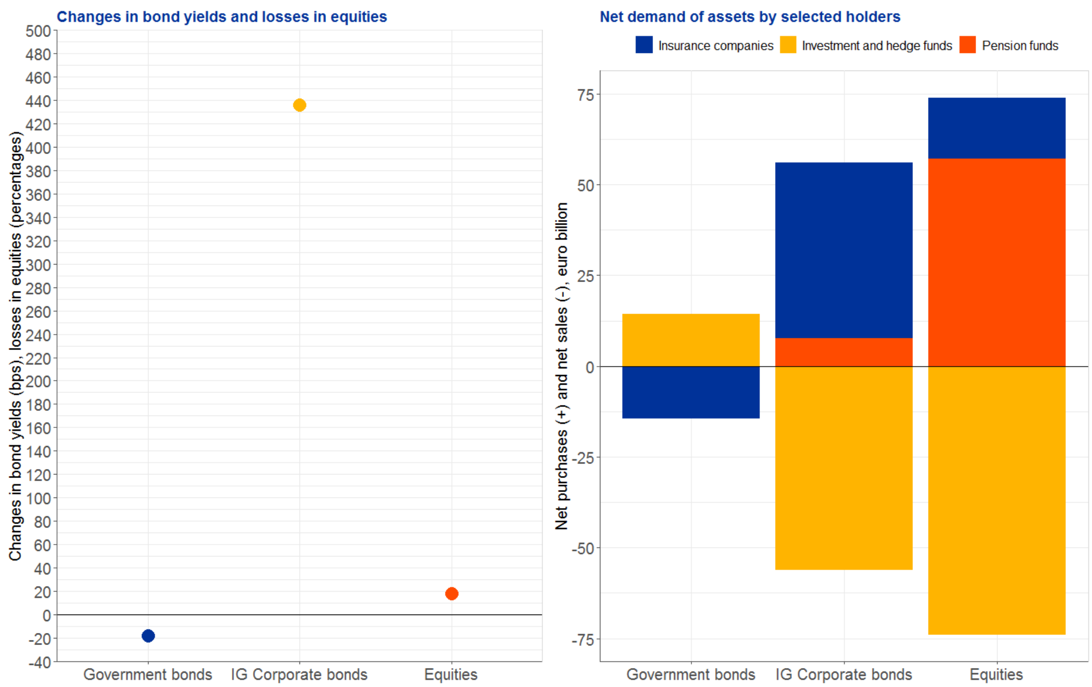

Figure 2: Layer 2: deterioration of the corporate outlook and rating downgrade shock. Left-hand panel: bps changes in yields for government and IG corporate bonds, percentage change in return for equities. Right-hand panel: net demand for equities, government and IG corporate bonds by selected investors.

In Layer 2 IG corporate bond prices drop more sharply. The spike in IG corporate bond yield is more than 430bps (Figure 2). The drop in the value of equities is very similar to the one obtained in Layer 1, as the rating downgrade shock almost exclusively affects the

[11] For an explanation of the figure see ECB (2020), chapter 2

corporate bond market. Asset flows in the equities market are also very similar across the two layers. These generalised stressed market conditions benefit sovereign bonds. Their yield declines by less than 20bps in Layer 2, whereas it was slightly more pronounced in Layer 1 (30bps). The rating downgrade shock imposes direct marked-to-market losses on holders of risky assets. These losses are quite large for investment funds and trigger endogenous investor redemptions. In aggregate, investment and hedge funds sell around €60bn of IG corporate bonds. In Layer 2 the pension fund becomes a net buyer of IG corporate bonds, alongside the insurance company.[12]

4.3 Balance sheet losses

The two shocks bring about balance sheet losses for the agents in the model. The deterioration of the corporate outlook is very severe. Investment and hedge funds lose around €360bn, or 5.3% of their initial total assets. This is a combination of negative price developments in equities and corporate bonds, and endogenous investor redemptions. Large investors such as banks, pension funds and insurance companies face balance sheet losses of €125bn, €130bn and €75, respectively. These losses are quite small in relative terms and represent 0.6%, 3.6% and 2.0% of their respective initial total assets. System-wide losses in Layer 1 amount to €690bn (1.9% of initial total assets of the model's agents).

The rating downgrade shock hits an economy already weakened by the deterioration of the corporate outlook. At the margin, the shock exacerbates negative price developments for corporate bonds. Adverse balance sheet effects are mainly concentrated in the investment fund sector. Funds are large holders of corporate bonds and investors are quite reactive to disappointing fund performance. As compared to Layer 1, investment funds incur a further €160bn of losses (2.4% of initial total assets). Other sectors are less affected. In Layer 2, insurance companies and pension funds incur a further €30bn (0.8%) and €15bn (0.4%) of losses, respectively. Euro area banks are large holders of securities. However, their additional losses triggered by the rating downgrade shock are limited (€35bn, less than 0.2% of their initial total assets).

[12]The pension fund purchases both IG corporate bonds and equities, while selling other assets, e.g. non-euro area assets, whose price formation mechanism is not explicitly modelled.

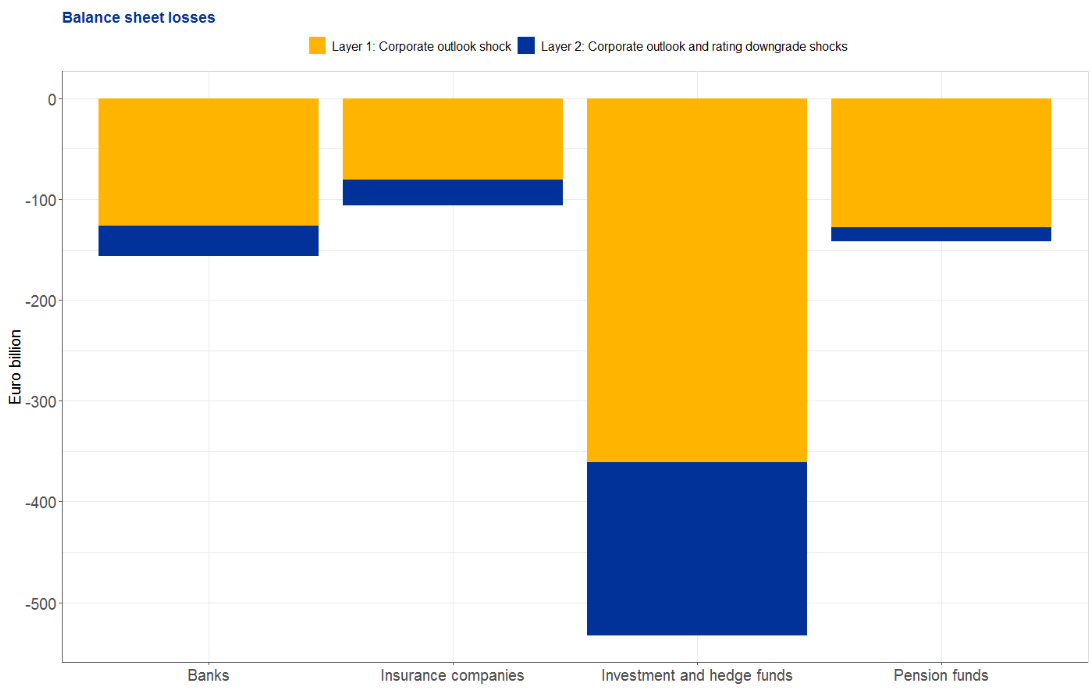

Figure 3: Balance sheet losses for selected holders of tradable assets.

5 Model sensitivity

This section provides more details on one key mechanism of the model, namely the way longer term investors react to shocks and how this reaction is affected by their initial portfolio and preferences. For sake of convenience we focus on investment funds but most of the discussion below would hold *mutatis mutandis* for other long term investors, such as the insurance company and the pension fund. The stylised portfolio of long term investors is a combination of marketable assets and cash. The amount of cash determines the easiness of the investor to meet liquidity shocks, e.g. redemptions. While the investor's initial allocation across risky assets observed in data is used to calibrate the investor's risk appetite. This parameter also contribute to determine the new target portfolio once the shock hits, thereby affecting buy and sell of different marketable securities.

We use two specific examples to describe these key mechanisms. Firstly, we assume funds enter the model with higher cash holdings (Section 5.1). This helps funds in meeting redemptions without being forced to sell assets in the market. More specifically, we document how higher cash buffers affect the mixed fund and single-asset funds. In our second example, we assume instead that funds have a stronger risk appetite (Section 5.2). This change is introduced by imposing a larger share of corporate bonds in funds' initial portfolios. More specifically, we run both exercises considering the Layer 1 shock, namely a deterioration of the corporate outlook as described in Section 4.1. Some of the findings of this section could also inform the policy discussion on the liquidity regulation of investment funds.

5.1 Higher cash buffers

In our first example, we assume single-asset investment funds have higher initial cash holdings compared to what we observe in data at Dec 2019. Single-asset funds are in a sense passive: they enter the model with cash and their initial allocation to marketable securities. In Layer 1, the fundamental values of shares and corporate bonds decline. Higher cash means that funds - mixed and single-asset funds - can more easily meet investor redemptions without engaging in considerable asset sales. This mechanism is relatively less relevant for the mixed fund, which can rotate across different marketable securities. Higher cash holdings are instead crucial in reducing sales of assets by single-asset funds, as their behavior is dictated by redemptions.

As an illustrative example, we consider a 1% increase in the initial cash holdings of single asset funds and then run our Layer 1 shock. We focus on the corporate bond market and the differences in results (yields and asset flows) obtained under the benchmark simulation and the one with higher cash holdings.[13] In the simulation with higher cash holdings, the Layer 1 shock would induce an increase of corporate bond yields of 250bps, compared to 265bps increase of the benchmark case. Figure 4 with asset flows shows that the lower increase in corporate bond spread is explained by the different behaviour of the corporate bond fund which, in the simulation with higher cash holdings, is not forced to sell corporate bonds to meet investor redemptions.

[13] In Layer 1 we consider a shock to fundamentals. This changes the target portfolio of the mixed fund which would sell corporate bonds and shares in any case, i.e. regardless to its cash holdings. For this reason, we prefer to focus our illustrative example on single-asset funds.

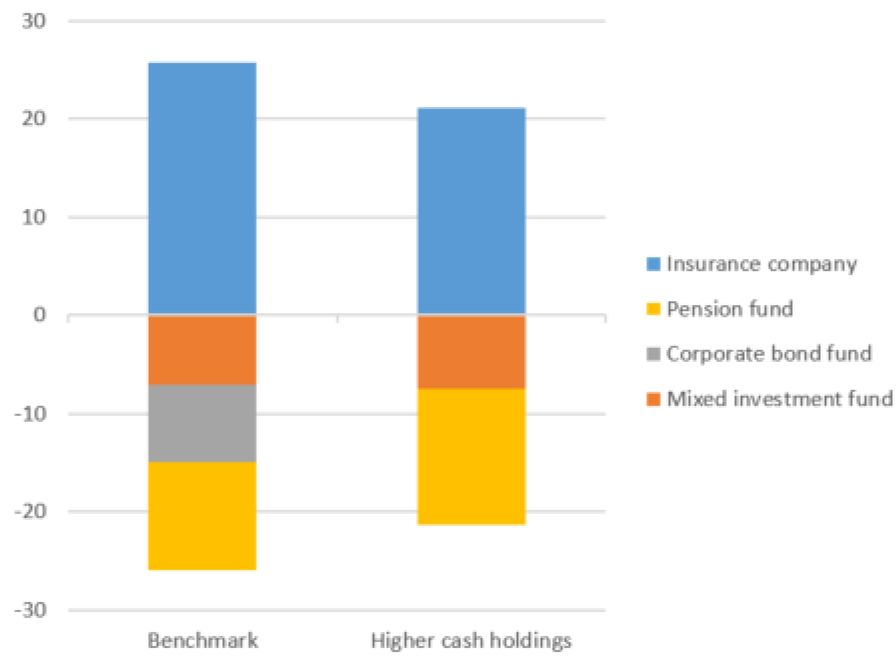

Figure 4: Asset flows in the corporate bond market (billions of euro) in the Benchmark and the 'Higher cash holdings' simulations.

Investment funds with more cash create less financial amplification when confronted with a shock to fundamentals, such as our Layer 1 shock. In a scenario where instead fund investors react to a non-fundamental shock, e.g. panic-mode outflows triggered by first-mover advantage, higher cash would have an even larger effect on yields. This is because, in case of non-fundamental shocks, optimising long-term investors would not sell assets. Having more cash would allow funds to minimise undesired changes in portfolio allocations. This exercise is an example of how the model can be flexibly used to build quantitative evidence on equilibrium effects of a macroprudential liquidity regulation of non-banks.

5.2 Stronger risk appetite

In our second example, we consider the case of investment funds with a stronger risk appetite. This tilts their initial portfolio allocation across marketable assets towards riskier assets (e.g. corporate bonds) and also changes funds' reaction to shocks. More specifically, to keep the analysis as simple as possible, we consider that the mixed fund has 1% more corporate bonds relative to the benchmark case calibrated with data at Dec 2019. The economy is subject to the same deterioration of the corporate outlook (i.e. Layer 1) as in the previous exercise. The impact of stronger risk appetite of mixed funds is relatively limited. Corporate bond yields would increase by 263bps, very much in line with the 265 bps increase of the baseline simulation. Asset flows shown in 5.2 suggest that the slightly lower rise in yields is driven by the mixed bond fund reducing its sales of corporate bonds, as expected.

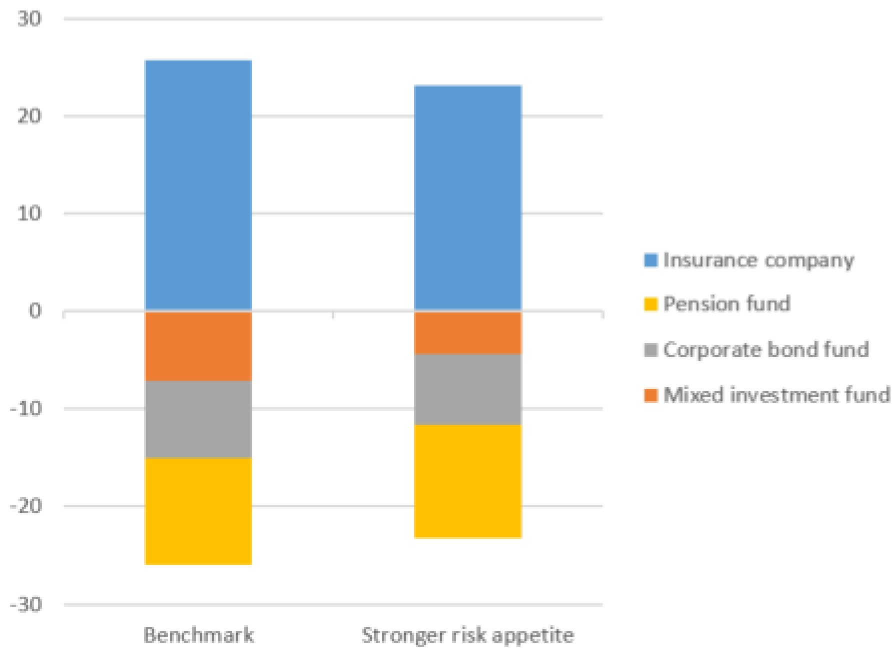

Figure 5: Asset flows in the corporate bond market (billions of euro) in the Benchmark and the Stronger risk appetite simulations.

This exercise focuses on an increase of risk appetite of investment funds. A similar change could be assumed for other long-term investors such as the insurance company or the pension fund. This would result in an even lower increase in corporate yields, having both entities increasing their net purchases or reducing their net sales.

6 Conclusion

This paper develops an equilibrium approach to explain short-term developments and financial amplification in the market-based financial system. One strength of our model is that it considers both buyers and sellers of securities. Buying and selling are driven by the behaviour of investors and the latter is derived from first principles and optimisation. This approach allows us to compute equilibrium allocations in terms of prices and quantities, an essential although quite unique feature among other models used to run system-wide stress simulations.

As examples of how the model can be used for policy purposes, we consider scenarios that capture the recent market stress of the COVID-19 crisis. Layer 1 shock introduces a deterioration of the euro area corporate outlook, while Layer 2 adds to the former a corporate bond rating downgrade shock. Our results show how shocks affect market prices and impose balance sheet losses to model's agents. In the final equilibrium, risky assets are traded with a large discount. This is due to the interaction of several behaviours and constraints affecting different agents in the market-based finance ecosystem. In our view, this approach considers these issues in a more thorough way. In our two specific exercises, while prices drop significantly in some of simulations, dynamics are still orderly, in the sense that they were not amplified substantially by binding capital or leverage constraints on the part of the bank or the insurance company.[14] However, a key result of the simulations is that large outflows from investment funds amplify system's response to shocks. We use the model to analyse system's response in the case funds have higher cash buffers, thereby providing preliminary quantitative results on the equilibrium effects of a liquidity buffer regulation of investment funds.

[14] Aikman et al. (2019) explore how such occasionally-binding constraints of this nature create 'tipping points', whereby the impact of shocks is amplified substantially as banks and other agents seek to delever their balance sheets.

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