A structural corporate insolvency model to predict sectoral Austrian insolvencies amid the COVID-19 pandemic and beyond[1]

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We employ a novel modeling approach to predict sectoral insolvency rates based on simulated firm-level data in Austria. Turnover shocks derived from a macroeconomic scenario generate stress to firms' profits and cash-flows. Over time, both the equity and the liquidity (cash and bank) positions deteriorate, which causes insolvencies if firms fall under certain thresholds. Our model builds on data for nonfinancial incorporated Austrian enterprises available from the BACH and SABINA databases. Since only two firm-level variables (equity ratio, cash and bank) are available at sufficient coverage, we generate a hypothetical firm-level dataset for 17 NACE-1 sectors by using a Monte Carlo simulation.

The granularity of our model allows us to assess the impact of mitigating measures implemented in light of the COVID-19 pandemic. Such measures serve to cushion the loss of companies' revenue and households' income triggered by the COVID-19 containment measures. Put differently, they are meant to minimize the damage resulting from the deliberate temporary reduction in economic activity. In our analysis, we only investigate measures aimed at incorporated firms. These measures include equity injections via grants and subsidies (e.g. short-time work), long-term payment deferrals (e.g. credit guarantees) and short-term payment deferrals (e.g. social security contributions).

Projected insolvency rates should be interpreted with caution. The merit of this novel approach, however, lies less in the calculated sectoral insolvency rates themselves, but in the model's capacity to compare and rank the efficiency and efficacy of various mitigating measures. At the OeNB, the model has also been frequently updated (e.g. with every new macro forecast, but also major extensions of the mitigating measures) and used to assess counterfactual scenarios such as implementation delays of policy measures. In this paper, we present the three simulation runs associated with the main macroeconomic forecasts of OeNB. Moreover, since its inception spring/summer of 2020, the core insolvency model has been expanded to incorporate cost-shocks on a granular basis in order to assess the impact of a carbon price tax on Austrian firms for OeNB's climate stress test.

Our experience with broadening the scope of analysis beyond the COVID-19 pandemic has been encouraging. We therefore intend to continuously expand the model, both in terms of its core functionality and the scenario generating input to address questions from (1) a macroeconomic perspective, in particular the loss of productive capacities (potential output) under different scenarios, (2) a fiscal policy perspective, to estimate the costs of policy measures, and (3) a macro- and microprudential banking supervisory perspective, to provide a basis for estimating credit default probabilities for the banking system. In the shot-term, our focus will firmly remain assessing various questions related to the COVID-19 pandemic, but lessons from OeNB's climate stress test suggest there is ample room for application of our model well beyond.

JEL classification: C15, E47, G33
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1 Introduction

The COVID-19 pandemic hit almost all countries worldwide in an unprecedented way. The supply side of economies was hit by measures implemented to contain the spread of the virus – lockdowns, business closures and social distancing – and by disruptions of global supply chains. At the same time, a drop in demand caused production to fall. Consumer demand was dampened by a combination of layoffs and heightened uncertainty about future income prospects. Investment decisions were hampered by extreme uncertainty about the path, duration and magnitude of the pandemic. These developments pose a serious threat to the survival of firms. Hence, the Austrian government has implemented a variety of measures meant to mitigate the negative economic impact on firms (hereafter mitigating measures). To assess the impact of these developments on sectoral insolvency rates, we developed a novel corporate insolvency model to forecast sectoral insolvency rates for Austrian firms and to assess the impact of the Austrian government's and other public institutions' mitigating measures.[3] Our model is based on a simulated firm-level dataset that contains balance sheet, profit and loss as well as cash-flow data. The model has been used by OeNB to inform policy discussions around the COVID-19 pandemic and beyond.

1.1 Literary review

At the time of implementation, we were – to our knowledge – among the first to develop such a model, lately more research looks at how firms' liquidity and solvency positions evolve and have evolved during the COVID-19 pandemic based on firm-level data. The OECD (2020) evaluates the risk of a widespread liquidity crisis, using a cross-sector sample of almost 1 million European firms (Orbis database), and discusses the pros and cons of different kinds of public support measures. Without any policy intervention, 20% of the firms in the sample would run out of liquidity after one, 30% after two and 38% after three months, with this result mainly driven by the hardest-hit sectors. Among the broad range of mitigating measures introduced by OECD countries, direct and indirect wage subsidies seem to be the policy most critical to curbing the liquidity crisis, given the high share of wage costs in total spending. Adding up different mitigating policy measures (tax deferral, debt moratorium and wage subsidies at 80% of the wage bill), the simulation suggests that, after two months, government interventions would decrease the share of firms running out of liquidity from 30% to 10%, compared to the non-policy scenario.

De Vito and Gomez (2020) investigate to what extent COVID-19 might affect the liquidity of listed firms across 26 countries. They use consolidated firm-level data for the fiscal year 2018, obtained from the Compustat Global and North America databases. They stress-test three liquidity ratios for each firm with full and partial operating flexibility in two simulated distress scenarios. In addition, they study the impact of two different fiscal mitigating measures, namely tax deferrals and bridge loans. In the most adverse scenario, an average firm with partial operating flexibility would exhaust its cash holdings within about two years. About 10% of all sample firms would become illiquid within six months.

[3] *In addition to the government, Austria's health insurance providers (deferral of social security contributions) and the banking sector (debt moratoria) introduced mitigating measures.*

Guerini et al. (2020) simulate the COVID-19 impact on corporate solvency from a sample of 1 million French companies (FARE data 2017). They find that the share of firms with negative equity increases by 1.4 percentage points (from 1.8% in a world without crisis to 3.2%), which corresponds to an increase of almost 80%. At the same time, they observe an increase of firms with liquidity problems from 3.8% to more than 10%.

Schivardi and Romano (2020) propose a method based on firms' balance sheet data from the Orbis database and sectoral predictions of sales growth to determine the number of illiquid firms for Italy on a monthly basis. They find that, at the peak of the pandemic, almost one-third of the firms become illiquid. Carletti et al. (2020) use the Orbis dataset of 80,000 Italian firms to study the impact of the pandemic on firms' net worth. They find that 17% of the firms would have negative net worth by the end of 2020.

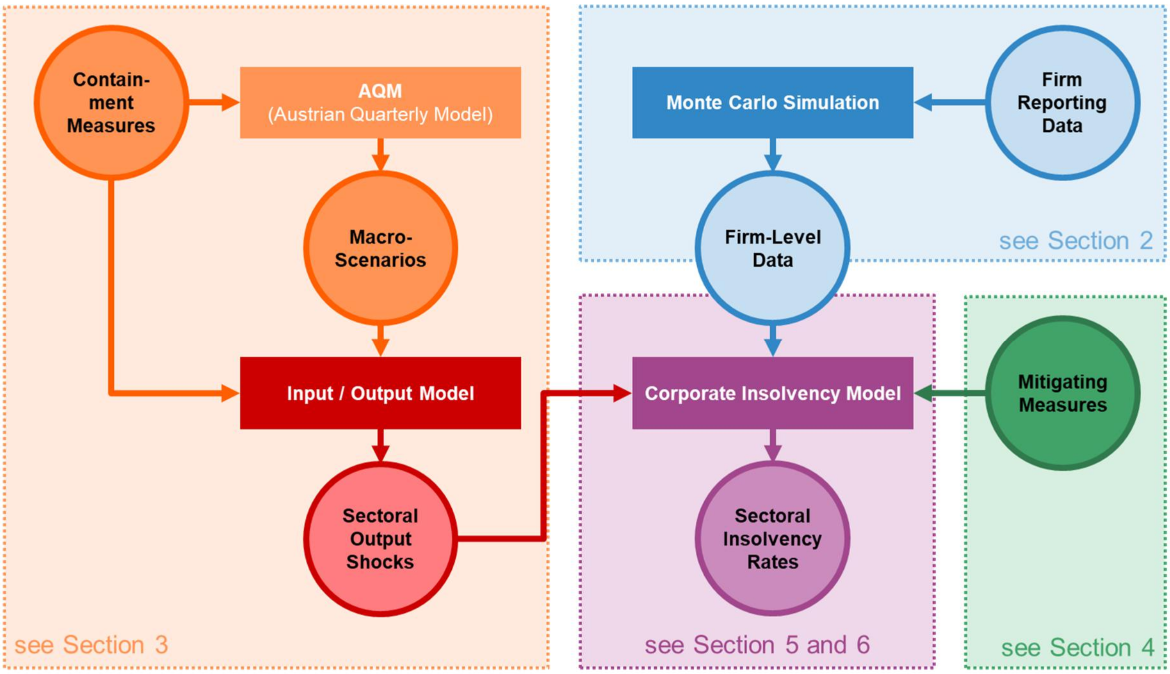
Gourinchas et al. (2020) estimate the COVID-19 impact on business failures among small and medium-sized enterprises (SMEs) in 17 countries, using a large representative firm-level database (Orbis). They use a model of firm short-run cost minimization and measure each firm's liquidity shortfall during and after COVID-19, arriving at a quasi-doubling of business failures: the non-COVID-19 bankruptcy rate of 9.4% rises to 18.2% amid the coronavirus pandemic, which reflects an 8.8-percentage-point increase. Gourinchas et al. (2021) extend their previous study until 2021, with a subset of 13 countries, questioning the potential for delayed insolvencies arising from expiring mitigating measures. They suggest that a tightened credit market scenario with missing pre-pandemic debt roll over options in 2021 would increase insolvencies up to 8.44 percentage points relative to a non-Covid scenario in the same year. Meanwhile the sole expiration of mitigating measure in combination with pandemic loan repayments lead to a rise in SME failures of only 1.88 percentage points relative to a non-COVID scenario in 2021.

Ebeke et al. (2021) simulate corporate bankruptcies for 26 European countries on firm-level data (Orbis) of approximately 4.5 million non-financial firms until year end 2020 and assess mitigating measure effectiveness. Firm balance sheets develop within a four stage and credit scenario setting in which different sets of mitigating measures (excl. changes to national bankruptcy laws) are available to the respective firms. Their model suggests that such measures, as designed, lessen liquidity deficits in Europe's advanced economies by around 80% and solvency gaps by less than 40%. They find guaranteed loans, job-retention programs, and debt moratoria among the most affective mitigating measures to prevent liquidity deficits across Europe. Given that all mitigating measures in Europe are accessible as designed, the simulation estimates a rise of on average 8% in insolvencies.

1.2 Model overview

Figure 1 presents our modelling set-up and links it to the structure of this paper: in Section 2, we discuss the micro level data that feeds into the model and the simulation techniques by which we fill data gaps to construct the firm-level data set required for the corporate insolvency model. In Section 3 we briefly summarize OeNB's semiannual macroeconomic forecasts from June 2020 to June 2021 that serve as the main scenarios for our model runs. As we derive the main shock from COVID-19 containment measures we describe how we use an input / output model (and additional assumptions) to translate the aggregate shock from the macroeconomic forecast to the sectoral impact on individual firms' output. In Section 4, we discuss the mitigating measures implemented up to end-June 2021 that counteract the containment measures from the scenario. Section 5 then explains the mechanics of our corporate insolvency model and in Section 6 we show how we integrate mitigating measures in the insolvency model. In Section 7 we present the main results of the major model runs based on the three scenarios mentioned above and discuss some selected highlights from disaggregated results to illustrate the interplay between scenarios, firms' solvency, and mitigating measures the model is able to capture. Section 8 concludes.

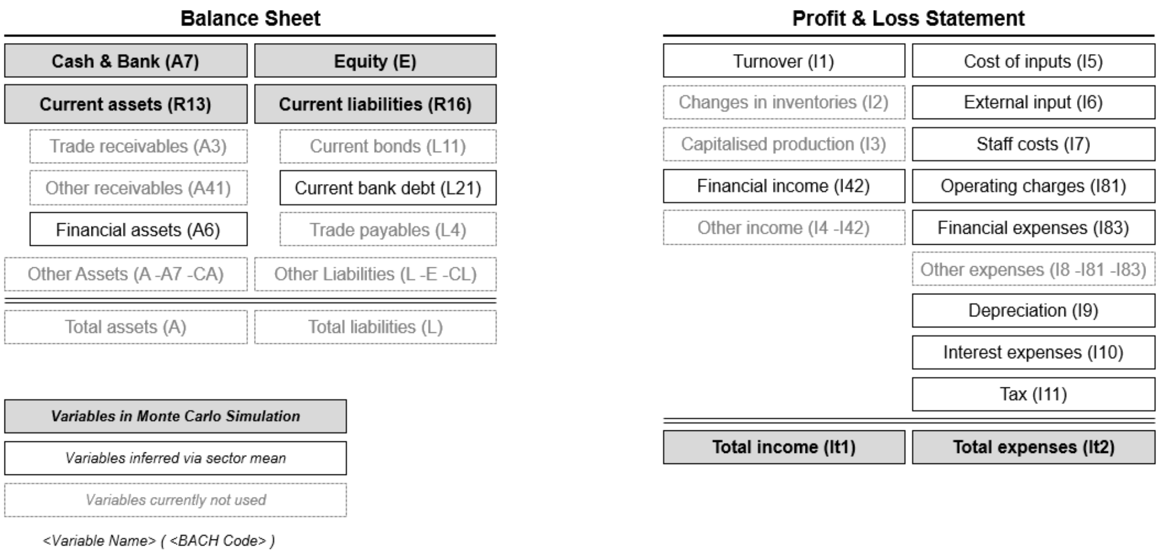
Figure 1
Model Overview



2 Data

Our corporate insolvency model builds on a firm-level dataset for nonfinancial incorporated Austrian enterprises with 18 firm-specific variables[4] for 17 NACE-1 sectors. We use data from the BACH[5] and SABINA[6] databases to construct this dataset. Since only two variables are available at the firm-level (equity ratio, cash and bank) to a sufficient extent in the SABINA database, we generate a hypothetical firm-level dataset. To this effect, we proceed in two steps. First, we simulate a firm-level dataset for six core variables (equity ratio, cash and bank, current assets, current liabilities, total income, total expenses) by means of a Monte Carlo method[7]. These core variables are shaded in gray in Figure 2. Second, we calculate all other variables used (black font) as shares of the simulated variables on a sectoral basis.

Figure 2
Variables of the firm-level dataset



What we need to perform the Monte Carlo simulation is the distribution of each variable over all firms in that sector and a covariance matrix that describes the joint distribution of all variables. We use a copula[8] approach, since it provides a flexible way to separately model the dependence structure between the variables and the marginal distributions (McNeil et al., 2015). The first step of the Monte Carlo simulation is to estimate marginal distributions for all variables. For the equity ratio and cash and bank, we draw on firm-level data that are available in the SABINA database for more than 110,000 firms. Table A2 in Annex 1 shows some statistics of the equity and cash and bank ratios from the SABINA database.

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4 *See Table A1 in annex 1 for a detailed description of the variables.*

5 *BACH is a database of aggregated and harmonized accounting data of nonfinancial incorporated enterprises of 13 European countries. It contains over 100 variables for 17 NACE sections, about 80 NACE divisions and 4 firm size classes (https://www.bach.banque-france.fr/?lang=en). Besides the weighted mean, data for the quartiles of the distribution for each variable are available.*

6 *The SABINA database contains firm-level accounting data compiled by Bureau van Dijk for more than 130,000 Austrian firms.*

7 *Monte Carlo simulation is a mathematical technique that generates random variables for modeling risk or uncertainty of a certain system. The random variables or inputs are modeled based on probability distributions such as normal or gamma distributions.*

8 *A copula is a multivariate cumulative density distribution for which the marginal distribution for each variable is uniform.*

The other four core variables (current assets, current liabilities, total income, total expenses) are taken from the BACH database, which contains aggregated data for the weighted mean and for the quartiles. We use the weighted mean and the first quartile to estimate the distributions for these variables. We assume a normal distribution for total income and total expenses and a gamma distribution for current assets and current liabilities.
Using a copula makes the simulation an easy task. For each sector, we generate 100,000 draws from a multivariate normal distribution $X = N(0,1,\sigma)$. Therefore, we need a correlation matrix that describes the dependencies between the variables. Since we have no micro data to estimate this matrix, we use correlations over time between the means of pairs of variables as a proxy. We then compute the cumulative density function (cdf) of this multivariate normal distribution, which is uniformly distributed in the interval [0,…,1]. The final step involves specifying the inverse cumulative density function for each variable. We can use any distribution family if we are able to compute the inverse cdf. For the equity ratio and cash and bank, we use the inverse cdf of the data[9]. For the other variables, we either use the inverse normal or the inverse gamma cdf.
Our simulated dataset has all the properties that we need to perform our analysis (marginal distributions that are identical to the estimated distributions and a correlation structure that is given by the estimated correlation matrix[10]). Four points are worth mentioning. First, our simulation approach effectively reproduces the empirical marginal distributions. Second, the distribution for the equity ratio is far from normal, which highlights the importance of the availability of firm-level data for this variable[11]. Third, a considerable share of firms has negative equity in 2018 (14% for manufacturing, 17% across all sectors). Fourth, we removed firms with equity of less than –30% from our dataset since such firms are insolvent according to our definition. A final note worth mentioning, to ensure that our simulated firms are always the same across simulations we seed the random number generator for all draws from distributions to ensure consistency and avoid associated differences when interpreting results in this paper.

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[9] *In this case, the inverse cdf simply involves referring to the i*Nth element of the sorted data, where i is the uniformly distributed value of the simulated copula for that variable and N the number of firms.*

[10] *Note that the copula approach does not allow to exactly reproduce the correlation structure for all families of marginal distributions other than normal distributions. What can be reproduced exactly is the rank correlation matrix. However, the error is marginal for our data.*

[11] *It would be possible to construct the firm-level dataset with variables from the BACH database only. However, according to SABINA firm-level data, the distribution of the equity ratio deviates considerably from a normal distribution for most sectors. For the cash and bank ratio, the distributions are very similar to a gamma distribution for all sectors.*

3 Scenario

The macroeconomic scenarios provide the main driver of stress to firms. The impact of the COVID-19 pandemic on the economy is huge and unprecedented in combining negative supply and demand shocks. For every model run, we start with the published biannual OeNB macroeconomic forecast based on national accounts data. For the purpose of this paper, three major model updates and, consequently, three macroeconomic forecasts are discussed (see Section 3.1 to 3.3 for a brief summary of each). Instead of applying highly aggregated national accounts variables, we generate the scenarios based on a sectoral input / output model (see Section 3.4) and finally distribute the shocks within sectors to reflect that firms within sectors are hit heterogeneously by the COVID-19 pandemic and/or it's containment measures (see Section 3.5).

3.1 OeNB's macroeconomic forecast June 2020[12]

In June 2020, Fenz et. al. (2020) wrote that lockdown measures adopted to contain the COVID-19 pandemic have sent economies worldwide into a deep recession. For the Austrian economy, that implied an economic decline by about 13.5% in the first half of 2020, but a visible revival already in the second half of the year. OeNB's projections were based on two key assumptions: first, that a second wave of COVID-19 infections in the fall of 2020 holds off, and second, that coronavirus drugs or vaccines will be available by mid-2021. While the latter was later confirmed, the former assumption unfortunately turned out to be wrong. In light of these assumptions, GDP in Austria was expected to contract by 7.2% in 2020, but to recover lost ground thereafter with growth rates of 4.9% in 2021 and 2.7% in 2022. Furthermore, a phase-out of the mitigating measures was anticipated around midyear 2021. In our paper, this forecast is the basis for the first set of model results (hereafter light blue lines in figures).

3.2 OeNB's macroeconomic forecast December 2020[13]

In December 2020, Fenz and Schneider (2021) wrote that over the summer months, the Austrian economy recovered faster than expected from the deep slump observed in the first half of 2020. However, the second wave of COVID-19 infections in Austria caused a renewed downturn in the fourth quarter of 2020. This downturn was expected to be only half as devastating for the economy as the spring 2020 contraction. Hence, the OeNB expected a strong economic recovery that rested on the following assumptions: a third wave of coronavirus infections in spring 2021 could be prevented; the related health policy measures would be phased out gradually over the first half of 2021; and a medical solution would be successfully implemented by end-2021. Again, the first assumption related to the containment of the COVID-19 pandemic would not hold. In any case, the OeNB expected – after negative real GDP growth of 7.1% in Austria in 2020 – growth rates of 3.6% in 2021, and 4.0% in 2022 and 2.2% in 2023. In our paper, an amended forecast from January 2021 in light of worse than expected COVID-19 developments is the basis for the second set of model results (hereafter medium blue lines in figures).

[12] *For details regarding OeNB's June 2020 macroeconomic forecast refer to Fenz et. al. (2020).*

[13] *For details regarding OeNB's December 2020 macroeconomic forecast refer to Fenz and Schneider (2021).*

3.3 OeNB's macroeconomic forecast June 2021[14]

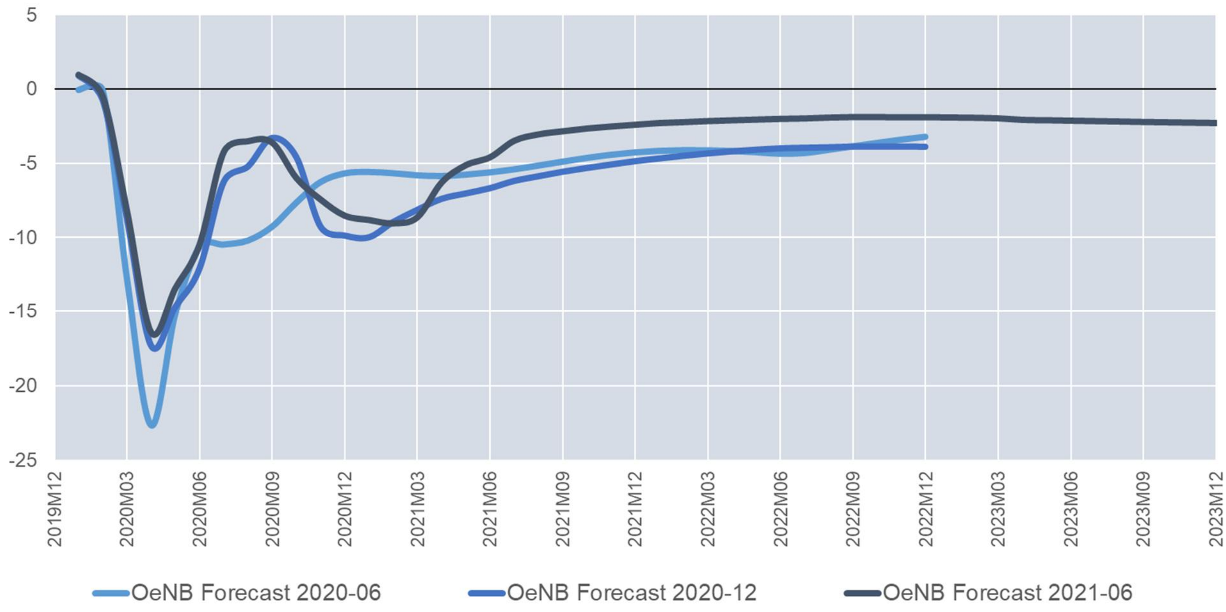
In June 2021 Ragacs et. al. (2021) wrote that the easing of containment measures in view of accelerated COVID-19 vaccination rates have put the Austrian economy back on the road to a strong recovery in mid-2021. In 2020, containment measures had caused real GDP to contract by 6.7% year on year. OeNB expected annual GDP growth to bounce back to 3.9% in 2021 and 4.2% in 2022, and to return to a normal growth rate of 1.9% in 2023. In our paper, this forecast is the basis for the third and last set of model results (hereafter dark blue lines in figures).

3.4 An input / output model to derive sectoral shocks

While we use OeNB's macroeconomic forecasts as the anchor for our scenarios, they only contain aggregated projections, whereas we need forecast output for 17 NACE-1 sectors. To this end, we developed an input / output model to calculate the effects of the COVID-19-induced demand shock on the output of all 17 sectors given intermediate goods linkages. This model includes a monthly forecast of 13 demand components: 7 private consumption components (food and beverages; housing (including energy and water); clothing, footwear and furnishings; recreation, sports and culture; restaurants and accommodation services; transport; other consumption), 2 investment categories (construction, other investment), 2 export categories (tourism, other), government consumption and changes in inventories. We map the 13 demand components to the 74 goods categories in our input / output model and use them to calculate the impact on the output of all 74 NACE-2 industries due to intermediate goods linkages. We aggregate results to NACE-1 levels to end up with 17 sector specific output loss projections.

Figure 3

Figure 3 – Aggregate output shocks based on OeNB's forecasts 2020H1-2021H2



[14] *For details regarding OeNB's June 2021 macroeconomic forecast refer to Ragacs et. al. (2021).*

We present aggregate results of our output loss projections in Figure 3. Across all three projections, two sectors clearly stand out. “Arts, entertainment and recreation” (NACE R) and “Accommodation and food service activities” (NACE I) are expected to suffer the most severe output losses relative to the pre-crisis trend in 2020, however less pronounced than initially expected. For a more detailed discussion of this fact and the implications modelling insolvency rates refer to the results Section 7.3.

3.5 Within sector output-shock variance

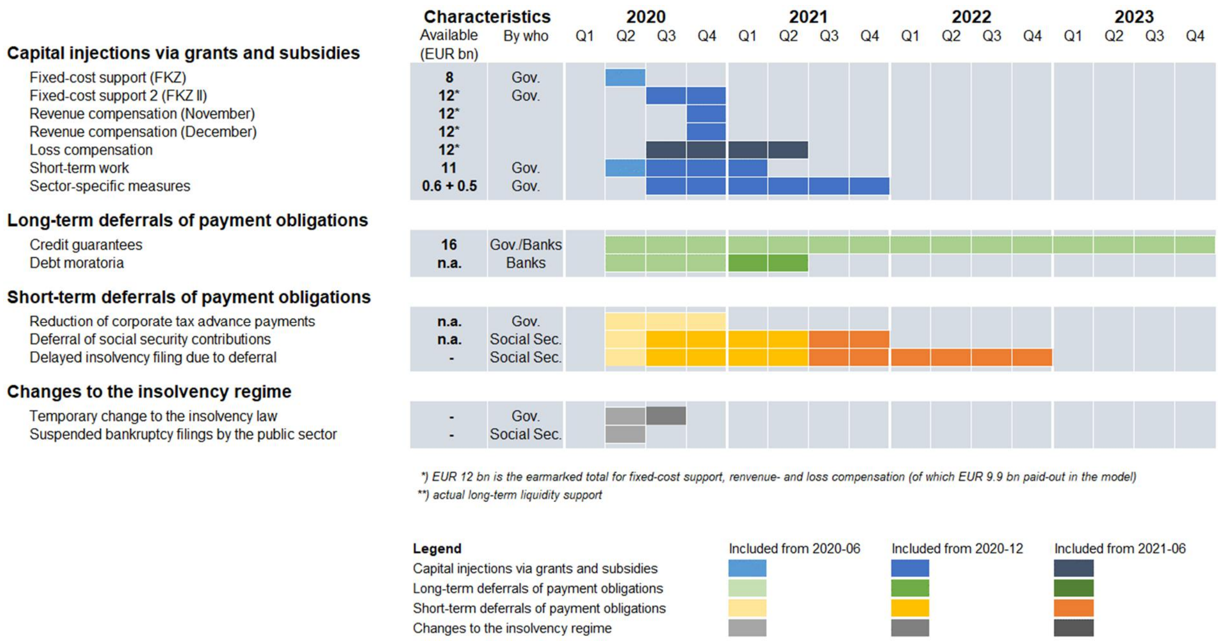
The reported output loss figures relate to the mean loss over all firms of each sector, however, within the same sector, the shock will impact firms differently. To account for this, we assumed that, for individual firms within each sector, the shock is normally distributed. The mean of the distribution equals the shock size per sector for each period. The variances are based on the heterogeneity of the sector and the shock magnitude.[15] This assumption allows us to model various effects more realistically, and it is an outright necessity to address some mitigating measures properly (e.g., fixed cost support, see next section).

[15] *An additional criterion was that the share of firms with output losses during the shutdown phase above 100% (for which we set the loss to 100%) is lower than 1%.*

4 Mitigating measures

Mitigating measures serve to cushion the loss of firms' revenue and households' income triggered by the COVID-19 containment measures in order to minimize the damage from the deliberate temporary reduction in economic activity. In our analysis, we investigate measures aimed at incorporated firms.[16] These include fiscal measures by the Austrian government and other legislative measures as well as private initiatives, such as private bank moratoria. For the purpose of this paper, we classify them, within our model, by their mechanics. We distinguish between equity injections via grants and subsidies (e.g. short-time work), long-term liquidity support via payment deferrals of more than three years (e.g. credit guarantees) and short-term liquidity support via payment deferrals of up to three years (e.g. social security contributions). We used all available data sources to calibrate the mitigating measures (see Figure 4).[17] Whenever firms in our model were not able to reach actual pay-outs (due to not meeting eligibility criteria), we stuck with model maximum payout. In case we had no data on the actual use, we assumed that all eligible firms apply to maximize payouts. Note that 30 June 2021, is the cutoff date for all mitigating measures and associated reporting included in this analysis. We are now going to briefly describe each of the four categories of mitigating measures.

Figure 4
Overview of mitigating measures



[16] *There are several other mitigating measures in place, most importantly the hardship fund, which, however, do not specifically address incorporated firms. For this reason, we excluded them from our analysis.*

[17] *Reruns of our model for the June 2020 and the December 2020 scenarios are also based on the latest available information regarding the use of measures by incorporated firms.*

4.1 Capital Injections via grants and subsidies

Financing of fixed costs for particularly hard-hit industries[18]

With the initial funding guidelines for grants for fixed costs (Fixkostenzuschuss-Richtlinie – FKZ) and their extension (FKZ II), the Austrian government introduced grants to cover firms' operating costs. Such grants are awarded to companies that have suffered a loss in sales of at least 40% (FKZ) or 30% (FKZ II). The fixed cost subsidy is staggered and capped depending on the turnover loss. In addition, several eligibility criteria are meant to ensure that firms that experience distress due to the COVID-19 containment measures may apply, but not those that were already struggling before. The overall volume of this measure initially amounted to EUR 12 billion, but the same earmarked funds were later also used for revenue and loss compensation (see next paragraph).

Revenue and loss compensation for industries affected by containment measures[19]

In addition to the fixed cost support for particularly hard-hit industries, the Austrian government introduced additional grants to cover firms' operating costs for industries directly and indirectly hit by lockdown measures. Directly affected firms are determined based on NACE code lists, eligible firms were granted 80% (November) and 50% (December) of the reference period's revenue. Indirectly hit firms were granted less, based on additional eligibility criteria and staggered rates. Moreover, for the period 16 September 2020 to 30 June 2021, firms that have suffered a loss in sales of at least 30% were eligible for loss compensation. Similar eligibility criteria as for the fixed cost support were introduced to ensure that only firms that came into trouble because of the COVID-19 containment measures may apply. Fixed cost support grants, revenue compensation and loss compensation for any period were mutually exclusive and the overall volume all measures amounts to EUR 12 billion.

COVID-19 short-time work[20]

The COVID-19 short-time work allowance is a modification of an instrument that was already installedduring the financial crisis. It was initially designed for a duration of three months, and twice extended, ultimately until the end of March 2021. Under this scheme, employees receive income support amounting to between 80% and 90% of their previous net wage or salary. The amount depends on their original net wage or salary and is capped at the maximum contribution basis for social security. During the first two phases, it was possible for firms to reduce employees' working hours – and thus remuneration – by 10% to 90%. In the final phase, working time could be reduced by 20% to 70%.

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[18] *Fixed cost support is based on Article 3b para 3 of the Act establishing a government-owned holding company for wind-down purposes (Bundesgesetz über die Einrichtung einer Abbaubeteiligungsaktiengesellschaft des Bundes – ABBAG; Federal Law Gazette I No. 12/2020), and two guidelines, namely guidelines for grants for fixed costs (phase 1) (Fixkostenzuschuss-Richtlinie, Federal Law Gazette II No. 225/2020) and guidelines for grants for fixed costs (phase 2)(Fixkostenzuschuss-Richtlinie 800.000, Federal Law Gazette II No. 326/2020).*

[19] *Revenue and loss compensation are based on Article 3b para 3 of the Act establishing a government-owned holding company for wind-down purposes (Bundesgesetz über die Einrichtung einer Abbaubeteiligungsaktiengesellschaft des Bundes – ABBAG; Federal Law Gazette I No. 44/2020), and three guidelines, namely guidelines for lockdown revenue compensation (November) (Lockdown-Umsatzersatz-Richtlinie; Federal Law Gazette II Nr. 565/2020), for lockdown revenue compensation (December) (3. Lockdown-Umsatzersatz-Richtlinie; Federal Law Gazette II Nr. 608/2020), and for loss compensation (Richtlinien über die Gewährung eines Verlustersatzes; Federal Law Gazette II Nr. 568/2020).*

[20] *Short-time work is based on Article 37b Public Employment Service Act (Arbeitsmarktservicegesetzt – AMSG; Federal Law Gazette I No. 71/2020).*

Sector-specific measures[21]

The support package for hospitality venues such as restaurants ("Wirtshauspaket"), which amounts to EUR 500 million, combines tax relief with measures aimed at stimulating demand. The emergency aid for the tourism sector includes bridge financing of up to EUR 100 million for domestic tourism. The overall volume of support measures comes to EUR 600 million.

4.2 Long term liquidity support via payment deferral greater than 3 years

Credit guarantees[22]

The Austrian government introduced several measures to provide support by guaranteeing new loans. Note that the new framework was put on top of existing structures and their guarantee products. Eight different guarantee schemes had been designed, each with its own terms and eligibility criteria. The overall volume of earmarked guarantees amounts to EUR 15 billion. By year end 2020, Austrian companies had drawn roughly EUR 7 billion of this amount according to data reported to the OeNB (EBA, 2020b).

Debt moratoria[23]

While the Austrian government also introduced a legislative moratorium on bank debt, eligibility restrictions mostly exclude incorporated firms. However, a private, i.e. nonlegislative, sector-wide debt moratorium (EBA, 2020a) peaked at EUR 14 billion (of affected credit volume) in June 2020, according to data reported to the OeNB (EBA, 2020b).

4.3 Short term liquidity support via payment deferral of less than 3 years

The Austrian government agreed on a tax relief package that contains various measures, including a reduction of 2020 corporate tax advance payments to zero, and a deferral of social security contributions. Since we focus on firms that suffer losses and hence face bankruptcy risk, we do not consider the former measure in our model. The deferral of social security contributions, by contrast, has an impact on all firms. Firms directly affected by the lockdown measures were automatically selected for the (interest-free) deferral for the period from February to April 2020. Other firms with COVID-19-related liquidity problems could apply for this measure. From August to December 2020, all firms could apply for an additional three-month deferral. Initially firms were to pay the contributions until mid-January 2021. This was extended multiple times in case of persistent payment difficulties, with the latest regime foreseeing both, a "safety car phase" with minimal payments until end-2021 and payment in installments until mid-2024. Interest must be paid by firms for all post-April 2020 contribution periods.

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[21] *The measures supporting restaurants are mainly based on a temporary tax relief granted pursuant to Article 28 para 52 VAT Act 1994 (Federal Law Gazette I No. 60/2020).*

[22] *Credit guarantees are based on three different laws and extended by COFAG, the Austrian COVID-19 financing agency, pursuant to Article 6a para 2 of the Act establishing a government-owned holding company for wind-down purposes (Bundesgesetz über die Einrichtung einer Abbaubeteiligungsaktiengesellschaft des Bundes – ABBAG; Federal Law Gazette I No. 12/2020); austria wirtschaftsservice (aws), a state-owned bank providing funding for Austrian companies, pursuant to Article 1 para 2a Guarantee Act 1977 (Federal Law Gazette I No. 23/2020); the Austrian Hotel and Tourism Bank ÖHT and aws, pursuant to Article 7 para 2a SME Promotion Act (Federal Law Gazette I No. 16/2020).*

[23] *The public debt moratorium is based on Article 2 2nd COVID-19 Act (Federal Law Gazette I No. 58/2020), the private sector-wide debt moratorium is based on EBA (2020a).*

In our model, we complemented this scheme with the inclusion of a mechanism we called "Delayed insolvency filing due to deferral". This permits us to reflect the fact that roughly 60% of insolvency filings in ordinary times are triggered by the public sector, which obviously will not file for insolvency if any of possibilities to defer payments are invoked.

4.4 Changes to the insolvency regime

The Austrian government also introduced a temporary change to the Austrian insolvency law.[24] Initially from April to June, later extended until October 2020, overindebtedness was suspended as a basis to open insolvency procedures. In addition, tax authorities and public health insurance providers agreed to suspend bankruptcy filings from March to May 2020.

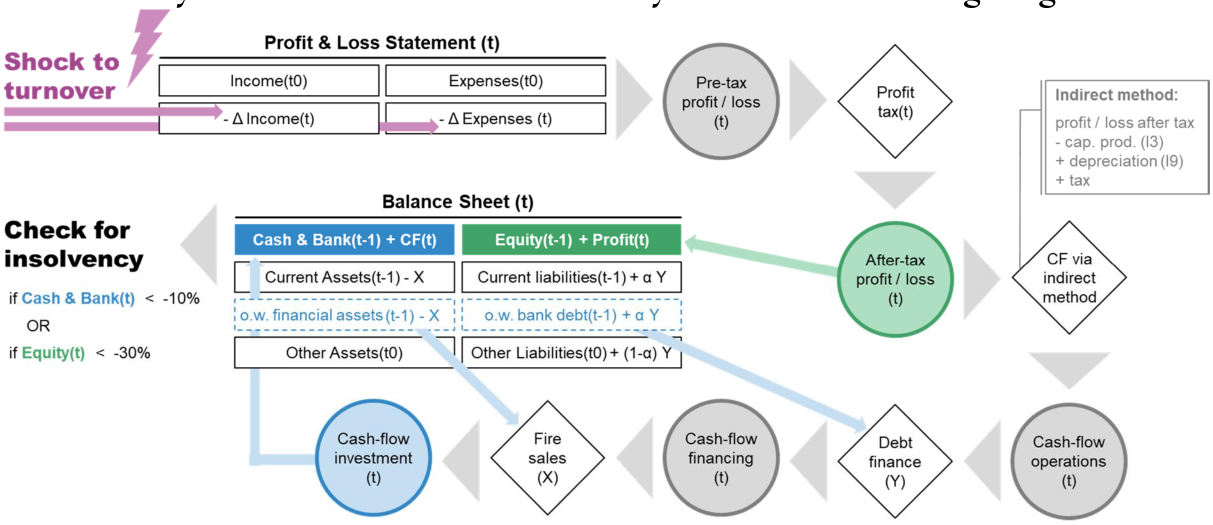
[24] *The insolvency moratorium is based on Article 9 2nd COVID-19 Act (Federal Law Gazette I No. 58/2020.*

5 The corporate insolvency model

Figure 5 shows a stylized version of the corporate insolvency model. For each firm, the model considers that firm's profit and loss statement, its cash-flow statement and its balance sheet. We simulate 100,000 firms per sector and calculate the effects of sector- and firm-specific shocks to profitability and, subsequently, liquidity, with liquidity being a function of a firm's profitability and balance sheet characteristics. We evaluate on a monthly basis whether firms fall below specific thresholds for solvency or liquidity, which triggers insolvency. This section explains the model in more detail. The model equations can be found in Annex 2.

Figure 5

Stylized overview of the insolvency model without mitigating measures



5.1 Profit and loss statement

An output shock in period t derived from a macroeconomic scenario generates stress to firms' income that can only be partly offset by a reduction in expenses. We take the sectoral output shock as loss in turnover and stress financial income in line as well. We also account for production-related costs and various fixed costs, including interest payments and depreciation. A crucial part here is the calibration of firms' responses to a fall in turnover. In our simulation, firms react by reducing their nominal cost components. We do not distinguish between the reduction of the quantity of the cost components and their prices. We do this by calibrating response elasticities of the different cost components with respect to changes in turnover (see Table A3 in Annex 1). Such an elasticity describes the percentage decline of a cost component relative to the percentage decline of turnover. We distinguish between cost components that are (partly or completely) related to the volume of production and cost components that are fixed in the short run. The costs of intermediate goods are directly related to the volume of production, which suggests an elasticity of 1. Due to firms' contractual obligations, we assume a slightly lower elasticity of 0.9 for all industries. Expenses for external supplies and services (e.g. maintenance of plants and buildings or the consumption of energy and water) are only partly related to the volume of production. Hence, we assume an elasticity of 0.5 for all industries.

For staff costs, we use data on unemployment and on the take-up of short-time work. We calculated sector-specific elasticities by dividing the cost savings (in % of the total wage bill), derived from laying off workers and receiving payments for short-time work at the beginning of May 2020, by the decline of turnover in April 2020. In the scenario without short-time work, we assumed that firms lay off 50% of the workers for whom they, in fact, used short-time work. Income and expense positions at time t are calculated as changes versus the starting value $t0$. This yields a new pre-tax profit, which is booked against equity (from $t{-}1$). In case of a positive pre-tax profit, we tax it with the implicit corporate tax rate of 15%.[25]

5.2 Cash-flow statement

We derive the operating cash-flow of each firm in period t based on the indirect method, which uses the pre-tax profit as a starting point, and adjust it for all noncash transactions. In our case, we account for capitalized production and depreciation/amortization but exclude any other structural changes of the balance sheet, such as a decrease (increase) in accounts receivable or a decrease (increase) in inventories. These simple accounting identities yield the net cash-flow from operating activities. For the cash-flow impact of financing activities, we solely focus on refinancing bank debt. As we take the starting balance sheet structure as a given, we do not account for the possibility of firms' access to new credit in the standard model. For refinancing, we introduce active banks. Any given firm with an equity ratio above zero is assumed to refinance its current bank debt, i.e. maturing bank debt and installments. To reflect the repayment of loans, firms do not refinance 100% but only 80%. We use this rate to match the historical ratio of interest to principal payments (see Schneider and Waschiczek, 2018). Firms with an equity ratio of zero or less, however, will not be able to refinance their current bank debt. Yet, they will be able to use undrawn credit lines, which are significant according to data reported by banks to the OeNB. Hence, in our model the impact on firms' cash-flow is 80% of the simulated current bank debt position.[26] Finally, we assume that firms' debt profile is stable over time, i.e. repayment is spread evenly across months for the first year, and current bank debt in the second and third year resembles current bank debt at $t0$. No other firm behavior is considered for calculating the cash-flow after financing. For the cash-flow impact of investment activities, we take an even more restrictive approach. In line with the static balance sheet assumption, we assume that firms do not invest. There is one important exception: firms with a negative cash-flow (first occurrence) can divest. The result is an unrealistic evolution of surviving firms' balance sheets, but as we are mostly interested in the insolvency rates at this stage, investments would hardly play a role. As far as divestments go, firms can only sell current other financial assets (restrictive), but they can sell at book value at short notice, i.e. without an additional equity impact due to a fire sale haircut.[27] Additional cash-flows from divestment leave us with the cash-flow after investments, which is used to update the cash and bank position in each firm's balance sheet.

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[25] *While 15% does not match Austria's statutory corporate tax rate of 25%, aggregate simulation results without a turnover shock based on the lower figure match the historical tax rates (measured as a share of the total balance sheet) of the BACH time series.*

[26] *Undrawn credit lines are part of banks' supervisory reporting to the OeNB (previously for the central credit register, now granular credit data reporting or GCR). It is, however, not possible to directly match the BACH/SABINA databases with banks' reporting. Hence, the calibration of 20% – while broadly matching aggregates – has to be considered experimental or preliminary.*

[27] *Of all the assumptions in our model, these probably have the weakest economic foundation and need to be considered purely ad-hoc-ish.*

5.3 Balance sheet

Broadly speaking, we model three categories of assets and liabilities: first, the buffers against insolvency, i.e. an aggregate liquidity position (cash and bank) on the asset side and an equity position on the liability side (equity). Second, we include current assets and liabilities, broken down into three subcategories to model firms' cash-flows. However, at this juncture, only current other financial assets (available for divestment) and current bank debt (that needs to be refinanced) are considered in our model. Third, we combine all other assets and liabilities, respectively, as they do not yet play a role in our model.

5.4 Insolvency thresholds

Both in general and according to Austrian insolvency law, corporate insolvencies can be triggered either by overindebtedness or illiquidity. To reflect these two dimensions in our model, we consider the equity and the aggregate cash and bank positions relative to total assets as best measure, respectively. We introduce two separate thresholds, namely –30% for the equity ratio and –10% for the liquidity ratio, i.e. cash and bank, to flag insolvency. A firm becomes insolvent if it falls below one of these thresholds, and the firm remains insolvent even if future profitability leads to a return above the threshold. While the threshold for overindebtedness is well justified by empirical evidence[28], the foundation for the illiquidity threshold is weaker. We use a negative liquidity threshold (instead of zero) since the firms can rely on undrawn credit lines from banks.

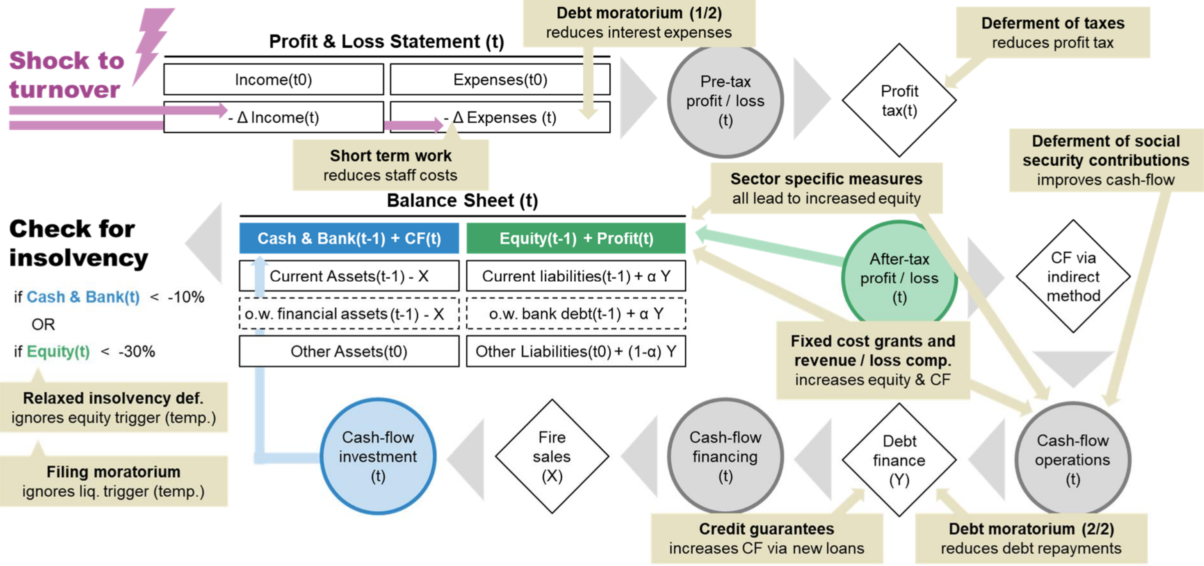
[28] We set the overindebtedness threshold at –30% for two reasons: (1) based on this threshold, we replicated recent insolvency rates per sector at the starting point, and (2) cross-country empirical studies show that the equity ratio commonly associated with insolvency ranges from –30% to –35% (see Davydenko, 2007).

6 Implementation of the measures in the insolvency model

Figure 6, which adds mitigating measures to Figure 5, shows how the above-mentioned measures (for details see Section 4) are implemented in the model. Note that the current calibration assumes maximum efficiency for all stakeholders: firms know when they are eligible for a measure and apply right away and the institutions charged with executing the measures pay out immediately.[29] This section explains the calibration in more detail.

Figure 6

Stylized overview of the insolvency model with mitigating measures



6.1 Capital injections via grants and subsidies

The *fixed cost grant* can be implemented easily, as both the eligibility criteria and the subsequent payouts are codified in law: the criteria as thresholds for lost turnover for a period of up to three months, namely from mid-March to end-July 2020 (phase 1 or FKZ), or up to four months, namely from June 2020 to mid-March 2021 (phase 2 or FKZ II), and the payouts as a share of fixed costs. Grants are not mutually exclusive, i.e. firms can apply for FKZ and FKZ II. They must, however, provide proof that they did not request support for the same expenses twice. In the insolvency model, we include these payout shares for the BACH positions operating charges and interest expenses. As some optionality is included, firms that apply for fixed cost support maximize payout. Nevertheless, of the overall FKZ volume, less than EUR 1 billion is paid out for each in our simulations, with the exception of the first (2020-06), for which FKZ II was not yet available and payout exceeded EUR 1 billion.[30] The payouts are modeled as even shares from the month after the first possible application to one month after the application deadline.

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[29] *One of the next model development steps is to relax this assumption and to replace it by more realistic assumptions based on experience gained with the measures.*

[30] *In previous iterations of our model, namely 2020-09 as published in Puhr and Schneider (2021), when revenue compensation was not yet available, but FKZ II, this quantification does not hold either.*

From 2020-12, we follow a similar logic for *revenue compensation* which was introduced to provide mitigation for the hardest hit sectors during Austria's second COVID-19 wave in the months November and December 2020. Again, eligibility criteria and the subsequent payouts are codified in law. There was slightly more conditionality depending on the two-digit NACE classification of each firm, but with some generalizing assumptions we are able to broadly mirror the law. Payouts depended on at least 30% of lost turnover and compensation was at 80% (*November*) and 50% (*December*) of the reference period's revenue, which we approximated with firms t0 (i.e., pre-simulation) revenue. As a consequence, we had to implement an artificial application rate (for eligible firms), to mirror the actual pay outs of EUR 2.2 and 1 billion as reported by Austria's government. Introduced even later (and therefore available only for the simulation 2021-06), *loss compensation* eligibility was again precisely defined in law, with the main material criterion a turnover shock of greater than 30%. As the measures from the *fixed cost grant* and the two compensations were mutually exclusive, the introduction of the latter lead to a drop in the former's take up rate in our simulations.
The impact of *short-time work* on staff costs is based on data on the take-up of short-time work as explained above. Short-time work reduces staff costs and hence directly impacts on profits. Payout is assumed to be immediate and figures in our results show a payout starting at roughly EUR 6 billion in the June 2020 simulation to close to the maximum of EUR 11 billion in June 2021. Given the multitude of transmission channels of the measures sketched out above and the lack of eligibility criteria, we treat *sector-specific measures* as an equity injection to all firms of a given sector and calibrate the volume as a share of turnover. A 2.5% share of turnover leads to a payout of EUR 600 million across all firms of the sector. Payout is again immediate.

6.2 Long term liquidity support via payment deferral greater than 3 years

Given the current granularity of our simulated data, we cannot replicate the eight, previously mentioned, different *credit guarantee schemes* as designed in our model. Hence, our modeling strategy relies on broader, common characteristics of the guarantees that are applied evenly across all firms. A firm will apply for a guaranteed loan the first time it faces a negative cash-flow in an observation period. In line with most guarantee schemes, the credit-issuing bank will vet the applicant firm and only grant credit in case of a positive equity ratio (the same criterion is applied for rolling over credit). However, these restrictions are still too soft and would result in the issuance of guaranteed credit of more than EUR 32 billion. This figure is more than twice the overall volume available or more than six times the guarantees that have been granted to firms by end-June 2021. Consequently, we introduce a random approval rate of between 40% and 80% in application months to match real world data available at OeNB. In our model, pay-out is immediate. *Debt moratoria* somewhat resemble credit guarantee schemes. Again, we have to make some broad-based assumptions in light of the different types of moratoria and, even more so, the lack of details regarding private moratoria. To match data available at OeNB from April 2020, we apply the following rules: any firm that makes a loss in April 2020 (worst monthly turnover shock for all sectors during the first COVID-19 wave) applies for this measure. 15% of applicants are granted relief from interest and principal payments from April to June 2020. From July to December 2020, the moratoria are phased out. Pay-out is again immediate.

6.3 Short term liquidity support via payment deferral of less than 3 years

The *deferral of corporate tax payments* has no effect on insolvency rates in our model, since only firms with a negative profit can become insolvent. While impacting on the cash-flow, the *deferral of social security contributions* has no impact on profits, since incorporated firms must use the accrual principle when preparing their balance sheet. The *filing moratorium* was implemented such that 50% of illiquidity-induced insolvencies are not triggered for the duration of the measure.[31] This reduced share equals the share of filed bankruptcies seen by tax authorities and public health insurance providers in normal times. Moreover, it is assumed that these institutions postpone their filings further as firms are offered the option to apply for payment in installments. For this reason, we phase out the 50% in steps from the end of the measure proper(the beginning of the optional payment-in-installment / "safety car phase").[32] This is meant to reflect a lack of filing opportunities due to the deferral of payments and administrative red tape. In other words, not all insolvencies can be immediately filed, when the first deferred social security payments will become due.

6.4 Changes to the insolvency regime

We model the temporarily relaxed insolvency law by excluding the overindebtedness trigger from April to June 2020 (June 2020 simulation), or to October 2020 (all other simulations).

[31] *As the maximum date of possible deferral has been frequently pushed back, the duration differs for the three simulation in this paper.*

[32] *For details refer to Section 4.3.*

7 Results

In this section we present the insolvency rates from three distinct simulations with our model (see Section 5 and 6) based on OeNB's macroeconomic forecasts (see Section 3) and mitigating measures in Austria (see Section 4) during the first year of the COVID-19 pandemic. In doing so, we follow the frequency of the official OeNB semiannual macroeconomic forecasts. Note that further intermediate simulations, entailed by quarterly forecast updates, the expansion of old and the addition of new mitigating measures, and counterfactual analyses, substantiate the hereafter mentioned findings in a consistent manner.

We want to highlight that several of the model's results have been published before (e.g. Puhr and Schneider 2021, but also other periodic OeNB publications in the second half of 2020 and the first half of 2021). Although some published results match the simulations in this section in terms of date, macroeconomic scenario, or mitigating measures, results deviate. These deviations mirror our model's evolution: We completed the development stage by 2021Q1 and its re-implementation by 2021Q3 (to put the model on a more sound basis from a software engineering point of view). Moreover, we continued to match available reporting data regarding the use of individual mitigating measures as they became available and when re-running simulations did not revert back to past measure uptake. Consequently, the basis for all simulations in this paper, makes use of improved calibrations and is identical for all simulations. This not only allows a better comparative analysis of the results but also helps to isolate the impact of adjustments to the model's main drivers, i.e., the macroeconomic scenarios and the mitigating measures.

In this section we will present the impact on both drivers on the aggregate insolvency rates in the model, illustrate the impact of different groups of mitigating measures and provide further sectoral decomposition of the results. For a more detailed discussions on, for example, the evolution of balance sheet positions over the simulation horizon (such as capitalization or liquidity positions) or the impact of individual mitigating measures on the model results, please turn to Puhr and Schneider (2021).

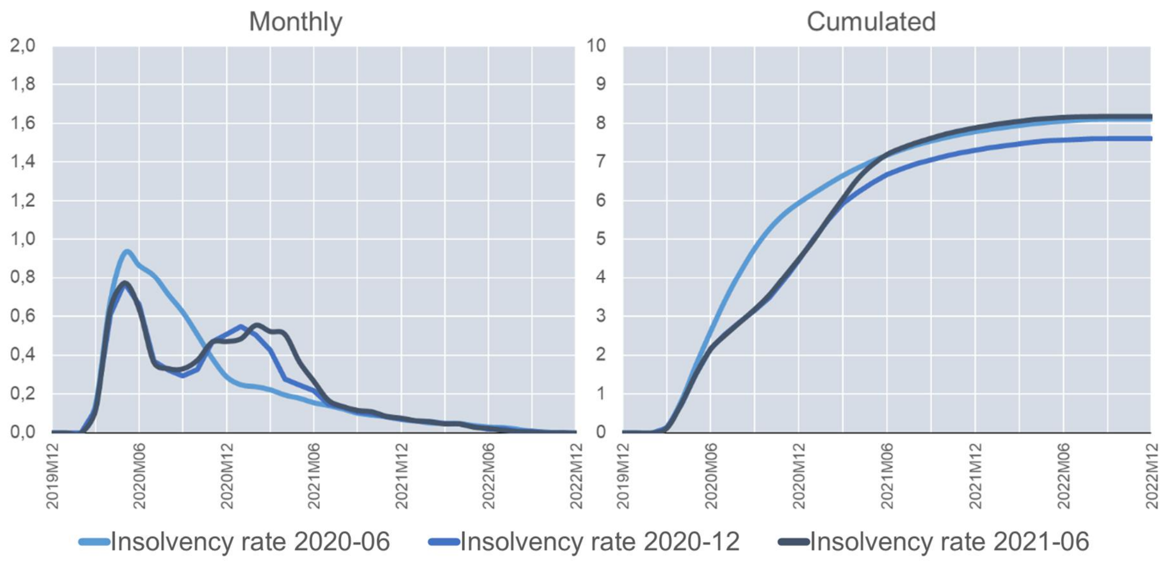
7.1 Aggregate impact of the mitigating measures over time

All three semiannual model runs – 2020-06 (light blue), 2020-12 (medium blue), and 2021-06 (dark blue) – produce insolvency rates based on exactly the same simulated firm-level data set over a period of three years, from January 2020 to December 2022. For 2021-06, a fourth year is available but not on display for an easier comparison across runs. In Figure 7 we show these insolvency rates, as monthly changes (left panel) and cumulated (right panel), for the respective underlying macroeconomic scenario without mitigating measures, i.e. the models outcomes if mitigating measures would not have been introduced. In other words, the chart illustrates the development of the simulated insolvency rates with only one of their main drivers (the macroeconomic forecast) affective. Hence, the aggregated monthly insolvency rates closely mirror the aggregate output shocks derived from the respective forecast (see Figure 3 in Section 3). Changes from one simulation to the next are therefore driven by changing economic expectations in forecast updates, mostly related to the development of the COVID-19 pandemic.

In the 2020-06 model run, monthly insolvencies are expected to rise drastically until mid-2020 based on a scenario with a single but severe COVID-19 wave. The rates thereafter gradually decline for the rest of the observation horizon. In the two latter runs, the forecasts included a second COVID-19 wave and another winter 2020/21 lock-down. In addition, these scenarios were updated in the sense that the initial real world hit on the hardest hit sectors was less severe and the recovery quicker (albeit counterfactual to a simulation without mitigating measures). For the first wave, this obviously leads to a lesser impact. To corroborate this, the last simulation (2021-06) also shows a higher impact from the second wave, even though the shock is shorter (but more pronounced). Finally, the right panel indicates that the model runs 2020-06 and 2021-06 arrive at a nearly identical cumulated insolvency rates by December 2022. This implies that not only the intensity of the output shock is crucial for the development of the insolvencies but also the timing and extent of the more severe shocks. We revisit this idea in more detail in Section 7.3.

Figure 7

Insolvency rates without mitigating measures over time (in %)

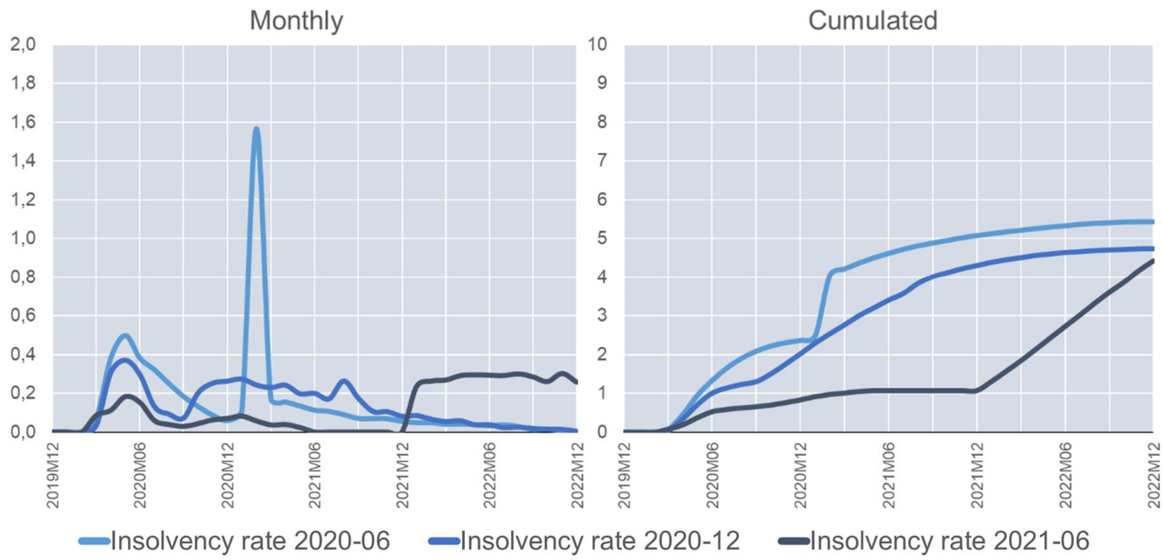


Next, we turn to the simulations with mitigating measures; that is allowing the two main drivers of the modeled insolvency rates to interplay. As expected, the mitigating measures counteract the shocks to output and reduce the insolvency rates. Figure 8 mirrors Figure 7 by displaying all three model runs' monthly and cumulated insolvency rates, now with mitigating measures in place. Note that the mitigating measures were not only expanded in duration and capacity between 2020-06 and 2021-06 but new measures were introduced between 2020-06 and 2020-12. While we include these changes, we apply the latest calibration of our model for each mitigating measure regarding real world pay-outs (for a more detailed description refer to Section 4). A comparison between the right panels of Figure 7 and Figure 8 suggests that the mitigating measures, regardless of the underlying scenario forecast or expansion stage of the measures, have a curbing effect on the cumulated insolvency rates, of, in our calculations, at least 2.7 percentage points. Differences in monthly insolvency rates for the three model runs, however, indicate that the available measures have an even larger impact on when insolvency rates rise.

This impact is most obvious for the model run 2020-06 with a spike of the insolvency rate in the first half of 2021. This cliff-effect is caused by the foreseen mitigating measures phase-out at around the same time (recall, a second COVID-19 wave was neither foreseen in the scenario nor in the design of the mitigating measures implemented by the Austrian government at that point in time). Such immediate phase-out would have hit the modeled firms hard as the shock they had just experienced would not have been digested yet. The expansion of the mitigating measures between 2020-06 and 2020-12 helps to avoid such abrupt cliff-effects. A similar difference in results through model updates is shown by Gourinchas et al (2021) who cannot verify the expectation of a rapid increase in insolvencies in 2021 in their second study. More importantly, this is also what realized data in Austria has shown, real world insolvency rates remain below the already historically low insolvency rates in the last couple of years leading up to the COVID-19 pandemic in 2020.

Figure 8

Insolvency rates with mitigating measures over time (in %)



A further expansion of the mitigating measures between 2020-12 and 2021-06, given broadly comparable macroeconomic forecasts and consequentially insolvency rates without mitigating measures, influences the timing of the insolvencies (by delaying them further) and, to a far lesser extent, the level of the cumulated insolvency rate by end-2022. We will discuss this observation in more detail in the next section. In any case, the latest set of mitigating measures nonetheless yields an insolvency rate approximately 1 percentage point smaller than that of our first model run. Remember that these two insolvency rates were similar in a scenario without mitigating measures. That is, the expansion of measures is effective, for a discussion of individual measures efficiency, however, we would again refer to Puhr and Schneider (2021).

7.2 Decomposition of the mitigating measures over time

Let us take a closer look at the impact of mitigating measures now. Figure 9 displays their impact for three different groups of mitigating measures and the aggregate, i.e. net-impact. The three clusters follow the structure introduced in Section 4: (1) Capital injections, (2) Long-term liquidity, and (3) Short-term liquidity support.[33] The net-impact of all mitigating measure is defined as the mitigating measure-driven percentage point difference between the insolvency rates of a certain simulation with (Figure 8) and without measures (Figure 7).The means by which we calculate the impact on individual groups of measures is turning off all other mitigating measures and re-running our model. Whenever some measures are excluded, more firms will make use of the ones available because they could not benefit from other measures that would have outright put firms on a solid financial basis or at least taken them out of measure eligibility. Consequentially more firms benefit from each measure in sequential runs which causes the combined effect in the run with all measures to be smaller than the sum of the impact of the three separate runs – a difference displayed in Figure 9 as simultaneity bias.

Starting off with the aggregate impact of the expansion of the mitigating measures, we observe several implications for the insolvency rates across our runs. First and most importantly an increasing delay of insolvencies, as visualized in the quarterly panels (on the left-hand side of Figure 9). However, insolvencies cannot be entirely prevented by the expansion of mitigating measures. For the first simulation 2020-06 we can observe the aforementioned immediate reversal in 2021Q1 (once measures run out), for the second simulation 2020-12, this reversal is already much more drawn out (and less pronounced), but peaking in the second half of 2021. Finally, in the last simulation 2021-06, we can observe significantly higher mitigation during the second wave (compared to the second simulation), but also a much starker reversal in 20222 once most measures run out.

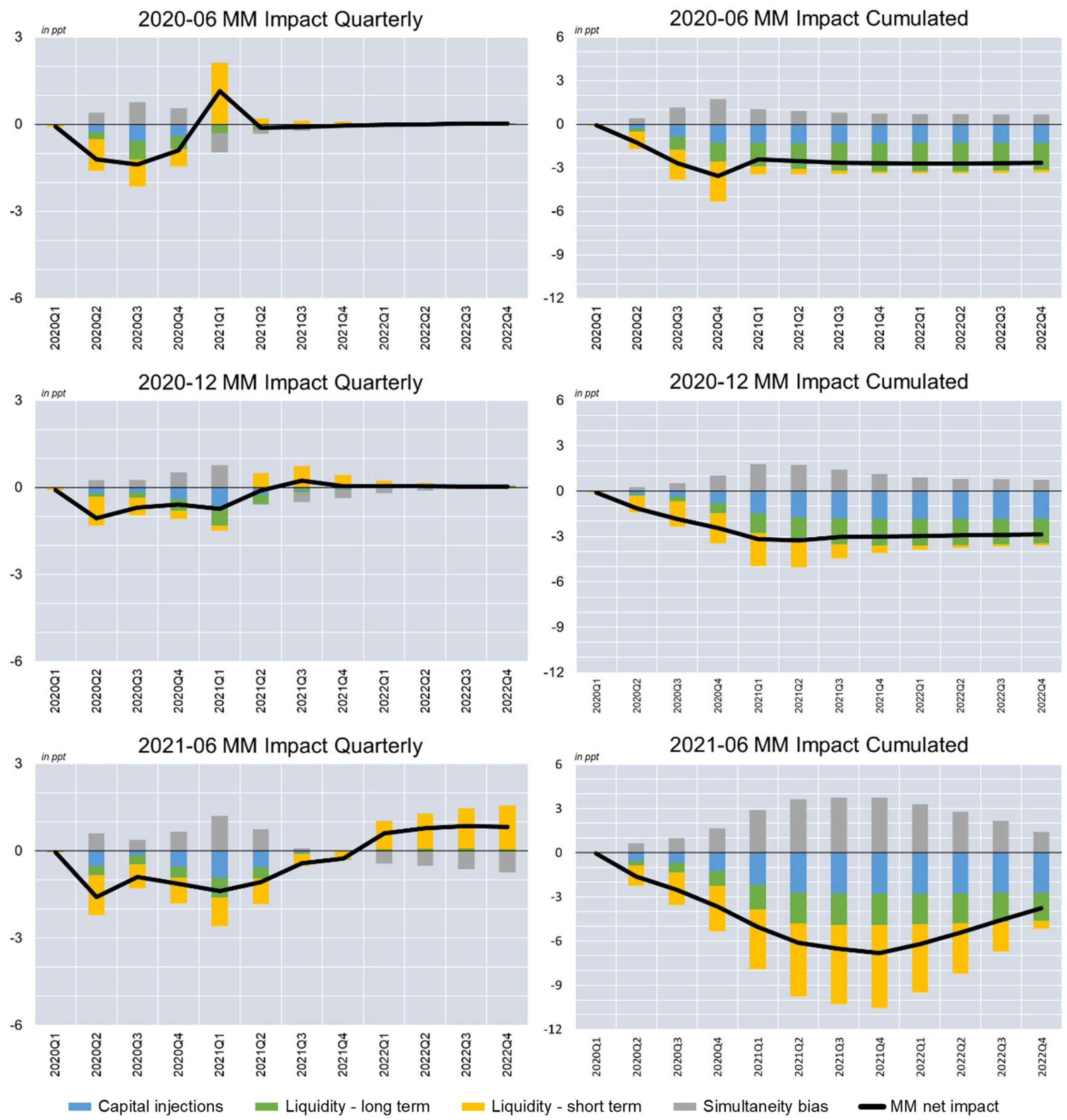
These observations merit closer inspection by the groups of mitigating measures introduced earlier. First turning to capital injections and long-term liquidity support (the latter of which are de facto capital injections during our observation horizon, as the bulk of repayments become due past our observation horizon). Capital injections are represented by the blue bars in Figure 9 and long-term liquidity support by green bars. The panels on the left-hand side, the quarterly impact on insolvency rates, therefore, provides two main lessons: from top to bottom in Figure 9, both the size of the bars increases and bars show further in the future. This reflects the expanding mitigating measures – in term of size and timing – put in place by the Austrian government. The right-hand panel confirms this observation, the cumulated impact on the insolvency rate becomes higher over time.

[33] *The temporary relaxed insolvency law is imputed to the latter cluster.*

Much more interesting is the development of the short-term liquidity support in our model, reflected by the yellow bars in Figure 9. Again, the expansion of these measures is reflected by increasing yellow bars from top to bottom. On the left-hand panels, however, we can now see the reversal of short-term liquidity support by a positive impact on the insolvency rate in later quarters of our observation horizon. A positive impact is obviously a bad thing, as it indicates increasing insolvency rates. This effect becomes more pronounced the more generous initial short-term measures become, as bills eventually become due. Turning to the right-hand panel, the cumulated impact. We see hardly a difference in the final yellow bars across simulations despite significantly different paths to the endpoint. Nevertheless, in the latest simulation (2021-06) the final yellow bar is still significantly larger (with a negative sign, helping to reduce the aggregate insolvency rate). However, this comes with one significant caveat, the grey bar (simultaneity bias), is also significantly larger.

Figure 9

Impact of mitigating measures over time



Returning now to the aggregate picture we can conclude that (i) the expansion of the mitigating measures between 2020-06 and 2020-12 had an irrevocably positive effect by reducing cumulated insolvency rates. (ii) the expansion of the mitigating measures between 2020-12 and 2021-06 points at a more nuanced conclusion, as the expansion and uptake are not fully mirrored in the net-impact. This highlights the conjecture of an optimal set of available mitigating measures (in terms of volume, type of measure, and time of availability). Bluntly speaking, "the more the merrier" does not apply in the context of mitigating measures.

Firms eligible for short-term liquidity support measures in 2021-06, presumably, are also able to make use of measures of the other two clusters whenever all mitigating measures are available in our model runs (as corroborated by the cumulated simultaneity bias of up to 4 ppt). Consequently, and due to our relatively short observation horizon, it appears as if the take up of short-term liquidity measures leads to mitigating measure-driven delayed defaults by the end of the observation period. This interpretation comes with several constraints: (i) neither are we able to model similar effects of measures that phase-out later (i.e. long-term liquidity support) nor do we measure later impacts of the short-termed measures (observation time constraint)[34], (ii) the results of each simulation are always dependent on the given macroeconomic forecast (as shown in 7.1), and (iii) any set of mitigating measures could never diminish the insolvency rate further than insolvencies additionally created by the COVID-19-driven output shock. In essence, our model suggests that although the extension of the mitigating measures between 2020-12 and 2021-06 results in a lower insolvency rate (by 1.2 percentage points), a sizable amount of the expansion was designed so that it targeted the same firms within our modeled firm universe.

7.3 Highlights from sectoral impacts over time

Let us conclude the results section with a closer look at the impact of the output shocks to the development of the insolvency rates in our model. For the full picture we have to introduce the sectoral granularity of output shocks, which we have skipped so far. In Figure 10 we chose one of the hardest hit sectors as example, namely the NACE I sector ("Accommodation and Food Service Activities", hereafter: Tourism; dotted lines). Due to COVID-19 containment measures and the fall-out from closed borders, tourism saw, not only extreme shocks to output (left panels) but consequentially reacts viciously in terms of insolvency rates in our model without mitigating measures in place (right panels).

The differences between the three model runs, as a quick comparison across all three panel rows in Figure 10 suggests, however, indicate a much more complicated picture. Differences in severity[35] can be observed over all three forecasts. Generally, a more severe aggregate output shock implies higher (and faster increasing) aggregate insolvency rates. Moreover, multiple COVID-19 waves that lead to further containment measures also yield higher output shocks and consequentially higher insolvency rates.

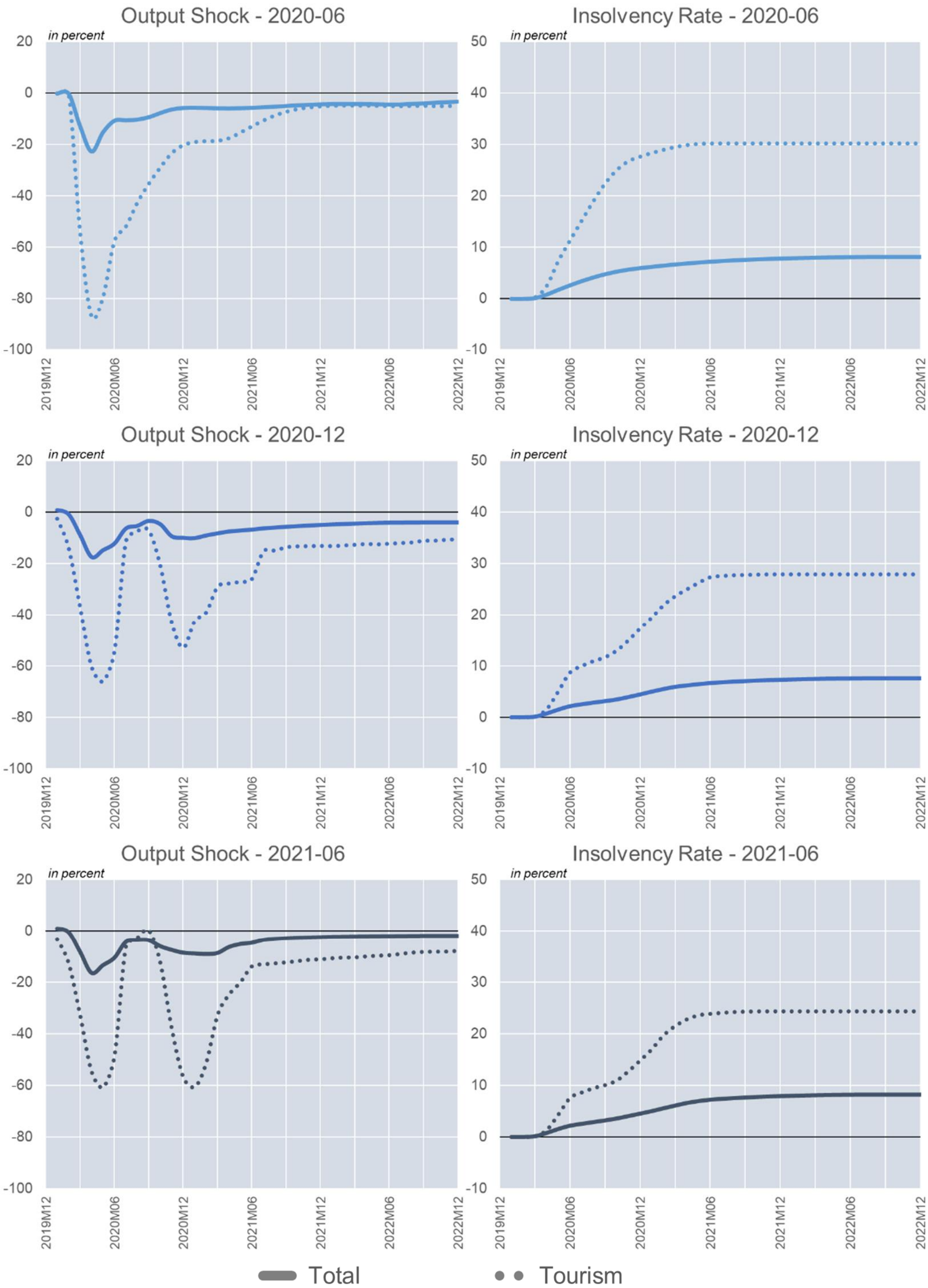
[34] *On a more positive note, however, for the 2021-06 simulation we do have a fourth year available as OeNB's forecast also covers 2023 and we know that under the June 2021 scenario the insolvency rate levels off in this year at less than historic rates in our model.*

[35] *Severity, in this subsection, refers to the magnitude of the mean output shock experienced by the firms of a sector (remember: "the lower the graph (or the more negative), the more severe the shock").*

Figure 10 actually shows this effect: in the latter two scenarios aggregate insolvency rates level-off at about half the level of the first scenario, despite a much lesser difference in severity. This highlights the importance of the initial severity. Subsequently, we would expect a reversal of fortunes, as the June 2020 forecast did not foresee a second COVID-19 wave, while by December 2020 it was already well under way. However, the aggregate cumulated insolvency rate for the latter remains below the former.

Figure 10

Impact of sectoral disaggregation on the cumulated insolvency rates (without MM)



For an explanation it is now time to turn to the output shock of the tourism sector. As it turned out, initial expectations were far too extreme. While the shock was severe, rather than -80%, it came in at -60% and even more importantly, the loss of international guests (as expected in the initial forecast) was almost entirely made up by domestic bookings, which yielded a V- rather than a U-shaped shock. Given the high concentration of insolvencies in the hardest hit sectors in our model, the sectoral update that is barely noticeable in the aggregate shock, yields a material impact on the aggregate results.

A comparison of 2020-12 and 2021-06 simulations complicates the picture even further when we compare the second output shocks. Here 2020-12 and 2021-06 results show that more negative output growth rates (up to 9 percentage points difference) may only translate in marginally higher growth rates for insolvencies (max. 0.3 percentage points). This might, however, be a modelling artifact, as the fortune of a firm in our model depends on a single draw from the multivariate distribution. A model-based explanation may therefore lie in the fact that all structurally weak firms (with negative or low profitability and initially weak equity or liquidity positions) have already defaulted during the first wave, i.e. the marginal impact of a second wave is less pronounced. This might explain why the severity of the second output shock is not leading to month-to-month growth in insolvency rates of an equal level as the first. In other word, more firms withstand two strong output shocks over a longer period than one very strong output shock.

This leads us to the last observation we can draw from the disaggregation of the output shock by sector: the duration of the shock at non-peak levels. In the 2020-06 model run, one shock persists from end Q1 2020 to end Q4 2020 with an impact of at least -20% on tourism's output. Figure 10 shows how the insolvency rates flatten out as soon as the output shock is more positive than -30% (or at least not more than the recent historic average of 2.0%[36]). This finding is corroborated by the difference in the impact of the second COVID-19 wave in the 2020-12 and 2021-06 simulations. The output shock in the tourism sector lasts three months less under the latter scenario. While the insolvency rates at end-Q3 2020 are separated by approximately 1 ppt, the difference increases to 3.5 ppt by end-Q2 2021. Given that the shock is shorter but more severe for the 2021-06 model run and it is this model run that has a lower insolvency rate (by year-end 2022). This somewhat counters our observation above, that one severe shock has more negative consequences, and points to the fact that the duration does indeed matter too.

In summary the disaggregation by sector sheds some light on the implication of our results that appear less straightforward if one were only to consider the aggregate insolvency rate. Ultimately, we can, however, point to a couple, rather unsurprising results: Very strong initial shocks trigger (fast) rising insolvency rates and, in sum, more insolvency rates than successive but less severe shocks. The impact of a second shock appears to be less than the first, but its duration becomes more important. This leads us to two policy conclusions: first, one has to consider the disaggregate picture, because the impact of the COVID-19 pandemic and the containment measures to combat it have vastly different effects on firms from different sectors. Second, the quick implementation of mitigating measures – particularly if the shock is severe – restores firms' financial positions and thereby reduces high insolvency rates (at least in very affected sectors).

[36] *The historic average is based on KSV 1870 data for the tourism sector from 2017 to 2019. It's about the same if we were to expand the average from 2010 to 2019.*

8 Conclusions

The final section tries to do justice to the twofold nature of our paper. On the one hand, we introduced a novel approach for modeling corporate insolvencies in Austria, and on the other, we also presented results of this model. Hence, we start out with important disclaimers regarding our modeling approach with a view to providing guidance as to the interpretation of the model results presented here. We conclude the paper by identifying next steps that we have in mind going forward.

8.1 Important disclaimers

As can easily be inferred from the paper, macroeconomic forecasts in such challenging times are subject to a high degree of uncertainty. OeNB's economists have faced substantial downside risks at each forecast iteration and, at the time of writing, a renewed increase of COVID-19 infections – a fourth wave? – is well underway. At the same time, the macroeconomic impact of each subsequent wave seems to be much lower, both than the wave before and than initially expected in June 2020.

The corporate insolvency model itself is highly stylized and relies on several heroic assumptions. Balance sheets are static (no structural changes/no growth/no investments) and no new firms are incorporated over the horizon of the projection. While balance sheet and profit and loss statement breakdowns are drawn from the multivariate distribution, subitems reflect the relative size of the sectoral means. Moreover, a single draw from the distribution determines how profitably a firm conducts its business over the entire projection horizon. In a similarly crude manner, we calibrate elasticities – i.e. firms' ability to reduce fixed costs – at an aggregate sector-specific or economy-wide level; here, we would certainly benefit from further investigation. In a similar vein, the link between solvency and liquidity is too mechanistic due to an oversimplified role banks play rolling over corporate credit. This also restricts the mitigating measures that firms facing a liquidity crunch can take by themselves. Overall, the calibration of the model probably errs on the conservative side.

The effects of the mitigating measures are also subject to considerable uncertainty. On the one hand, they could be overestimated, since we assume a quick payout of funds based on the eligibility criteria. Delays in application and/or payment would certainly lead to higher insolvency rates and thus make measures less effective. On the other hand, the measures could reduce insolvencies more strongly than assumed due to possible impacts on GDP growth. We based the insolvency rate projection with and without mitigating measures on the same macroeconomic scenario. This can be justified since the mitigating measures are not designed as economic stimulus packages but aim at maintaining the solvency and/or liquidity of the corporate sector. Hence, they do not lead to an increase in demand and thus in production (except for some sector-specific packages). While this holds in the short term (during lockdown and initial easing phase), in the longer term, a scenario without mitigating measures and more insolvencies would negatively impact GDP via production linkages and confidence effects. This would trigger a feedback loop with higher insolvencies. Hence, the effects of the mitigating measures could be even higher than reported.

In light of these important qualifiers, a healthy distrust of absolute results – mainly the projected insolvency rates – should, however, not diminish the valuable structural insights our model provides. While mitigating measures can only partly offset the COVID-19-induced shock to Austrian firms, they play an important role in lowering insolvency rates on aggregate and in the hardest-hit sectors.

As real world insolvency rates have firmly remained below both model results and already low historic rates it is important to note, that we nevertheless expect rising insolvency rates once mitigating measures run out, but that they will most likely not reach the cumulated level foreseen in our model results over the three year observation horizon.

Long-term impact due to long term liquidity support is much harder to assess. Of all measures, credit guarantees in particular appear to have the highest marginal impact in our observation period until end-2022. However, many firms will not be able to rebuild their capital reserves and survive with a weaker balance sheet. While it is outside the scope of our model and therefore also this paper, this issue would merit further investigation in the future.

8.2 Next steps

Within the current framework, i.e. without addressing the above weaknesses, the most important refinement relates to the recalibration of the mitigating measures included in the model as more empirical data become available. Also, if existing measures are extended, endowments change or further measures are put into law, our model allows for a quick integration thanks to the way it is designed. Similarly, the model allows for a simple assessment of counterfactuals. Examples are the integration of frictions with regard to the payout of existing mitigating measures, the recalibration of existing or introduction of additional measures that are not (yet) on the table. Since its first iteration in June 2020, the model has been re-run multiple times to inform internal policy debates.

Beyond the current framework, i.e. when we address the above weaknesses, we see multiple avenues to improve the model. Most importantly, the static balance sheet assumption currently limits the conclusions that can be drawn from our work. An enhancement in this regard would, however, rely on more realistic investment behavior of firms, as profitable firms improve their equity position throughout the observation horizon, while not expanding their business. We believe that this does not impact the lower rung of firms in or close to insolvency, but it is certainly a requirement to be able to draw broader conclusions on a sectoral level. Unfortunately, an extension of the model in this regard is not a straightforward procedure: while we currently assume passive reactions to outside circumstances, firms would have to be transformed into active agents with objective functions.

In the meantime, we can turn to low-hanging fruit to improve the model. Many of the empirical calibrations mentioned throughout the paper merit revisiting. Whenever we chose to rely on economy-wide parameters, we can move to sectoral calibrations, e.g. regarding the calibration of the elasticities of how many firms can reduce fixed costs, but also regarding sectoral differences regarding access to credit in difficult macroeconomic circumstances. Finally, further research could be put into the simulation of firms, be it the extrapolation of profit and loss subitems via sectoral means or the single draw that determines medium-term profitability. Any improvements in these areas will certainly help make our model output more realistic and therefore more valuable for the policy discussions it was initially designed to enlighten.

Finally, we want to mention that we use our insolvency model together with the OeNB's top-down stress testing framework ARNIE to assess the impact of the COVID-19 pandemic on the banking system (see Guth et al., 2020). Rather than employing large-scale regression models to derive risk parameters for credit risk, we infer default probabilities of banks' credit exposure from our results described above. For nondomestic exposures of the Austrian banking system, we extrapolate insolvency rates based on the assumptions that individual sectors face similar challenges across countries and that the overall severity with which individual countries are affected by the pandemic is reflected in country-specific GDP forecasts. To this end, we utilize GDP forecasts by the European Central Bank (ECB) for other countries/country aggregates to calculate scaling factors based on the relative GDP-level deviation.

In a similar exercise, we have marginally expanded the insolvency model to incorporate sectoral cost shocks. This allowed us to make use of our investment in the model for OeNB's first climate risk stress test (see Guth et al., 2021). For this paper, an alternate input / output model generated sectoral output and cost shocks due to the introduction of carbon pricing. Similarly to the regular top-down stress testing exercise, we were able to use the insolvency model's output as input to OeNB's top-down stress testing framework ARNIE to assess the impact of various carbon pricing schemes on the banking system.

We therefore chose to end on a positive note, despite all the remaining challenges, together with our stress testing infrastructure, we see a multitude of future applications of our insolvency model to assess actual and counterfactual scenarios and / or policies and their impact on the Austrian corporate sector and its banking system.

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Annex I: Tables

Table A1
Description of the variables of the firm-level data set

Source	BACH code	Short description	Long description
SABINA	A7	Cash & bank ratio	Includes the amount available in cash, demand deposits and other deposits in financial institutions.
SABINA	E	Equity ratio	Total equity
BACH	R13	Current assets	Ratio of current assets (A2+A3+A41+A51+A6+A7) to total assets (A)
BACH	R16	Current liabilities	Ratio of current debt (L11+L21+L311+L321+L4+L5) to total balance sheet (A)
BACH	A6	Current financial assets	Includes financial assets held for trading and derivatives.
BACH	L21	Current bank debt	mounts owed to credit institutions due to be settled within 12 months after the reporting period
BACH	I1	Turnover	Includes sales of goods and services net of returns, deductions and rebates. Sales ncludes sales of goods and services net of returns, deductions and rebates. Sales are net of VAT and Excise taxes.
BACH	I42	Financial income	Details of other income relating to financial income.
BACH	It1	Total income	I1+I2+I3+I4
BACH	I5	Cost of goods sold, materials and	Sum of costs for raw-, auxiliary- and operating materials, purchased goods and services.
BACH	I6	External supplies and services	Expenses for services rendered by third parties that directly serve to provide own services and for other areas of the company (outside of production) for expenses incurred for purchased services (e.g. maintenance of plants and buildings), provided the material consumption predominates. This also applies to expenses for the consumption of energy and water or waste disposal services.
BACH	I7	Staff costs	Wages, salaries and social contributions (expenses for severance payments and benefits to company employee pension funds, expenses for retirement benefits, expenses for statutory social security contributions as well as taxes and compulsory contributions dependent on remuneration)
BACH	I81	Operating taxes and other operating charges	This item includes expenses that do not require separate disclosure, such as taxes (excluding taxes on income and profits), administrative expenses, sales expenses and operating expenses (e.g. transport costs, consulting expenses, rent, telephone, energy etc.).
BACH	I83	Financial expenses	Expenses from financial assets and from securities held as current assets (e.g. correction of shares held by the company).
BACH	I9	Depreciation	Depreciation on intangible assets and property, plant and equipment as well as capitalized expenses for the start-up and expansion of a business.
BACH	I10	Interest expenses	Interest payments for bank loans, bank overdraft and supplier credit
BACH	I8	Other expenses	Depreciation on current assets, insofar as these exceed the depreciation customary in the company and items I81 and I83.
BACH	It2	Total expenses	Sum of all expenses. Consists of positions I5 + I6 + I7 + I8 + I9 + I10 + I11 (I11 = Tax on profits)

Source: BACH and SABINA databases.

Table A2
Statistics of “Equity” and “Cash and bank”-ratios from the SABINA Database 2018

	Equity ratio							Cash and bank					Number of firms	Average size of balance sheet (1,000 EUR)
					Share of firms with equity ratio							Share of firms with		
	Mean	1. quartile	Median	3. quartile	<-100%	<-30%	<0	Mean	1. quartile	Median	3. quartile	Cash and bank < 0		
TOTAL	39.9	8.7	37.7	71.1	5.4	9.9	17.4	7.7	1.8	9.9	32.9	2.5	129,239	5,506
A	55.5	6.1	29.5	63.3	3.1	7.6	16.2	6.7	1.6	5.4	19.4	0.1	956	2,549
B	50.3	16.4	42.1	70.0	6.2	10.1	14.4	2.4	−0.9	3.8	20.9	35.0	303	20,774
C	45.9	15.1	39.2	66.5	4.5	8.8	14.0	6.8	1.4	7.7	25.6	0.1	10,981	14,402
D	36.1	2.7	18.8	50.5	2.5	6.8	20.9	3.4	0.9	3.7	13.4	0.2	1,527	33,016
E	32.1	16.7	40.5	67.6	3.6	6.1	11.6	4.5	−0.5	6.2	25.4	28.0	621	7,585
F	31.4	10.8	36.1	64.9	3.2	6.8	14.2	11.7	1.5	9.5	29.0	0.1	15,648	2,426
G	42.7	11.1	38.4	69.5	6.8	12.0	17.8	10.0	2.0	10.3	31.6	0.1	27,337	4,067
H	32.7	6.3	29.2	58.4	4.9	10.6	19.6	5.6	2.1	9.8	26.6	0.2	4,672	10,631
I	26.3	−14.9	19.2	51.5	11.0	20.4	32.1	8.5	2.4	8.2	24.7	0.2	8,782	1,984
J	44.6	14.2	49.3	77.3	8.4	12.9	17.6	13.9	7.0	26.5	55.2	0.1	7,877	2,815
L	38.8	2.3	24.6	73.7	2.8	5.8	19.4	4.9	0.4	3.0	14.8	13.7	21,261	7,674
M w.o. 70100	49.5	25.9	58.3	83.9	4.2	6.9	10.4	17.5	4.5	20.1	47.9	0.1	18,427	1,537
N	27.5	10.7	36.3	67.0	5.6	10.3	16.3	8.7	3.9	16.3	41.9	0.2	5,505	5,059
PQ	30.9	9.4	37.4	70.6	6.7	12.1	18.2	17.9	3.6	17.2	45.2	0.1	2,287	1,805
RS	28.8	−8.2	29.1	65.3	11.2	19.4	28.4	16.0	2.3	11.2	34.4	0.2	3,055	2,410

Source: SABINA database.

Table A3
Elasticities with respect to changes in turnover[1)]

	I5 Cost of goods sold, materials and consumables	I6 External supplies and services	I7 Staff costs 2)				I81 Operating taxes and other operating charges	I83 Financial expenses	I9 Depreciation	I10 Interest expenses	I11 Taxes on profits
			Layoffs	Short-term work	Total						
					w.o. short-term work2)	with short-term work					
Elasticities with respect to changes in turnover											
Agriculture, forestry and fishing (A)	0.90	0.50	0.64	0.55	1.19	0.92	0.00	0.00	0.00	0.00	1.00
Mining and quarrying (B)	0.90	0.50	0.38	0.54	0.92	0.65	0.00	0.00	0.00	0.00	1.00
Manufacturing (C)	0.90	0.50	0.10	0.92	1.02	0.56	0.00	0.00	0.00	0.00	1.00
Electricity, gas, steam and air conditioning supply (D)	0.90	0.50	0.02	0.15	0.17	0.10	0.00	0.00	0.00	0.00	1.00
Water supply & sewerage (E)	0.90	0.50	0.28	0.57	0.85	0.56	0.00	0.00	0.00	0.00	1.00
Construction (F)	0.90	0.50	0.68	0.58	1.26	0.97	0.00	0.00	0.00	0.00	1.00
Trade (G)	0.90	0.50	0.20	0.88	1.09	0.64	0.00	0.00	0.00	0.00	1.00
Transportation and storage (H)	0.90	0.50	0.43	0.70	1.13	0.78	0.00	0.00	0.00	0.00	1.00
Accommodation and food services (I)	0.90	0.50	0.35	0.26	0.61	0.48	0.00	0.00	0.00	0.00	1.00
Information and communication (J)	0.90	0.50	0.18	0.58	0.75	0.47	0.00	0.00	0.00	0.00	1.00
Real estate (L)	0.90	0.50	0.64	0.67	1.31	0.97	0.00	0.00	0.00	0.00	1.00
Professional, scientific & techn. services (M)	0.90	0.50	0.19	0.70	0.89	0.54	0.00	0.00	0.00	0.00	1.00
Administrative and support services (N)	0.90	0.50	0.90	0.80	1.70	1.30	0.00	0.00	0.00	0.00	1.00
Education (P)	0.90	0.50	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	1.00
Human health and social work activities (Q)	0.90	0.50	0.90	0.00	0.90	0.90	0.00	0.00	0.00	0.00	1.00
Arts, entertainment and recreation (R)	0.90	0.50	0.11	0.42	0.53	0.32	0.00	0.00	0.00	0.00	1.00

1) These elasticities describe the percentage response of the cost components of the firms relativ to the percentage drop in turnover.
2) In the scenario without short-term work, we have assumed that firms will lay off 50% of the workers for which they have applied for short-term work.
Source: Author's own assumptions.

Annex 2: Equations of the insolvency model

A) Model without mitigating measures

Profit P of firm i in sector n at time t is calculated as total income $I^{t,n,i}$ minus total costs $C^{t,n,i}$. Total revenues $I^{t,n,i}$ are the sum of turnover $TO^{t,n,i}$ and financial income $FI^{t,n,i}$. We considered eight cost components $C_m^{t,n,i}$ in our analysis (cost of inputs, external inputs, staff costs, operating charges, financial expenses, interest expenses, depreciation and other expenses).

$$P^{t,n,i} = I^{t,n,i} - C^{t,n,i} = TO^{t,n,i} + FI^{t,n,i} - \sum_{m=1}^{M} C_m^{t,n,i} \tag{1}$$

Turnover in period t is calculated by multiplying pre-pandemic turnover $TO^{0,n,i}$ by 1 minus the relative shock size the firm faces. To obtain the shock size $\sigma^{t,n,i}$ for firm i in sector n, we assumed that the distribution of the sectoral macroeconomic shock over firms follows a normal distribution.

$$TO^{t,n,i} = TO^{0,n,i}\left(1 - \sigma^{t,n,i}\right) \tag{2}$$

For financial income $FI^{t,n,i}$, we assumed that it follows the development of turnover.

$$FI^{t,n,i} = FI^{0,n,i}\left(1 - \sigma^{t,n,i}\right) \tag{3}$$

The cost components are obtained in a similar way by multiplying the shock to turnover by the response elasticities of the respective cost components.

$$C^{t,n,i} = \sum_{m=1}^{M} C_m^{0,n,i}\left(1 - \sigma^{t,n,i}\varepsilon_m^n\right) \tag{4}$$

Positive profits are taxed with the corporate income tax rate *cit*.

$$P^{t,n,i} = P^{t,n,i}(1 - cit) \tag{5}$$

Each firm's equity position is updated by adding the profit in period t to the equity position of the previous period t-1.

$$E^{t,n,i} = E^{t-1,n,i} + P^{t,n,i} \tag{6}$$

The cash-flow from operating activities $CF_{op}^{t,n,i}$ is calculated via the indirect method by subtracting debt repayment $DR^{t,n,i}$ (our sole source of financial expenses) and adding depreciation $DE^{t,n,i}$. Due to the *static balance sheet assumption*, we do not consider *capitalized production* or similar changes to the balance sheet in our cash-flow calculation.

$$CF_{op}^{t,n,i} = P^{t,n,i} - CP^{t,n,i} - DR^{t,n,i} + DE^{t,n,i} \tag{7}$$

Again, due to the *static balance sheet assumption*, the cash-flow after refinancing activities $CF_{fin}^{t,n,i}$ only considers bank refinancing of already existing debt $D^{t,n,i}$. Banks refinance existing debt minus the share of principal repayment α only if a bank's equity $E^{t,n,i}$ is positive. If it is negative, firm $F^{t,n,i}$ can only make use of undrawn credit lines, expressed as the share of its debt β.

$$CF_{fin}^{t,n,i} = \begin{cases} if\ E^{t,n,i} \geq 0 & CF_{op}^{t,n,i} - \alpha D^{t,n,i} \\ if\ E^{t,n,i} < 0 & CF_{op}^{t,n,i} - (1-\beta) D^{t,n,i} \end{cases} \tag{8}$$

Again, due to the *static balance sheet assumption*, firms do not invest. Therefore, for most firms the cash-flow after investments $CF^{t,n,i}$ (the actual cash-flow in period t) equals the cash-flow after refinancing activities $CF_{fin}{}^{t,n,i}$. However, firms with a negative cash-flow after refinancing activities $CF_{fin}{}^{t,n,i}$ in period t are allowed to disinvest by fire-selling financial assets $FA^{t,n,i}$. We assume that this is possible at book value, i.e. without the application of a haircut. Obviously, firms can divest only once.

$$CF^{t,n,i} = \begin{cases} if\ CF_{fin}^{t,n,i} \geq 0 & CF_{op}^{t,n,i} \\ if\ CF_{fin}^{t,n,i} < 0 & CF_{op}^{t,n,i} + FA^{t,n,i} \end{cases} \tag{9}$$

The liquidity position of each firm $L^{t,n,i}$ is updated by adding the cash-flow (after investments) $CF^{t,n,i}$ in period t to the liquidity position ("cash and bank") of the previous period t-1.

$$L^{t,n,i} = L^{t-1,n,i} + CF^{t,n,i} \tag{10}$$

A firm i in sector n becomes overindebted, i.e. insolvent, in period t if its equity ratio $E^{t,n,i}$ falls below –30%.

$$I_E^{t,n,i} = \begin{cases} if\ E^{t,n,i} \geq -30\% & 0 \\ if\ E^{t,n,i} < -30\% & 1 \end{cases} \tag{11}$$

The firm becomes illiquid if its liquidity ratio $L^{t,n,i}$ falls below –10%.

$$I_L^{t,n,i} = \begin{cases} if\ L^{t,n,i} \geq -10\% & 0 \\ if\ L^{t,n,i} < -10\% & 1 \end{cases} \tag{12}$$

The firm becomes bankrupt if it is either insolvent or illiquid.

$$I_{tot}^{t,n,i} = \begin{cases} if\ F_{Ins\,(E)}^{t,n,i} = 1 & 1 \\ elseif\ F_{Ins\,(L)}^{t,n,i} = 1 & 1 \\ else & 0 \end{cases} \tag{13}$$

B) Model with mitigating measures

The structure of the model with mitigating measures basically equals the structure of the model without these measures. Therefore, we just present the equations that include the measures. For this purpose, we classify mitigating measures according to their impact into *profit-related mitigating measures*, *cash-flow-related mitigating measures* and *mitigating measures that suspend the filing for bankruptcy*. For the sake of simplicity, we refrain from presenting the implementation details of the mitigating measures in algebraic form.

Profit-related mitigating measures $MM_P^{t,n,i}$ include the fixed cost support, short-time work and sector-specific measures (equity injection for NACE I and decrease of value-added tax for NACE I and NACE R). The debt moratorium impacts on profits via deferred interest payments. These measures have a direct impact on firms' equity position. Note that all profit-related measures also impact on the cash-flow and hence the liquidity position of firm *i*.

$$E^{t,n,i} = E^{t-1,n,i} + P^{t,n,i} + MM_P^{t,n,i} \tag{6}$$

In addition to profit-related measures, the liquidity position of firm *i* also depends on *cash-flow-related mitigating measures* $MM_{CF}^{t,n,i}$ (credit guarantees, deferral of social security contributions and the deferral of the principal from the debt moratorium).

$$L^{t,n,i} = L^{t-1,n,i} + CF^{t,n,i} + MM_{CF}^{t,n,i} \tag{10}$$

In addition to profit- and cash-flow-related measures there are *measures that suspend the filing for bankruptcy*. The relaxed insolvency law suspends firms' obligation to apply for bankruptcy in case of overindebtedness. Hence, the insolvency variable $I_E^{t,n,i}$ is set to zero for all firms.

$$I_E^{t,n,i} = 0 \tag{11}$$

The filing moratorium granted by health insurance providers and tax authorities directly impacts on the liquidity variable $I_L^{t,n,i}$. In normal times, half of all filings for bankruptcy due to illiquidity come from these two institutions, which is why we randomly draw from a uniform distribution between 0 and 1 and retain a firm as illiquid if the draw is below 0.5.

$$I_L^{t,n,i} = I_L^{t,n,i} * rand < 0.5 \tag{12}$$