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Modelling the financial situation of Portuguese firms using micro-data: a simulation for the COVID-19 pandemic

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Abstract
We develop a model to simulate firms' balance sheet, income and cash statements and we use it to study the Portuguese firms' financial situation in the aftermath of the COVID-19 shock (2020-2023 horizon). After a significant negative shock to firms' activity in 2020, firms' aggregate profitability recovers until 2023, when it surpasses the pre-pandemic level. During this period, the firms' aggregate capital ratio increases marginally while the cash ratio rises significantly. The increase in the dispersion of firms' financial ratios points to increasing insolvency risks in worst performing firms, particularly for smaller firms and firms in sectors most affected by the pandemic crisis. The proportion of firms with negative equity or insolvent between 2020 and 2023 rises. However, the increase in firms with negative equity is smaller than in the sovereign debt crisis period (2010-2014). The increase is less pronounced when the metrics are weighted by firms' total assets. These results are robust to numerous changes in model assumptions and parameters.

JEL: G17, G32, G33
Keywords: Firms, Micro-simulation, COVID-19.

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1. Introduction

This article presents a model to simulate firms' balance sheet, income and cash flow statements with the aim to assess the financial situation of firms in the short to medium term. The model combines accounting data at the firm level with macroeconomic projections at a sectoral level. The exercise simulates firms' reports at the firm level, from which we derive a large number of financial indicators over the short to medium term horizon, under a set of assumptions on firms' characteristics and economic profile.

We apply the model to the 2020-2023 period in order to analyse the COVID-19 pandemic shock. The abrupt and unexpected reduction in economic activity immediately weakened the liquidity position of firms and increased uncertainty going forward. The persistence of the sanitary crisis turned short term liquidity risks into medium term insolvency risks for some firms, exacerbated by asymmetric effects among different activity sectors.

The relevance and uniqueness of this shock motivated a broad set of analyses to characterize firms' financial situation during the pandemic and assess firms' resilience. Given the magnitude of the pandemic shock and the underlying heterogeneity, assessing firms' resilience at the outbreak of the pandemic was crucial to identify and anticipate risks to financial stability and to support the design of policy measures.

We estimate a gradual recovery of firms' aggregate profitability until 2023, when it surpasses the pre-pandemic level. Still, we find some heterogeneity across sectors of activity and an increase in the dispersion among firms in the same sector. Firms' aggregate capital ratio, which did not decline after the pandemic shock, shows a marginal increase over the simulation horizon. In turn, a robust increase in firms' aggregate cash ratio is estimated.

The reduction in the profitability and in the capital ratio of worst-performing firms, measured in the lower percentiles of the respective distributions, suggests that heterogeneity in recovery may contribute to an increase in firms' insolvency risk, particularly in the most affected sectors.

Consistently, an increase in the number of firms with negative equity or insolvent between 2020 and 2023 was estimated. The deterioration of the financial situation of some firms and the insolvency are regular events in any economic cycle, varying in intensity according to the economy's performance. Compared with previous periods we conclude that the increase in the proportion of firms with negative equity is higher than that observed in the period preceding the pandemic crisis (2015-2019), but lower than in the period of the sovereign debt crisis (2010-2014).

Several papers have been assessing the impact of the Covid-19 pandemic on firms' financial situation, using simulation models at the firm level with varying complexity. Some analysis were published just a few months after the start of the pandemic and focused mainly on firms' short-term liquidity and solvency needs. Carletti *et al.* (2020) assessed the impact of different lockdown periods on profits and capital positions of Italian firms. It concludes that SME and firms

in the manufacturing and wholesale trade sectors would be more affected. Banco de Portugal (2020) analyses the impact of short-term working arrangements on Portuguese firms' liquidity position. Also on the short-term impact of the pandemic, Schivardi and Guido (2020) focuses on the adequacy of liquidity provision schemes implemented in Italy to conclude that firms' liquidity needs would be manageable, even under a more pessimistic/second wave scenario. The authors build on a detailed estimation of intermediate goods and staff costs elasticities to firm sales.

Blanco *et al.* (2020) adds new layers to the simulation exercise by explicitly considering assumptions for a more diverse set of variables, such as the investment in fixed assets and debt repayments, for Spanish firms. The authors put more emphasis on solvency risks by considering three alternative indicators (equity over net assets, the proportion of firms with negative equity and the probability of default). In turn, Puhr *et al.* (2021) considers a 3-year macroeconomic scenario from the Oesterreichische Nationalbank June 2020 projection exercise and a broader set of mitigating policy measures, in order to simulate the financial situation of Austrian firms. The authors also propose an alternative insolvency threshold that incorporates both an undercapitalization criterion and an illiquidity criterion, to conclude that mitigating measures were effective in reducing insolvency rates in aggregate terms and in sectors most affected by the pandemic.

Gourinchas *et al.* (2020) and Gourinchas *et al.* (2021) broaden the scope of analysis with a cross-country perspective, focusing on SMEs and establishing a link between firms' liquidity stress, non-performing loans and bank capital depletion in terms of common equity tier 1 ratio. Several international institutions also conducted related work with a cross-country perspective (EU Comission (2020), IMF (2020) and OECD (2020)). Despite their valuable contributions in terms of methodological innovation and the assessment of policies' adequacy and expected impact, the data considered is typically less granular, resulting in the need to follow simplifying assumptions based on aggregate patterns and a more limited evaluation of tail risk.

More recently, Banco de Portugal (2021a) analyses the evolution of Portuguese firms' liquidity during the pandemic. The main conclusion is that the decrease in operating cash-flows was offset by a reduction in investment and, especially for firms in the most affected sectors and that benefited from support policies, such as loan moratoria and State-guaranteed credit lines, an increase in credit. Banco de Portugal (2021b) analyses the impact of the pandemic on Portuguese firms' equity in 2020 and 2021. The results points to an increase in the percentage of firms with negative equity due to losses' accumulation, especially in the accommodation and food services sector. However, the results also show that more than 80% of firms could strengthen their equity by 2021, compared to 2019, under the assumption of no profits distribution.

Our paper adds to the existing literature in four main aspects: i) it focuses on firms in Portugal, ii) it considers a 3 year horizon after the onset of the pandemic, iii) it takes into account important variables not modeled in most other studies (e.g. an endogenous rule to the supply of new credit and the dynamics of liquidity

accumulation), and iv) it introduces firm level heterogeneity not only from firms' pre-pandemic financial position but also from differentiated paths within each sector of activity in the projection horizon.

We carry extensive sensitivity analysis in order to evaluate the adequacy of the assumptions and parameters considered in the simulation model. Common complexities in forecasting firms' financial variables are enhanced by the elevated uncertainty and potential post-pandemic structural changes in the economic activity. Overall, conclusions continue to follow the same economic intuition and are little impacted by most alternative specifications. The largest impact emerges from a higher operating income rigidity of intermediate expenses and the assumption of no new credit, which led to the increase of insolvent firms over the simulation horizon. Our paper relates with the analysis presented in a Special Issue of the Banco de Portugal December 2021 Financial Stability Report (Banco de Portugal (2021c)), in particular it fully describes the methodological framework and presents evidence on important robustness analysis.

The paper is structured as follows: section 2 describes the methodology and assumptions underlying the firm-level simulation of firms' financial statements, section 3 analyses firms' financial situation over the 2020-2023 horizon and section 4 summarizes the sensitivity analyses to the simulation parameters and assumptions. Section 5 concludes.

2. Modelling the firms' financial statements over the simulation horizon

2.1. Sample of firms

The simulation exercise is focused on Portuguese non-financial private corporations with positive equity at the end of 2019, i.e. before the pandemic, herein referred to as firms. It considers firms with 2019 information available in the Central Balance Sheet Database (CBSD), excluding those in the public administration and defence, financial services and head office and management services sectors.

In order to mitigate issues related to the quality of the baseline information, the simulation exercise excludes firms with no reporting in 2019 in at least one of the following items: (i) turnover, (ii) staff expenses or (iii) total assets.

The sample under analysis includes around 241 thousand firms, which account for 64% of assets, 87% of gross value added (GVA) and 86% of staff expenses of all firms in 2019. This set of firms was kept constant over the 2020-2023 simulation horizon, i.e. no entries or exits were considered. CBSD data for 2020, the starting point of the analyses, was available for most of these firms.

Still, for firms with no 2020 information we considered 2019 as baseline and simulated the values for 2020 in accordance with the assumptions of the exercise. There are approximately 17 thousand firms in this situation which, in 2019, account for 7% of the assets and equity of the set of firms considered. Firms with no 2019 information and with 2020 information (most of them entries) were not considered in the simulation exercise. These approximately 28 thousand firms corresponded in 2020 to 5% of assets and 4% of equity of the set of firms considered.

2.2. Model and main assumptions

The economic and financial situation of each firm is analysed on the basis of an exercise that simulates its balance sheet, income and cash flow statements through a 3 years period. Taking as a baseline the situation of firms in December 2020 the exercise simulates the evolution until the fourth quarter of 2023, using a sequential approach. The exercise uses firm level data available in the CBSD, for 2019 and 2020, and in the Central Credit Register (CCR), for the period between the 4th quarter of 2019 and the 2nd quarter of 2021, combined with the macroeconomic scenario associated with Banco de Portugal's projections for the Portuguese economy published in the June 2021 Economic Bulletin.

2.2.1. Income statement The starting point of the simulation exercise is the net income of each firm i in quarter t, estimated as:

$$\begin{aligned} \textit{Net income}_{it} = {} & I_{it} * \textit{Operating Income}_{i0} - (1 + c_{sdc} * I_{it}) * \textit{Intermediate expenses}_{i0} \\ & - (1 + g_{sdc} * I_{it}) * \textit{Staff expenses}_{i0} - \textit{Other expenses and income}_{it} \\ & - \textit{Interest expenses}_{it} - \textit{Income tax}_{it} \end{aligned} \tag{1}$$

where operating income, intermediate and staff expenses evolve according to firms projected operating income path over the 2020-2023 horizon, embodied in the index I_{it}, and, with respect to intermediate and staff expenses, the weights c_{sdc} and g_{sdc}, accounting for the respective operating income elasticity (where s is the activity sector, d the firm size and c the periods of crisis or recovery).

Table 1 summarises the assumptions made for each item of the income statement. The simulation sequence and variables calibration resort to assumptions anchored in the firm's tax and accounting framework and/or the historical pattern. Most of the assumptions also take into consideration the sector of activity and firm size.

We consider a decomposition of the aggregate macroeconomic projections over thirteen sectors of activity. In order to account for further heterogeneity in the evolution of firms' operating income, it is assumed that the evolution profile of each firm is randomly attributed on the basis of a uniform distribution with an average equal to the projected GVA of the firm's sector of activity:

$$I_{it} = I\_gva_{st} * \textit{idiosyncratic factor}_{is} \tag{2}$$

where I_gva_{st} corresponds to the GVA index of activity sector s and $\textit{ideosyncratic factor}_{is}$ is randomly generated, for a firm of the same activity sector s, according to a uniform distribution:

$$\textit{idiosyncratic factor}_{is} \sim U(0.05, 1.95) \tag{3}$$

The idiosyncratic factor determines the extent to which the evolution of a firm is more or less pronounced with reference to that projected for its activity sector. This factor allows to incorporate some firm heterogeneity while keeping a balanced distribution among firms of the same sector of activity and size. The results presented in this paper refer to a total of 1000 simulations of the idiosyncratic factor for each firm, in a process commonly called Monte Carlo simulation. Taking into account the large number of firms considered in the model, this number of simulations was considered sufficient since a fast convergence of the results and a reduced dispersion of the estimates is observed.[1]

1. The option for the uniform distribution in the Monte Carlo simulations' exercise does not follow the bell-shaped historical profile of GVA changes, i.e. the existence of negative and positive extreme values, which would be closer to the normal distribution. However, the uncertainty regarding the impact of this crisis (which may be very different from those previously observed) motivated the option for the uniform distribution, which limits the extreme values of the distribution, but reduces the concentration around the mean.

+ Operating income	Simulated taking into account the GVA projected for the activity sector and the idiosyncratic evolution profile of the firm.
- Intermediate expenses - Staff expenses	Evolution simulated in line with that of the operating income of the firm, weighted by an elasticity that, in the case of intermediate expenses, encompasses the effect of fixed costs and, in the case of staff expenses, the rigidity in the labour market. The estimated elasticities differ according to the size and sector of activity of the firms and between periods of crisis and recovery. For this purpose the crisis and recovery periods were defined according to GDP developments (2010-2013 and 2014-2019, respectively) The elasticities were estimated with firm-level data between 2010 and 2019, regressing GVA on intermediate expenses or staff expenses, respectively (in line with the approach in Schivardi and Guido (2020)), as detailed in Appendix A.1. Within the simulation period, the crisis period is assumed to be between the Q1 2020 and de Q2 2021 and the recovery between Q3 2021 and Q4 2023.
+/- Other expenses and income	Assumed to remain constant (2020 value). Assumption based on the historical pattern. Between 2010 and 2019, this item remained relatively stable at the firm level.
= **EBITDA**	
- Depreciations	Assumed to remain constant (2020 value). This hypothesis reflects the accounting perspective, whereby depreciation is not impacted by changes in the production output.
- Impairments	Assumed to be null. Hypothesis based on the values observed between 2010 and 2019, in which more than 99% of the firms reported null impairments and, among the firms with impairments in this period, more than 98% presented null values in most years.
+ Interest received	Assumed to be null. Hypothesis based on the values observed between 2010 and 2019, in which about 82% of the firms do not report interests received, and, among the firms that do receive interest in this period, about 85% presented null values in most years.
- Interest expenses	Interest expenses, including paid and unpaid interests, are estimated based on the average interest rate on loans from credit institutions, charged to each firm between 2020 Q1 and 2021 Q2 (source CCR), which is applied to the outstanding amount of bank loans and other financial debt. Between 2021 Q3 and 2023 Q4 interests are estimated taking the average interest rate of the last quarter with observed data (2021 Q2) and assuming that it evolves in line with the macroeconomic scenario projection for the interest rate on new bank loans to non-financial corporations.
= **Gross income**	
- Income taxes	Estimated in line with the general corporate income tax framework: 21% of gross income for large corporations and 17% for SMEs, with exemption for the first €25,000.
= **Net income**	

Table 1. Simulation of the income statement for each firm | Baseline: December 2020 observed data

2.2.2. Cash flow statement and balance sheet dynamics The cash flow statement is estimated from the income statement cash flows and the financing obtained in the period (Table 2).

It is assumed that each firm seeks financing for two reasons:

- Suppress the liquidity shortfall. This corresponds to the amount needed to bridge the gap that occurs when cash and bank deposits at the beginning of the period are insufficient to cover negative operating and financial cash flows:

$$\begin{aligned} \textit{Cash and bank deposits}_{it-1} - (\textit{EBITDA}_{it} - \textit{Income tax}_{it} - \textit{Investment}_{it} \\ - \textit{Paid interest}_{it} - \textit{Financial debt redemptions}_{it}) < 0 \end{aligned} \tag{4}$$

- Restore the pre-pandemic liquidity position (precautionary motive). In order to anticipate upcoming financing needs or because it is the equilibrium situation in terms of treasury, the firm will seek to restore its cash and bank deposits to the value observed before the pandemic or to the historical sector-size average, if the pre-pandemic figure is higher than this average. The cash and bank deposits target is:

$$Min(cx_{i2019}, \overline{cx}_{sd}) \tag{5}$$

where cx_{i2019} is the firm's observed cash and bank deposits in December 2019 and $\overline{cx}_{i2019}$ is the cash and bank deposits corresponding to the average liquidity ratio of the set of firms of sector of activity s and size d between 2010 and 2019. This hypothesis is supported by the fact that in 2020, during the pandemic shock, the liquidity position of firms recorded an increase in aggregated terms.

It is assumed that a firm is able to obtain new financing if it meets at least one of the following criteria:

- *Pre-pandemic growth*, i.e., if the firm had increasing sales between 2017 and 2019.
- *Financial debt below the excess debt threshold*, i.e., when the firm's interest expenses over average EBITDA ratio is less than 0.5 the operating results should be sufficient to ensure the financial burden associated with the debt service. Following Augusto *et al.* (2021) excess debt is defined as:

$$\textit{Financial debt}_{it} \text{ below } \textit{excess debt} \text{ threshold if } \begin{cases} \textit{Interest expenses}_{it} \,/\, \overline{EBITDA}_{it} < 0.5 \\ and \\ \overline{EBITDA}_{it} > 0, \end{cases} \tag{6}$$

where *Interest expenses*$_{it}$ are the interest expenses of firm i in period t associated with *Financial debt*$_{it}$ and $\overline{EBITDA}_{it}$ it is the average EBITDA of the 3 years ended in period t. Financial debt includes bank loans, debt securities and other financing recorded in the firm's liabilities. Firms with a ratio equal or higher than 0.5 are typically associated with a probability of default equal or higher than 20% in a 5-year horizon IMF (2013).

Cash and bank deposits at the beginning of the period	
+ Operating *cash-flows*	EBITDA (*v.d.* income statement).
- Taxes	Income taxes (*v.d.* income statement).
- Investment	It is assumed an average investment rate, taken as a percentage of the depreciation of the firm's fixed capital. The investment rate varies according to the size of firm and leverage bucket (in agreement with the results of Farinha *et al.* (2013)), further distinguishing between crisis and recovery periods (as detailed in Appendix A.2).
- Paid interest	Includes paid interest from the current year and from previous years (e.g. deferred due to moratoria).
- Financial debt redemptions	Computed assuming a constant amortization schedule and the average loan maturity observed for the firm between the Q1 2020 and the Q2 2021 (source CCR). It is considered the average original or residual maturity, depending on whether it is a new loan or not, respectively.
- Distributed dividends	It is assumed an average dividend ratio, taken as a percentage of firm's net income. No dividend distribution is considered in periods with negative net income. The average dividend ratio varies according to the sector of activity and size of the firm, further distinguishing between crisis and recovery periods (as detailed in Appendix A.3).
+ New financing	New financing (bank loans and non-bank financing) is the result of the firm's financing needs, conditional on an eligibility assessment.
+ Proceeds from the sale of assets	Funds obtained with the sale of liquid assets (other than cash or bank deposits), which occurs when the firm has a liquidity shortfall that cannot suppress by using cash and bank deposits or by new financing.
= **Cash and bank deposits at the end of the period**	

Table 2. Simulation of the cash flow statement for each firm | Baseline: December 2020 observed data

In each period, the actual new financing is thus the result of the firm's financing needs and its "eligibility assessment". In a situation where the firm has financing needs and does not meet the necessary conditions to obtain it, it is assumed that the firm sells liquid assets (other than cash and bank deposits) to the extent needed to suppress the liquidity shortfall. It is assumed that the firm does not sell liquid assets to restore its pre pandemic liquidity position (precautionary motive). Additionally, it is assumed that this sale implies a loss of 10% over the gross balance sheet value of the assets sold.

The framework described so far allows the estimation of the economic and financial situation of firms during and after the pandemic and incorporates heterogeneity through several channels. In particular, heterogeneity across firms is driven by the idiosyncratic factor of the GVA evolution, by considering the individual financial situation and operational structure of each firm before the pandemic and by the assumptions (e.g. eligibility to access new credit and recourse to support measures), which typically also consider the size and sector of activity of the firm.

However, there are idiosyncratic elements that are not captured in this exercise. In particular the model does not incorporate structural changes or exceptional restructuring that may have occurred during this period, nor the dynamics of creation/destruction of firms after 2019. In addition, the exercise is developed with information from firms on an individual basis and does not reflect the consolidated management of firms within the same economic group, due to unavailability of information.

2.3. Support measures for firms during the Covid-19 pandemic

In the baseline simulation, the model incorporates the main support measures for firms in Portugal during the Covid-19 pandemic: the public credit moratorium,[2] State-guaranteed credit lines,[2] simplified layoff, support for gradual recovery and extraordinary incentive for the normalization of business activity[3] (for simplicity, these three employment support measures, commonly designated as furlough schemes, are referred to as "layoff"). The support measures are incorporated considering the specific conditions and eligibility criteria defined in the respective legal diplomas (see Table 3). The support received by each firm is simulated on the basis of the micro data available at Banco de Portugal, which, in some situations, identify the firm and the amount of support received (e.g. data on the public credit moratorium and State-guaranteed credit lines are available in the CCR), or by applying eligibility criteria based on the firm size, turnover loss or other relevant economic or financial characteristics (e.g. allocation of firms to layoff based on the findings of the COVID-IREE, the COVID-19 Fast and Exceptional Enterprise Survey launched by the Statistics Portugal and the Banco de Portugal in the beginning of the pandemic).

2.4. Definition of indicators to assess firms' financial situation

The simulation of the balance sheet, income and cash flow statements allows for the calculation of several financial indicators. **ROA** (EBITDA to assets ratio), the **capital ratio** (equity to assets ratio) and the **cash ratio** (total cash and bank deposits to assets ratio) are analysed with respect to the overall value of the set of firms. Moreover, the analysis of the distributions of these variables is based on the percentiles weighted by each firm's assets as at December 2019. In turn, firms' solvency is analysed based on the following indicators:

- **Negative equity**: indicator commonly used in the literature (Carletti *et al.* (2020), Guerini *et al.* (2020), Ebeke *et al.* (2021)) to assess situations where

2. Decree-law No 10-J/2020, of 26 March 2020, as subsequently amended.

3. Decree-Law No 10-G/2020 of 26 March 2020, Resolution of the Council of Ministers No 41/2020 and Decree-Law No 27-B/2020 of 19 June, as subsequently amended. The *Apoiar programme* was not considered due to lack of sufficiently detailed information to set assumptions for the incorporation of this support measure in the model.

the assets of the firm are insufficient to meet its liabilities. This is a limited indicator because it omits the liquidity position of the firm, and the book value of assets and liabilities may differ from the market value.

- **Insolvency**: indicator based on the insolvency definition of the Portuguese Insolvency and Corporate Recovery Code (Decree-Law No 53/2004, of 18 March 2004), which considers a firm unable to meet its due obligations (liquidity criterion) or that has liabilities that clearly surpass its assets (balance sheet criterion). Within the model framework, this definition encompasses firms with cash and other liquid assets below -10% of assets (liquidity criterion) and firms with equity below -30% of assets (balance sheet criterion).[4] Some recent work, in particular Puhr *et al.* (2021), also consider these two dimensions.

4. The -10% and -30% threshold are not set in the Portuguese Insolvency and Corporate Recovery Code although there is some economic reasoning for not setting them to zero. Namely, differences between book and market valuation and sources of liquidity recorded off-balance sheet (e.g. undrawn credit lines).

Measure	Period during which the measure was in place	Firms selection / identification	Main features considered in the model
Public credit moratorium[a]	Q2 2020 to Q3 2021	CCR	Suspension of payments of principal until Q3 2021 and of interest until Q1 2021 (Q3 2021 for firms in the most affected economic activity sectors, as identified in the legal diploma) Non paid accrued interests added to principal at the end of the suspension period Firms in the most affected economic activity sectors (as identified in the legal diploma) have a 1 year loan maturity extension. Firms that took up moratoria are able to obtain financing by using previously agreed credit lines up to the contractual limit in place, even if they do not meet the general eligibility criteria to access banks loans No distribution of net income
State-guaranteed credit lines[a]	Possibility of applying to the credit lines between Q2 2020 and Q4 2021.	CCR and specific eligibility criteria[c]	Firms are able to obtain this source of financing even if they do not meet the general eligibility criteria to access bank loans More favourable financing conditions, with a 18-month suspension of principal payments and long loan maturities Maximum loan plafond established to each firm based on its size, turnover and staff expenses and, if necessary, adjusted according to the actual State-guaranteed credit line amount reported to CCR in 2020
Employment support measures (Layoff)[b]	Q2 2020 to Q4 2021	Assumption based on COVID-IREE[d] and firms' profitability after the pandemic first shock	Savings in staff expenses supported by the firm in accordance with the specific conditions in place in each quarter (e.g. reduction of working hours, exemption of social security contributions and payment of working and not working hours) Maintenance of staff at the level observed before benefiting from this measure until the first quarter after the end of the benefit (although the expenses supported vary according to firms operational income loss) No distribution of net income

[a] Decree-Law No 10-J/2020 of 26 March 2020, as subsequently amended. Although the European Commission State aid Temporary Framework was extended (in November 2021) until 2022Q2, we only allow firm applications to state-guaranteed credit lines until December 2021. [b] The three employment support measures for firms are considered under the term layoff: simplified layoff, support for gradual recovery and extraordinary incentive for the normalisation of business activity. Decree-Law No 10-G/2020 of 26 March 2020, Resolution of the Council of Ministers No 41/2020 and Decree-Law No 27-B/2020 of 19 June, as subsequently amended. The *Apoiar programme* was not considered due to lack of sufficiently detailed information to set assumptions for the incorporation of this support measure in the model. [c] Included firms that have benefited from State-guaranteed credit lines (source CCR, up to 2021Q2) and firms that as of December 2019, i.e. before the pandemic, met all the following criteria: (i) had positive equity, (ii) had no overdue loans; and (iii) were not considered an *undertaking in difficulty*, following criteria adapted from Regulation (EU) No 651/2014, which, within the framework of the model is materialised by the following conditions: (i) the firm has positive equity, and (ii) the firm is not a SME and has a financial debt to equity ratio of less than 7.5 and interest expenses to EBITDA lower than 1. [d] COVID-IREE stands for the COVID-19 Fast and Exceptional Enterprise Survey launched by the Statistics Portugal and the Banco de Portugal in April 2020, aiming to identify some of the major effects of the COVID-19 pandemic on business activity.

Table 3. Criteria for modelling firms' support measures

3. Projecting firms' financial situation into the 2020-2023 horizon

3.1. Key aggregates and firms' financial indicators

The pandemic shock decreased firms' aggregate ROA and increased firms' aggregate capital ratio and cash ratio in 2020 (Table 4). The economic recovery starting in 2021 leads to an increase in aggregate profitability, capital ratio and cash ratio. The three indicators exceed 2019 figures in 2023.

The pandemic crisis' impact differed among sectors of activity, with severe effects on accommodation and food services, where average profitability fell by 11.1 p.p. to -0.7% in 2020, and in transport and storage, where it decreased 4.7 p.p. to 8.5%.

In the accommodation and food service sector, the shock led to a decline in the capital ratio in 2020 and the estimated recovery fails to restore the 2019 values (43.2% in 2023 against 47.3% in 2019). In turn, profitability decreased in the transport and storage sector in 2020 concurrently with a slight increase in the capital ratio. The increase in the capital ratio results from a greater decrease in assets than the decrease in equity. We estimate this sector's capital ratio to be higher in 2023 than in 2019: around 33.4% compared to 32.9%. For these two sectors, there was a decrease in the cash ratio in 2020, as opposed to increases in the remaining sectors of activity. However, the cash ratio is expected to increase in both sectors until 2023.

In the remaining sectors, the pandemic crisis brought about a drop in profitability in 2020, which is expected to reverse until 2023.The capital ratio increased in most of these sectors in 2020. This trend is expected to continue and 2023 values should be higher than in 2019. Simultaneously, cash ratios grow robustly in this period. It should be noted that, on top of improved operational activity, the increase in the cash ratio for all sectors is also driven by the precautionary liquidity accumulation assumption. This assumption has an average effect of $+1$ p.p. on the cash ratio and financial debt in the projection.[5]

In 2020, profitability fell across all firm size classes, most notably in large enterprises (-2.4 p.p.). Profitability recovers faster in large enterprises but all classes manage to reach the pre-pandemic level in 2023. Throughout the horizon, smaller firms' profitability is lower than for larger firms.

The cash ratio is higher in smaller firms, in particular for micro enterprises whose ratio increases 9.7 p.p. in 2023 compared to 2019, against $+1.6$ p.p. in large enterprises. The capital ratio increases for micro and medium sized enterprises between 2019 and 2023, and more markedly for small sized enterprises. In turn, large enterprises' profitability recovery occurs alongside with a drop in the capital ratio, as a result of an increase in assets and a decrease in equity. In fact, the higher dividend ratio considered for large enterprises constrains their liquidity and equity

5. We clarify further the impact of such assumption in subsection 4.4.

accumulation. This assumption matches historical developments, as discussed in Appendix A.3.

We estimate that the full recovery of Portuguese firms applies to most sectors. There is, however, an increase in the dispersion of profitability, capital ratio and cash ratio and, in particular, an increase in the number of firms with lower values in these three ratios (Figure 1). This pattern reveals increased risk in firms with the poorest financial performance, even in a scenario of full recovery in aggregate terms.

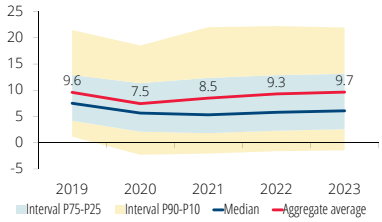
The decrease in the lower percentiles of those ratios is particularly relevant in micro enterprises (for which the ROA's 10th percentile falls from -1% in 2019 to -5% in 2023 and the capital ratio's 10th percentile from 9% to -4%) and in the accommodation and food service sector (ROA's 10th percentile falls from 1% to -3% and capital ratio's 10th percentile from 13% to -10%) (Table 5). In terms of the capital ratio, in addition to the negative change in the 10th percentile in the accommodation and food services sector (13% in 2019 and -10% in 2023), we estimate a larger fall in the transport and storage sector (9% in 2019 and -6% in 2023) and of the construction and real estate activities sector (8% in 2019 and -3% in 2023).

ROA (EBITDA / Assets)					
	2019	**2020**	**2021**	**2022**	**2023**
TOTAL FIRMS	9.6	7.5	8.5	9.3	9.7
Firm size					
Micro	8.7	6.7	7.3	8.3	8.7
Small	9.2	7.2	7.9	9.0	9.4
Medium	9.7	7.8	8.6	9.5	9.8
Large	10.1	7.7	9.3	9.9	10.1
Selected sectors of activity					
Manufacturing	10.4	8.5	9.5	9.9	10.2
Construction and real estate activities	7.2	6.2	6.9	7.0	7.2
Trade	9.0	7.3	8.1	8.8	9.0
Accommodation and food services	10.4	-0.7	3.5	8.9	10.2
Transportation and Storage	13.2	8.5	11.6	12.5	12.6

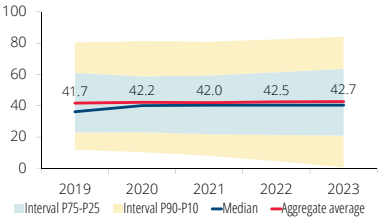
Capital ratio (Equity / Assets)					
	2019	**2020**	**2021**	**2022**	**2023**
TOTAL FIRMS	41.7	42.2	42.0	42.5	42.7
Firm size					
Micro	48.5	48.2	48.1	50.0	51.7
Small	46.0	46.1	46.3	48.4	50.1
Medium	42.3	43.0	42.8	43.5	43.7
Large	36.3	36.9	36.2	35.2	33.9
Selected sectors of activity					
Manufacturing	45.6	46.3	46.4	47.0	47.2
Construction and real estate activities	44.3	45.1	45.7	47.0	48.0
Trade	40.2	41.2	41.5	42.8	43.8
Accommodation and food services	47.3	42.7	40.2	41.7	43.2
Transportation and Storage	32.9	33.3	32.7	33.3	33.4

Cash ratio (Cash and bank deposits / Assets)					
	2019	**2020**	**2021**	**2022**	**2023**
TOTAL FIRMS	8.8	10.4	12.2	12.4	13.3
Firm size					
Micro	15.1	16.8	20.4	22.1	24.8
Small	11.4	13.5	16.1	16.2	17.4
Medium	8.4	9.9	11.6	11.2	11.7
Large	5.0	6.1	6.5	6.4	6.6
Selected sectors of activity					
Manufacturing	8.1	10.2	11.4	11.0	11.4
Construction and real estate activities	8.9	10.3	12.6	13.4	15.0
Trade	10.6	12.5	14.1	14.4	15.6
Accommodation and food services	9.7	9.6	12.0	12.3	14.0
Transportation and Storage	12.0	11.5	14.6	14.7	15.5

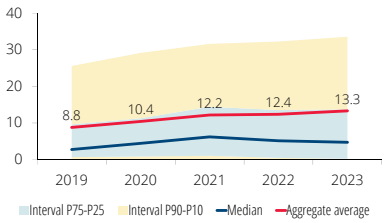
Table 4. ROA, capital ratio and cash ratio | As a percentage of assets



(a) ROA



(b) Capital ratio



(c) Cash ratio

Figure 1: ROA, capital ratio and cash ratio | As a percentage of assets

Note: The percentiles underlying the P75-P25, P90-P10 intervals and the median are weighted by the firms' assets as at December 2019.

	ROA		Capital ratio	
	2019	**2023**	**2019**	**2023**
TOTAL FIRMS	1	-1	12	1
Firm size				
Micro	-1	-5	9	-4
Small	1	-2	12	3
Medium	2	0	13	-3
Large	3	0	12	2
Selected sectors of activity				
Manufacturing	3	0	14	12
Construction and real estate activities	0	-3	8	-3
Trade	2	-1	11	6
Accommodation and food services	1	-3	13	-10
Transportation and Storage	2	1	9	-6

Table 5. 10^{th} percentile of ROA and capital ratio in 2019 and 2023 | As a percentage of assets

Note: The 10^{th} percentile is weighted by firms' assets in December 2019.

3.2. Evolution of solvency indicators

We estimate an increase in the percentage of firms with negative equity or insolvent firms over the simulation horizon, reaching 21% and 18%, respectively, of total firms included in the analysis in December 2023 (Figure 2). These ratios are in line with Portuguese firms' historical financial performance throughout different economic cycles (Figure 3).

These metrics were also weighted by firms' total assets to reflect the weight of each firm in the economy. By doing this, estimates associated with the percentage of firms with negative equity or insolvent weighted by asset value in the 2020-2023 period are halved: 11% of firms with negative equity and 8% of insolvent firms. This weighting is particularly pertinent as it shows that micro enterprises represent a significant share of the total number of firms with negative equity or insolvent over the simulation horizon. Moreover, the share of firms with negative equity or insolvent in total micro enterprises is higher than the shares estimated for larger enterprises.

As regards asset-weighted values, we estimate that around 15% of firms in the accommodation and food service sector have negative equity in 2023, a share that is higher than that estimated in most sectors of activity, which ranges between 7% and 14%. The share of insolvent firms in the accommodation and food service sector in 2023 is similar to that estimated for the share of firms with negative equity (14%), but lower in most other sectors of activity, ranging between 2% and 13%.

The increasing percentage of firms with negative equity or insolvent among a set of firms with positive equity at a given starting point is a stylised fact, which is related to the life cycle of firms and not only determined by the performance of the economy over that period. However, the intensity of this phenomenon varies across business cycles. Comparing the estimates of the percentage of firms with negative equity in the 2019-2023 horizon with the 2010-2014 and 2015-2019 periods, the evolution of these indicators is more severe compared to the period preceding the pandemic crisis, but less severe than in the sovereign debt crisis period (Figure 3).

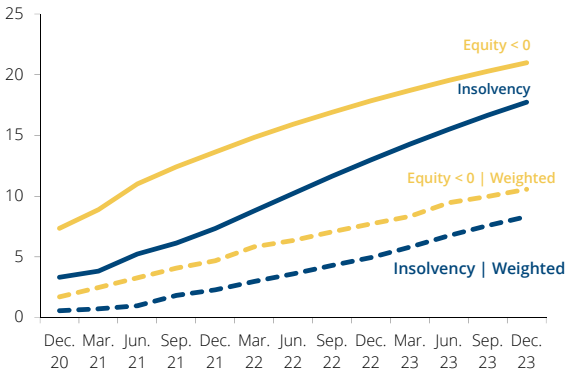
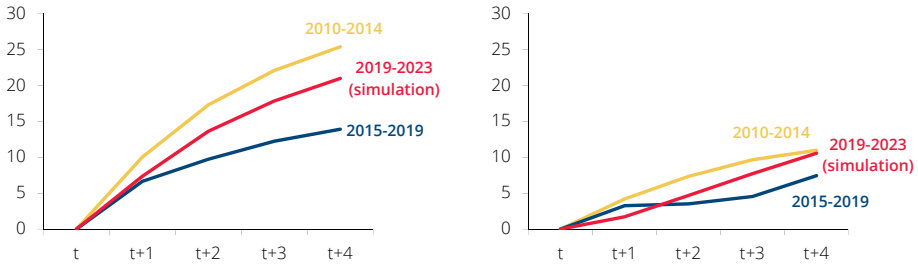


Figure 2: Percentage of firms with negative equity or insolvent | As a percentage of the number of firms and as an asset-weighted percentage

Note: Figures weighted by total assets in 2019.



(a) Percentage of the total number of firms (b) As an asset-weighted percentage

Figure 3: Percentage of firms with negative equity at different horizons | As a percentage of the total number of firms and as an asset-weighted percentage

Notes: For each horizon represented in the figure, the reference t on the x-axis corresponds to the first year of the interval (e.g., for the 2010-2014 horizon, t corresponds to 2010 and t + 4 corresponds to 2014). At each horizon only firms with positive equity at the starting point are considered. In the right-hand side panel the values are weighted by assets at the starting point. The 2010-2014 and 2015-2019 ranges correspond to observed values. The 2019-2023 range corresponds to the simulation exercise, for which 2019 and 2020 have already been observed. In the 2010-2014 and 2015-2019 periods, the total number of firms defined in t gradually dropped in the years following the starting point. This effect results from firms closing down or not reporting the simplified corporate information (*Informação Empresarial Simplificada* - IES). To keep the number of firms constant over the comparison horizon it was assumed that firms which in the latest year for which information was available report a negative ROA or a capital ratio below 10% would be firms with negative equity over the remainder of the period.

4. Sensitivity analysis

Estimating the balance sheet, the income and the cash flow statements at the firm level in the short-medium term is a complex exercise that turned even more challenging in the context of the unprecedented pandemic shock. As in any projection exercise, the conclusions presented herein depend on assumptions that do not encompass all firms' idiosyncratic features.

In this section, we consider different hypotheses on a comprehensive set of variables and evaluate their impact on the results of the baseline simulation. In particular, we compare the baseline estimates against alternative assumptions for: (i) income elasticities of intermediate and staff expenses, (ii) bank loans interest rates, (iii) firms' investment rate, (iv) firms' demand for credit, and (v) credit supply.

Overall, alternative assumptions have limited impact on the baseline conclusions. Furthermore, most changes are economically intuitive. The largest impact would emerge from higher rigidity in intermediate expenses and from shutting down new credit to firms. Both scenarios would lead to a significant increase in the percentage of insolvent firms over the horizon.

4.1. Income elasticities of intermediate and staff expenses

The overall pandemic impact on firms' activity depends on the severity of the pandemic shock, on a firm's income profile and, among other factors, on the firm's ability to adjust its cost structure. In the baseline model, we estimate the operating income elasticities of intermediate expenses and of staff expenses referring to the period 2010-2019 at about 0.96 and 0.84, respectively (Appendix A.1).

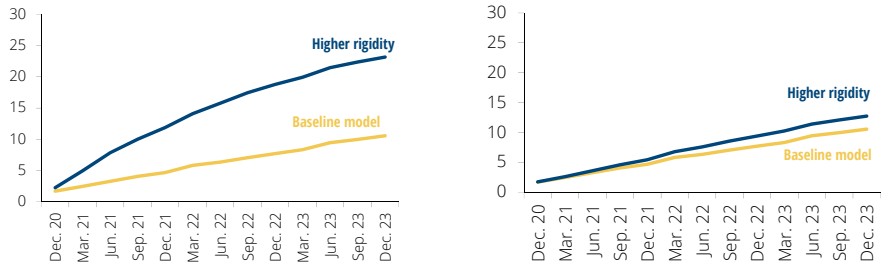
However, faced with a pandemic shock firms' adjustment capability may be limited in the very short term leading to income elasticities smaller than those estimated from historical figures. We thus repeated the simulation exercise setting income elasticities to 0.5 to evaluate the impact a higher rigidity[6], in line with Schivardi and Guido (2020).

The increased rigidity in intermediate expenses leads to a sharp reduction in EBITDA during the pandemic crisis' peak which acts as the main driver for the deterioration of firms' financial situation. On the other hand, during the recovery phase, the higher rigidity in intermediate expenses leads to a stronger increase in EBITDA by the end of the simulation horizon. Still, this recovery is insufficient to revert in full the negative impact from the original shock, leading to a significant reduction in firms' capital ratio (-10.0 p.p. compared against the baseline in 2023) and an increase in the financial indebtedness ratio (+6.6 p.p.). In fact, higher

6. The sensitivity analysis to each elasticity is carried out separately. We have also considered a benign scenario, with income elasticities set to 1, reflecting full cost adjustment capacity to the pandemic shock. The results were line with economic theory, but the change in the proportion of firms with negative equity or insolvent was not material.

rigidity in intermediate expenses increases the proportion of firms with negative equity (Figure 4) and the proportion of insolvent firms in 2023 by 13 p.p. and 11 p.p. respectively.

A higher rigidity on staff expenses leads to smaller changes when compared to the baseline. This result reflects two factors: the average operating income elasticity of staff expenses is lower than the operating income elasticity on intermediate expenses; and layoff policies' support staff expenses on severely affected firms during the crisis peak. In this setting, the proportion of firms with negative equity increases by 2 p.p. while insolvent firms increases by 0.2 p.p.



(a) Intermediate expenses (b) Staff expenses

Figure 4: Percentage of firms with negative equity under different assumptions on operating income elasticities | As an asset-weighted percentage

Notes: Figures weighted by total assets in 2019. The baseline model stands for the estimates obtained from the model described in section 2, where average operating income elasticity of intermediate expenses is 0.96. Regarding the income elasticity of staff expenses the average is 0.84. Higher rigidity corresponds to an operating income elasticity of intermediate expenses and staff expenses of 0.5.

4.2. Bank loans interest rate increase

As the simulation exercise extends up to 2023, there is the risk that firms may face an increase in interest rates up to the end of the horizon. To assess the impact of such an increase on firms' financial situation we increase interest rates by 1 p.p., affecting all firms' bank loans starting in the first quarter of 2022. We have however excluded State-guaranteed credit lines, that were granted with maturities beyond our horizon, and for which price conditions will not change, mitigating firms' credit risk.

We estimate that a 1 p.p. increase in interest rates would not significantly change aggregate figures: referring to 2023, liquidity would decrease by 0.1 p.p., the capital ratio would decrease by 0.3 p.p. while financial debt would increase by 0.2 p.p. (Table 6).

The effects on the capital ratio vary by sector of activity, though: transport and storage's equity ratio decreases by 1.4 p.p. in 2023 while manufacturing, construction and accommodation and food services equity ratios decrease less than 0.5 p.p. There are no significant changes among the cash ratios of different sectors of activity.

Regarding firms' solvency position, the interest rate hike increases the proportion of firms with negative equity or insolvent firms, although to a moderate extent: +0.6 p.p. and + 0.9 p.p. in 2023, respectively. This effect is larger in the most affected sectors of activity: transport and storage (+2.9 p.p. in insolvent firms) and accommodation and food services (+ 1.6 p.p.), mainly driven by the depletion in firms' liquidity position (liquidity criterion).

Cash ratio	**2020**	**2021**	**2022**	**2023**
Baseline model	10.4%	12.2%	12.4%	13.3%
Interest rate increased by 1 p.p.	10.4%	12.1%	12.2%	13.2%
Capital ratio	**2020**	**2021**	**2022**	**2023**
Baseline model	42.2%	42.0%	42.5%	42.7%
Interest rate increased by 1 p.p.	42.2%	41.9%	42.3%	42.4%
Indebtedness ratio	**2020**	**2021**	**2022**	**2023**
Baseline model	30.1%	30.6%	29.8%	29.5%
Interest rate increased by 1 p.p.	30.1%	30.7%	29.9%	29.7%

Table 6. Aggregate cash, capital ratio and indebtedness ratio considering an increase in firms' financing costs | As a percentage of assets

Notes: The baseline model stands for the estimates obtained from the model described in section 2. Interest rate increase by 1 p.p. defines an increase in interest rates on all firms' bank exposures starting in the first quarter of 2022, with the exception of State-guaranteed credit lines.

4.3. Firms' investment rate

In the simulations, firms' operating income depends on the sector of activity projected path and on their idiosyncratic factors but not on the firms' asset composition and productive capacity. Therefore, firms' investment decisions influence mostly firms' liquidity position, with no direct impact on firms' profitability. Investment profiles considering higher investment rates require more liquidity, which may translate into higher financing needs and contribute to an increase in corporate indebtedness (c.f. cash flow statement, Table 2).

In the baseline model, the firms' investment rate (the ratio of gross fixed capital formation to the depreciation) varies by the firms' size, the economic cycle (crisis/recovery) and the firms' indebtedness ratio in the previous year.

We consider two alternative assumptions to assess the impact of different investment profiles: (i) an investment rate that varies according to the GVA of

each firm, taking as a starting point the investment rate observed in 2019; and (ii) a constant investment rate equal to the one observed for the firm in 2019.

The first alternative will fit the projected decline and recovery profile following the pandemic shock, although the large variations in firms' GVA in such a short period of time may overestimate impact on firms' investment. The second alternative results in an investment rate which is higher than the one considered in the baseline model, but invariant to the business cycle.

In both scenarios the investment/capital stock and, therefore, total assets are above the observed in the baseline simulation. Furthermore, the increase in assets following the GVA anchoring alternative exceeds that of the constant investment assumption. There is a decrease in the capital ratio in both alternatives against the baseline scenario, which is larger on the GVA setting (-1.9 p.p.) than the constant investment setting (-0.7 p.p.). One should note that the equity accumulation pattern is similar in all these three scenarios.

The increased investment leads to a higher indebtedness ratio in both settings and contributes to liquidity pressures on some firms. In fact, there is an increase in insolvencies in both settings against the baseline scenario: the proportion of insolvent firms increases by $+1.5$ p.p. on the GVA setting and $+0.8$ p.p. on the constant investment rate setting. This increase is not matched by an increase in the proportion of firms with negative equity.

4.4. Firms' demand for credit

In this section, we evaluate firms' precautionary behaviour assumption under two alternative hypothesis. First, we set firms' cash and deposits target to match the combined firm size and sector of activity's cash and deposits average amount in 2019 and, second, we remove firms' liquidity precautionary behaviour assumption from the model.

There is a significant increase in the cash and deposits of firms when we set the precautionary liquidity target to the combined firm size and sector of activity average in 2019. In fact, the aggregate cash ratio surpasses the one from the baseline model by an average 3.8 p.p. between 2021 and 2023. This increase in liquidity is matched by an increase in firms' indebtedness ratio which increases by 3.5 p.p. in the same period (Table 7). On the other hand, shutting off firms' liquidity precautionary behaviour decreases firms' cash and indebtedness ratios over the simulation horizon: an average decrease of about 1 p.p.

Furthermore, there is no impact on the proportion of firms with negative equity. One should note, though, that the surge in debt leads to an increase in interest expenses, which contributes to a reduction in earnings and, ultimately, to lower retained earnings/equity (-1 p.p. comparing to the baseline scenario).

The effects on the proportion of insolvent firms are somewhat limited but consistent with the changes in firms' liquidity: an increase in targeted liquidity decreases the proportion of insolvent firms against the baseline model in 2023

(-0.6 p.p.), while the no precautionary motive slightly increases that proportion (+0.3 p.p.).

Cash ratio	**2020**	**2021**	**2022**	**2023**
Baseline model	10.4%	12.2%	12.4%	13.3%
Industry's average amount in 2019	10.7%	16.1%	16.3%	17.0%
No precautionary liquidity accumulation	10.4%	11.3%	11.2%	12.1%
Indebtedness ratio	**2020**	**2021**	**2022**	**2023**
Baseline model	30.1%	30.6%	29.8%	29.5%
Industry's average amount in 2019	30.4%	33.8%	33.4%	33.3%
No precautionary liquidity accumulation	30.1%	29.8%	28.7%	28.3%

Table 7. Aggregate cash and indebtedness ratio under alternative liquidity precautionary behavior | As a percentage of assets

Notes: The baseline model stands for the estimates obtained from the model described in section 2.

4.5. Credit supply

Our baseline assumption on the supply of credit differs from other papers recently developed. In fact, most common assumptions are more extreme and are commonly defined such as the absence of new financing (Gourinchas *et al.* (2020))) or some degree of refinancing of loans at maturity exogenous to firms' financial situation (Puhr *et al.* (2021), Ebeke *et al.* (2021)).

We consider two alternative assumptions on the loan supply criteria. The first precludes firms' access to new credit (including refinancing operations), with the exception of loans with State guarantees and unused credit from credit lines covered by the public moratorium.

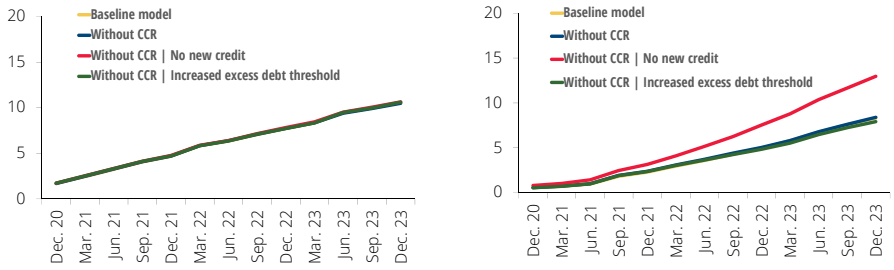
The second relaxes the excess debt threshold, which thus increases the maximum amount of debt a firm can hold before losing access to new credit. We introduce this hypothesis by setting the threshold's interest-to-EBTIDA ratio to 1, as opposed to 0.5 in the baseline model. According to Klein (2016), an interest-to-EBITDA ratio above 1 corresponds to technically defaulted firms, while ratios between 0.5 and 1 correspond to firms with high credit risk. In 2019, 0.9% of the firms had an interest-to-EBITDA ratio higher than 1 and 2.8% had ratios higher than 0.5. It should also be noted that 11% of the firms are unable to access new credit in the model because of the negative EBITDA condition.

As bank financing data is available from the CCR until the second quarter of 2021, to evaluate the impact of changing these financing assumptions in the whole period, we re-estimated the baseline model and the alternative approaches in accordance to a scenario in which bank credit reported to the CCR is not considered.

No new financing over the horizon reduces the financial debt ratio in 2023 (about 5 p.p. less than in the baseline model). In turn, easing the excess

debt threshold marginally increases the financial debt ratio in the same period (+0.4 p.p.).

The no new financing scenario augments the proportion of insolvent firms (+5 p.p. in 2023) reflecting the contribution of the (lack of) liquidity criterion. On the other hand, we do not identify further significant impacts on the proportion of firms with negative equity estimates from these new assumptions (Figure 5).



(a) Firms with negative equity (b) Insolvent firms

Figure 5: Percentage of firms with negative equity or insolvent firms under different assumptions on firms' access to financing | As an asset-weighted percentage

Notes: Amounts weighted by total assets in 2019. The baseline model corresponds to estimates obtained from the model described in Section 2. Without CCR corresponds to simulations that do not consider the reporting to the CCR of credit information between the first quarter of 2020 and the second quarter of 2021, taking as starting point firms' debt as at December 2019. No new credit corresponds to estimates of a model where firms cannot take out new credit, except for that associated with State-guaranteed credit lines and potential credit associated with exposures under moratoria. Increased vulnerable debt threshold corresponds to the loosening of the restriction associated with the definition of the vulnerable debt threshold, having considered an interest expenses to EBITDA ratio equal to 1, instead of the interest expenses to EBITDA ratio equal to 0.5 of the baseline model.

5. Conclusion

In this paper, we use a stylized model of firms' financial statements over the short to medium term to explore the pandemic crisis impact and its uneven effects on firms' financial situation. In particular, we simulate the evolution of the balance sheet, income statement and cash flow statement of firms at a micro-level on the 2020-2023 horizon. We combine data from the Central Balance Sheet Database, the Central Credit Register and the Banco de Portugal July 2021 macroeconomic projections to evaluate the COVID-19 economic shock's impact on firms' financial situation.

The pandemic crisis represented an abrupt negative shock to Portuguese firms' activity, characterised by a protracted period of restrictions on the regular functioning of economic activity, which resulted in an asymmetric impact across sectors. Understanding this heterogeneity and how it persists over the short term is key to assess firms' financial situation following the pandemic shock and, ultimately, which risks will persist for financial stability.

We estimate that Portuguese firms' financial situation will revert the COVID-19 shock by end-2022. This turnaround is characterised by higher profitability, capital ratio and cash ratio in 2023, in aggregate terms, compared to 2019 values.

However, there is an increase in the dispersion of firms' profitability, capital and cash ratios, resulting in a higher percentage of firms with a deteriorated financial situation, compared to 2019. This effect is particularly relevant in the accommodation and food service sectors and in micro enterprises.

The deteriorating financial situation of these firms results in an upward trend in the share of firms with negative equity or insolvent over the simulation horizon, but less marked than in the sovereign debt crisis period. The share of firms with negative equity or insolvent in 2023 is lower if weighted by the total assets of firms. This reduction stems from a greater weight of smaller enterprises in the number of enterprises in a worse financial situation.

These conclusions rest upon assumptions and parameters which simplify firms' characteristics and economic profile over the simulation horizon. We assess some of those settings by re-estimating the model under different conditions. We find that most changes are economically intuitive and have limited impact on the conclusions drawn from the baseline model. Among the different settings analysed, increasing the rigidity of intermediate expenses to changes in operational income and considering a scenario of no new credit lead to increases in insolvent firms.

Given the magnitude of the pandemic shock, its uncertainty and the risks faced by firms in the recovery period, firm-level simulation tools are crucial to assess risks for financial stability. Possible avenues for future developments to the model presented in this paper may include developments on operating income elasticities and investment rate calibration and incorporating full-fledge endogenous credit market dynamics.

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Appendix | Calibrating firm level parameters from historical data

Estimating the balance sheet, income and cash flow statements of firms requires a significant number of assumptions. We calibrate some of the models' parameters referring to firm-level data from the Central Balance Sheet Database (CBSD). This yearly dataset encloses all Portuguese firms' official accounting data since 2006. To avoid inconsistencies arising from the change in accounting standards in 2010, we have only considered data from 2010 onwards. In this appendix, we briefly detail the calibration procedure for the operating income elasticity of intermediate expenses, the operating income elasticity of staff expenses, the investment ratio and the dividend distribution rate.

A.1. Operating income elasticity of intermediate expenses and operating income elasticity of staff expenses

The operating income elasticities of intermediate expenses and of staff expenses were computed with reference to the methodology of Schivardi and Guido (2020). We regress the percentage annual changes (log differences) of intermediate expenses and staff expenses on the percentage annual changes in operating income, interacting firms' sector of activity and firm size.

Firm-level data refer to the CBSD, including only private non-financial firms and comprising data from 2010 to 2019. We exclude firms in the public administration and defence, financial services and head office and management services sectors. In addition, we exclude year-firm observations on firms with negative sales, negative employee expenses or negative operational results.

Firms' sector of activity refer to 11 sectors defined as in Table A.1. Firm size is defined as in the Recommendation of the European Commission 2003/361/EC, setting 4 firm classes: micro, small, medium and large enterprises. In addition, we split CBSD data in two time-frames: 2010 to 2013, which we define as *crisis period*, and 2014-2019, which we define as *recovery period*. We limit extreme percentage changes replacing the values up to the 1^{st} percentile and larger than the 99^{th} percentile by the 1^{st} percentile and 99^{th} percentile figures, respectively.

According to our estimates, rigidity is larger in staff expenses than in intermediate expenses. In both cases we find considerable heterogeneity among sectors of activity and firm size. In particular, elasticities increases with firm size, a pattern that is more pronounced on the operating income elasticity of staff expenses.

CAE (rev3.0)	Sector of activity
A	Agriculture, forestry and fishing
B+D+E	Mining and quarrying, electricity, gas and water
C	Manufacturing
F(41) + L	Construction and real estate activities
F (42+43)	Other construction
G	Trade
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
M + N	Professional, scientific, technical and administrative activities
Other services	Other services

Table A.1. Sector of activity definition

Notes: The sectors of activity refer to the Portuguese *Classificação das Atividades Económicas* (CAE) - 3rd Revision. The Construction and Real estate activities sector comprises divisions 41 and 68 and the Other construction sector comprises divisions 42 and 43 as in Augusto *et al.* (2021).

A.2. Firms' investment rate

We define firms' investment rate as the ratio between gross fixed capital formation (GFCF) and the depreciation. The investment rate is calibrated by firm size, indebtedness level in the previous year and distinguishing between *crisis period* (2010-2013) and *recovery period* (2014-2019). Conditioning on firms' indebtedness level is in line with previous research as it is expected that highly indebted firms invest less in the subsequent year (Farinha *et al.* (2013)). As such, we compute the average investment rate with respect to 12 indebtedness buckets: the first for firms with no financial debt, the following comprising ten indebtedness ratio buckets from 0% to 100% and the final bucket for indebtedness ratios larger than 100%.

We estimate average investment rates from CBSD data for private non-financial firms from 2010-2019 and exclude firms in the public administration and defence, financial services and management services sectors, including head offices. In the context of the CSBD, we define GFCF as the sum of changes in fixed tangible assets, intangible assets, investment property, non-consumable biological assets, assets held for sale (corrected from changes not related to the previous asset classes) and the current year depreciation and amortization figures. We exclude year-firm observations for firms with negative sales, negative employee expenses or negative operational results.

There are three additional assumptions to the dimensions already discussed: (i) average investment rates only consider observations with positive depreciation figures; (ii) if GFCF is negative (divestment) we reset that year-firm observation to 0.01, such that there are no negative investment rates and (iii) each average

estimate excludes the bottom 5^{th} percent and the top 95^{th} of the respective distribution.

From our estimates, average investment rates decrease with firms' indebtedness level, as expected. The average investment rates increase with firm size and are lower during the crisis period than in recovery period.

A.3. Firms' dividend ratio

We define the firms' dividend ratio as the ratio between dividends paid in a year and the net income in the previous year. Dividends paid by firms are not reported to the CBSD. We compute them by comparing the evolution of the net income in a given year with the changes in reserves and retained earnings and equity instruments in the subsequent year.[7] Furthermore, we consider negative changes in the stakeholders account and interim dividends figures as dividends paid in the period.

We use information from firms reporting to CBSD from 2010 to 2019 and exclude observations from firms not paying dividends or with negative or null net income in the previous year. We trimmed observations with respect to the overall dividend ratio distribution's 1^{st} percentile and 99^{th} percentile. Finally, firms' sector of activity (defined as in Table A.1), firms' size and *crisis period* (2010-2013) and *recovery period* (2014-2019) define distinct firm groups over which we estimate the dividend ratio.

Albeit there is some heterogeneity among firm groups, some regularities should be highlighted. There is some heterogeneity on the dividend ratio averages among sectors of activity, which increases with firm size. For the subset of firms paying dividends in a given period, the average dividend ratios are larger for the crisis period than for the recovery period, in particular for small and medium enterprises. Several factors contribute to this pattern: i) a smaller number of firms paying dividends during a crisis; ii) lower investment opportunities during the crisis period and iii) the existence of dividend targets regardless of the economic cycle.

7. Equity instruments are equal to the sum of capital, share premium and other equity instruments, including treasury shares.

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