

Technical Paper

Analysis of (stressed) allocation risk
in the aggregate credit portfolio of
domestic banks

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Non-technical summary

This paper analyses risks that arise from banks' credit portfolio composition and can be referred to collectively as allocation risk which is an important risk dimension in the current financial stability review (Deutsche Bundesbank, 2021). That is, a potential increase in, or elevated levels of, allocation risk mean a larger exposure of banks to borrowers at the upper end of the risk distribution. In this sense, allocation risk does not concern a borrower's absolute risk, but rather its relative risk compared with other borrowers and whether banks have a disproportionately high level of exposure to those borrowers. To analyse allocation risk, data on the financial statements of domestic, non-financial corporations are merged with data from the German credit register. The period under review spans from 2000:Q1 to 2020:Q4 and covers a sizeable part of the banks' total exposure to the real economy. Moreover, the paper models possible real economic changes in 2020. Specifically, companies are exposed to various stress scenarios, among others an increase in interest expenses as well as increase in debt levels. A total of six borrower-specific risk measures are utilised. Though risk measures improved for most borrowers, some exhibited greater tail risks towards the end of the period under review.

The borrower-specific risk measures and stress scenarios translate into the banks' aggregate credit portfolio as follows. Measures that proxy borrowers' medium-term probability of going bankrupt show elevated or even increasing levels of allocation risk. First, the debt overhang ratio indicates not only an elevated but also increasing level of exposure to borrowers across various parts of the risk distribution. Consequently, the riskiness of the banks' aggregate credit portfolio increased not only on average but also in the tails. Second, the Altman Z-score, which proxies borrowers' probability of reaching the stage of bankruptcy within the next two years, likewise indicates elevated and increasing levels of risk in the banks' aggregate credit portfolio. By contrast, the results based on the banks' self-reported PDs do not give any indication of elevated risk, at least at the aggregate level. Based on the equity ratio, which proxies borrowers' long-term PD, but more importantly the banks' recovery rate in the event of default, the results likewise give no indication of elevated or increasing allocation risk. With respect to stressed allocation risk, these measures indicate, to some extent, resilience to scenarios stressing borrowers' debt and income levels. The results for allocation risk based on measures that proxy borrowers' short-term probability and immanent probability of reaching the stage of bankruptcy indicate heightened risks in various ways. Specifically, based on the interest coverage ratio, the results indicate elevated but not increasing risk levels in the banks' aggregate credit portfolio. By contrast, banks are not disproportionately exposed to borrowers with a relatively low cash ratio, which proxies a borrower's liquidity. However, it should be noted that, in absolute terms, a significantly large number of borrowers would use up their liquid assets after just one month in the absence of an inflow of funds. Against this background, the measures taken to support corporate liquidity in response to the COVID-19 pandemic appear all the more important with respect to the stability of both the real economy and the banking system. The results for stressed allocation risk based on these two risk measures indicate vulnerabilities to scenarios stressing borrowers' interest expenses, i.e. higher interest rates.

Nichttechnische Zusammenfassung

In diesem Papier werden Risiken analysiert, die sich aus der Zusammensetzung des Kreditportfolios von Banken ergeben, welche eine wichtige Risikodimension im aktuellen Finanzstabilitätsbericht (Deutsche Bundesbank, 2021) darstellen, und als Allokationsrisiko bezeichnet werden. Das heißt, ein potenzieller Anstieg bzw. ein erhöhtes Niveau des Allokationsrisikos bedeutet ein höheres Engagement von Banken gegenüber Kreditnehmern am oberen Ende der Risikoverteilung. In diesem Sinne geht es beim Allokationsrisiko nicht um das absolute Risiko eines Kreditnehmers, sondern um sein relatives Risiko und darum, ob Banken überproportional hohe Engagements gegenüber diesen Kreditnehmern aufweisen. Zur Analyse des Allokationsrisikos werden Informationen zu Jahresabschlüssen inländischer, nichtfinanzieller Unternehmen mit dem deutschen Kreditregister zusammengeführt. Der betrachtete Zeitraum erstreckt sich von 2000:Q1 bis 2020:Q4 und deckt einen signifikanten Teil des realwirtschaftlichen Gesamtengagements der Banken ab. Darüber hinaus modelliert das Papier mögliche realwirtschaftliche Veränderungen im Jahr 2020. Das heißt, die Unternehmen sind verschiedenen Stressszenarien ausgesetzt, u.a. einem Anstieg der Zinsaufwendungen, sowie der Verschuldung. Insgesamt werden sechs kreditnehmerspezifische Risikomaße verwendet. Obwohl sich die Risikomaße für die meisten Kreditnehmer verbessert haben, deuten einige von ihnen am aktuellen Rand auf größere Risiken in den Rändern der Verteilung hin.

Die kreditnehmerspezifischen Risikomaße und die Stressszenarien übersetzen sich wie folgt auf das aggregierte Kreditportfolio der Banken. Gemessen an Risikomaßen, die die Wahrscheinlichkeit darstellen, mittelfristig insolvent zu werden, zeigt sich ein erhöhtes oder sogar steigendes Allokationsrisiko. So zeigt erstens die dynamische Verschuldungsquote sowohl ein erhöhtes, als auch ein steigendes Engagement gegenüber Kreditnehmern in verschiedenen Teilen der Risikoverteilung. Folglich hat sich das Risiko des Kreditportfolios der Banken nicht nur im Durchschnitt, sondern auch in den Rändern der Verteilung erhöht. Zweitens weist der Altman-Z-Score ebenfalls auf ein erhöhtes und zunehmendes Risiko des aggregierten Kreditportfolios hin. Im Gegensatz dazu deuten die Ergebnisse hinsichtlich der bankeigenen Ausfallwahrscheinlichkeiten nicht auf ein erhöhtes Risiko hin, zumindest im Aggregat. In Bezug auf die Eigenkapitalquote, die die langfristige Ausfallwahrscheinlichkeit der Kreditnehmer, aber vor allem die Wiedereinbringungsquote der Banken im Falle eines Ausfalls darstellt, zeigen die Ergebnisse ebenfalls kein erhöhtes oder steigendes Risiko. Hinsichtlich des gestressten Allokationsrisikos zeigen die genannten Maße in gewissem Umfang eine Widerstandsfähigkeit gegenüber Szenarien, die sowohl die Verschuldung der Kreditnehmer als auch das Einkommensniveau stressen. Die Ergebnisse des Allokationsrisikos in Bezug auf Maße, die die kurzfristige bzw. immanente Wahrscheinlichkeit des Erreichens des Insolvenzstadiums eines Kreditnehmers approximieren, deuten in unterschiedlicher Weise auf erhöhte Risiken hin. Das heißt, dass die Ergebnisse in Bezug auf die Zinsdeckungsquote zwar auf ein erhöhtes, aber nicht auf ein steigendes Risikoniveau des Kreditportfolios der Banken hinweisen. Im Gegensatz dazu sind die Banken nicht überproportional stark gegenüber Kreditnehmern mit einer relativ niedrigen Cash-Quote, die die Liquidität eines Kreditnehmers approximiert, exponiert. Allerdings ist zu beachten, dass in absoluten Zahlen eine signifikant große Anzahl von Kreditnehmern ihre liquiden Mittel bereits nach einem Monat ohne Mittelzufluss aufbrauchen würden. Vor diesem Hintergrund erscheinen die Maßnahmen zur Stützung der Unternehmensliquidität im Zuge der COVID-19-Pandemie sowohl im Hinblick auf die Realwirtschaft als auch auf die Stabilität des Bankensystems umso wichtiger. Die Ergebnisse zum gestressten Allokationsrisiko in Bezug auf diese beiden Risikomaße deuten auf eine Anfälligkeit gegenüber Szenarien hin, in denen die Zinsaufwendungen der Kreditnehmer gestresst werden, d.h. höhere Zinsen angenommen werden.

Analysis of (stressed) allocation risk in the aggregate credit portfolio of domestic banks[§]

Peter Bednarek¹

Abstract

This paper analyses risks that arise from banks' credit portfolio composition and can be referred to collectively as allocation risk. That is, a potential increase in, or elevated levels of, allocation risk mean a larger exposure of banks to borrowers at the upper end of the risk distribution. In this sense, allocation risk does not concern a borrower's absolute risk, but rather its relative risk compared with other borrowers and whether banks have disproportionately high level of exposure to those borrowers. To analyse allocation risk, data on the financial statements of domestic, non-financial corporations are merged with data from the German credit register. The final sample covers a sizeable part of the banks' total exposure to the real economy, with nearly 4.9 million credit relationships between over 99,000 borrowers and 1,700 banks in a period spanning from 2000:Q1 to 2020:Q4. On the one hand, allocation risk based on measures that proxy borrowers' medium-term probability of default (debt overhang ratio and Altman Z-score) indicate elevated and even increasing levels of the risk in the banks' credit portfolio. On the other hand, those measures show, to some extent, resilience to scenarios stressing borrowers' debt and income levels. By contrast, allocation risk based on measures that proxy borrowers' short-term probability and immanent probability of reaching the stage of bankruptcy (interest coverage and cash ratios) indicate elevated risks in relative and absolute terms, respectively. The results for stressed allocation risk based on these two measures indicate vulnerabilities to scenarios stressing borrowers' interest expenses, i.e. higher interest rates.

Keywords: allocation risk, bank lending, credit risk-taking, credit portfolio composition, real sector risk measures

JEL classification: G21, G33

[§] Technical Papers represent the authors' personal opinions and do not necessarily reflect the views of the Deutsche Bundesbank or the Eurosystem.

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1. Introduction

This paper analyses risks that arise from banks' credit portfolio composition and can be referred to collectively as allocation risk which is an important risk dimension in the current financial stability review (Deutsche Bundesbank, 2021). It is important to note, first, that the term *risk* is not defined by borrowers' absolute risk but rather their relative risk and, second, that the analysis abstracts from credit supply and demand effects. That is, a potential increase in, or elevated levels of, allocation risk mean a larger exposure of banks to borrowers at the upper end of the risk distribution at equilibrium. In this sense, allocation risk does not concern a borrower's absolute risk, but rather its relative risk compared with other borrowers and whether banks have a disproportionately high level of exposure to those borrowers. Nonetheless, as microprudential supervision focuses on a borrower's absolute risk, allocation risk in this sense is by its very nature not taken into account. Whilst an increase in, or elevated levels of, allocation risk do not necessarily imply any immediate risk to financial stability, they serve as a warning sign at the very least. First, this is because given the favourable macroeconomic environment in Germany in the wake of the global financial crisis through to the outbreak of the COVID-19 pandemic, which saw it experience relatively high (GDP) growth rates and low and decreasing interest rates, the full distribution of borrowers' risk has shifted in a favourable direction. This, in turn, could lead to relatively riskier lending and potentially result in credit risk being underestimated.² Underestimation of credit risk should not necessarily be interpreted as a (conscious) decision by banks but rather, amongst other things, as the expected result of risk models' outcome when borrower defaults are washed out of the models' underlying data estimating PDs.³ Second, when a potential recession causes a deterioration in aggregate conditions, thus moving the entire distribution of borrowers' risk upwards, loss allowances and credit defaults might increase more rapidly and by a greater amount than they would if credit risk were distributed more evenly. Third, because of information asymmetries, banks cannot internalise allocation risk properly and consequently do not build up buffers addressing this risk. Amongst other things, banks have no precise information about their peers' credit portfolios and only limited information about the risk exhibited by borrowers with whom they have no credit relationship.

The analysis of allocation risk in this paper is based on data sourced from JANIS (*Jahresabschlüsse nichtfinanzieller Unternehmen*),⁴ a dataset containing the financial statements of domestic, non-financial corporations, which have been merged with data from the German credit register (*Evidenzzentrale für Millionenkredite*).⁵ Financial institutions in Germany are required to report to the credit register if their exposure to an individual borrower or the sum of their exposure to borrowers belonging to one hypothetical borrower unit has on at least one occasion exceeded a threshold of €1 million during the reporting period.⁶ Here, the term *exposure* is broadly defined to include traditional loans, bonds, off-balance-sheet positions and exposure from derivative positions. Moreover, a borrower unit comprises legally and/or economically independent borrowers that are connected to each other, e.g. due to (major) shareholdings ($\geq 50\%$), profit transfer agreements, etc. In other words, if two smaller borrowers that are economically or legally affiliated each have €0.5 million credit outstanding,

² See Bednarek et al. (2021), and Deutsche Bundesbank (2017, 2018, 2019, 2020, 2021).

³ This is the case even when it is necessary to incorporate data points from crisis periods into the estimation procedure, because defaults steadily decreased in non-crisis periods over the last decade.

⁴ For detailed information see <https://www.bundesbank.de/en/bundesbank/research/rdsc/research-data/janis-ustan-618088>

⁵ For detailed information see <https://www.bundesbank.de/en/tasks/banking-supervision/individual-aspects/lending-business>.

⁶ Prior to 2014, this threshold was €1.5 million.

both loans have to be reported to the credit register. Consequently, the actual reporting threshold is markedly lower.⁷

The period under review in this paper spans from 2000:Q1 to 2020:Q4, but as JANIS data are only available (partly) up to 2019, the data are rolled forwards so that potential risks from the COVID-19 pandemic in 2020 can be analysed.⁸ This analysis takes two forms. First, as borrower-specific risk measures are held constant, changes in allocation risk in 2020 stem from changes in banks' credit portfolio composition. This case represents the baseline scenario and makes it possible to identify banks that are exposed in 2020 to borrowers with elevated risk levels in the past, which in turn may be more vulnerable to the deterioration in macroeconomic conditions triggered by the COVID-19 pandemic. Second, the paper models possible real economic changes in 2020. Specifically, companies' balance sheets are exposed to various stress scenarios, e.g. an increase in interest expenses (i.e. higher interest rates), for example due to a higher risk premium, an increase in debt levels and a decrease in a company's income. On the one hand, the outcome of this exercise can be interpreted as the true fallout underlying the COVID-19 pandemic, which will possibly then be reported in the companies' balance sheets in the next one or two years. On the other hand, the results can be interpreted at least as risks or vulnerabilities in banks' credit portfolios should those stress scenarios materialise in the near future, all else being equal.⁹

Table 1 provides information on the final sample. Using JANIS, balance sheet information on a total of more than 99,500 borrowers can be matched to the credit register, resulting in over 4.9 million observations at the bank-firm-quarter level. The manufacturing and wholesale and retail trade sectors combined account for roughly 45% of all observations and borrowers, respectively. Borrowers in those sectors matched with JANIS information cover a total of roughly 77% and 63%, respectively, of the total balance sheet exposure¹⁰ of the sample banks' aggregate exposure to those sectors of economic activity. However, depending on the sector, JANIS coverage is quite heterogeneous. For example, borrowers covered in JANIS make up only 18.3% of the total exposure to sector I (accommodation and food service activities), the sector most affected by the lockdowns imposed due to the COVID-19 pandemic. The last two columns present sector-specific changes in credit (i.e. exposure) from 2019 to 2020 based on the credit register as well as changes in gross value added.¹¹ Those two data series alongside changes in the interest rate based on scenarios underlying the Basel interest risk coefficient¹² determine the stress scenarios for the borrower specific-risk measures and, consequently, the allocation risk for the banking sector itself. Allocation risk is calculated both for the overall sample of domestic banks comprising 1,758 (CRR) institutions in Germany and for other systemically important institutions (O-SIIs)¹³ and less systemically important institutions (L-SIIs)¹⁴ separately.

The remainder of the paper is organised as follows. **Section 2** discusses six borrower-specific risk measures that, in the further course of the paper, form the basis for calculating allocation

⁷ For instance, the in-sample 25th percentile of the balance sheet exposure amounts to €0.08 million. Moreover, besides large, mid-cap and small companies, the credit register also covers micro companies to some extent (see Bednarek et al., 2021).

⁸ For companies with missing values in 2019, the 2018 values are used.

⁹ Assuming constant bank balance sheets.

¹⁰ In contrast to previous analyses, allocation risk is calculated using not the reported total (BA100) but the balance sheet exposure (BA110) of banks. As total exposure is broadly defined to include not only traditional loans but also bonds, off-balance-sheet positions and exposure from derivative positions, it does not correspond, for instance, to the assumed interest rate stress scenarios affecting borrowers' credit risk. Changing interest rates might affect off-balance-sheet positions differently. Moreover, balance sheet exposure corresponds more closely to exposure definitions in other analyses related to the Financial Stability Review 2021.

¹¹ Values are taken from DESTATIS (Fachserie 18 Reihe 1.4).

¹² For detailed information, see [Basel Framework \(bis.org\)](https://www.bis.org).

¹³ Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

¹⁴ All other banks not designated as an O-SII.

risk, as well as the stress scenarios affecting those measures. Moreover, ten risk bins are calculated for all borrower-specific risk measures, where risk bin one is to be interpreted as borrowers with the lowest risk and risk bin ten as borrowers with the highest risk.¹⁵ The risk bins are calculated by splitting borrowers into ten deciles according to the distribution of the borrower-specific risk measures. The distribution is calculated per year and sector of economic activity (Table 1). This prevents the results from being influenced by changes over time or structural differences between the various sectors of economic activity. **Section 3** depicts the development of aggregate allocation risk as a stock variable – or in other words, as potential exposure at risk – by presenting the aggregate exposure of the aforementioned groups of banks in various risk clusters relative to their total exposure. In this context, the risk clusters are calculated on the basis of the risk bins defined in Section 2. **Section 4** divides banks into the same groups as in Section 3, but this section examines the extent to which banks’ median, rather than aggregate, lending differs for various risk clusters. Thus, this section presents more of a flow analysis, in the sense of a potential risk build-up at the intensive margin. That is, if relatively riskier borrowers receive larger loans on average over the long run than less risky ones, aggregate allocation risk may build up over time. Above all, if this ratio increases over time, it indicates a growing risk appetite. Lastly, **Section 5** summarises and concludes.

Table 1: Descriptive statistics of the final dataset covering 2000:Q1 to 2020:Q4

Code	Sector of economic activity	Number of observations	%	Number of borrowers	%	JANIS coverage, %	Δ credit in 2020, %	Δ gross value added in 2020, %
A	Agriculture, forestry and fishing	32,315	0.66	1,021	1.03	21.15	4.73	-0.70
B	Mining and quarrying	15,615	0.32	373	0.37	69.77	-7.89	-9.70
C	Manufacturing	1,300,280	26.57	22,866	22.97	76.62	-2.33	-10.50
D	Electricity, gas, steam and air conditioning supply	210,129	4.29	3,153	3.17	45.89	2.08	-9.70
E	Water supply; sewerage, waste management and remediation activities	81,427	1.66	1,498	1.51	67.81	5.63	-9.70
F	Construction	253,696	5.18	7,557	7.59	37.90	8.44	2.80
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	947,113	19.35	20,733	20.83	62.81	1.71	1.70
H	Transportation and storage	207,069	4.23	4,220	4.24	53.94	2.21	-9.60
I	Accommodation and food	20,357	0.42	1,024	1.03	18.30	12.43	-43.70

¹⁵ This approach borrows from the IMF’s Global Financial Stability Report (GFSR, 2018).

Code	Sector of economic activity	Number of observations	%	Number of borrowers	%	JANIS coverage, %	Δ credit in 2020, %	Δ gross value added in 2020, %
	service activities							
J	Information and communication	97,375	1.99	2,947	2.96	58.84	-3.12	-0.90
K	Financial and insurance activities	107,152	2.19	3,076	3.09	14.76	2.62	-0.20
L	Real estate activities	785,764	16.06	13,959	14.03	39.56	6.22	-0.50
M	Professional, scientific and technical activities	545,398	11.14	9,277	9.32	53.77	8.14	-8.10
N	Administrative and support service activities	83,098	1.70	2,963	2.98	32.94	12.18	-8.10
O	Public administration and defence; compulsory social security	17,603	0.36	190	0.19	11.97	2.96	-3.00
P	Education	8,021	0.16	415	0.42	33.15	4.86	-3.00
Q	Human health and social work activities	148,756	3.04	3,120	3.13	37.24	5.80	-3.00
R	Arts, entertainment and recreation	22,391	0.46	708	0.71	47.44	11.39	-11.40
S	Other service activities	10,288	0.21	426	0.43	23.77	-2.51	-11.40
Total		4,893,847	100.00	99,526	100.00	-	-	-

2. Borrower-specific risk measures and stress assumptions

This section presents the borrower-specific risk measures underlying the paper's analysis, their definition, descriptive statistics as well as the specific stress scenarios affecting those measures.¹⁶ It should be noted that the first five risk measures are calculated on the basis of the JANIS data, i.e. the companies' balance sheet information, whereas the probabilities of default (PDs) are taken from internal ratings-based (IRB) banks' reports in the credit register.¹⁷ Moreover, ten risk bins are calculated for all borrower-specific risk measures, where risk bin one is to be interpreted as borrowers with the lowest risk and risk bin ten as borrowers with the highest risk. The risk bins are calculated by splitting borrowers into ten deciles according to the distribution of the borrower-specific risk measures. The distribution is calculated per year

¹⁶ The risk measures are derived from and motivated by, inter alia, Ben-Zion and Shalit (1975), Jensen and Meckling (1976), Carling et al. (2007), Duchin and Sosyura (2014), Acharya et al. (2017), te Kaat (2018) and Bednarek et al. (2021).

¹⁷ All risk measures are calculated as moving averages over the last three time periods. For risk measures based on JANIS data, the moving average is calculated over the last three years. The risk measure based on the reported IRB PDs is a moving average over the last three quarters.

and sector of economic activity (Table 1). The borrower-specific risk measures are defined as follows:

1. **Debt overhang ratio:** Total debt (i.e. total assets minus equity) in relation to earnings before interest, taxes, depreciation, and amortisation (EBITDA).
2. **Equity ratio:** Equity in relation to total assets.
3. **Interest coverage ratio:** EBITDA in relation to interest expenses.
4. **Cash ratio:** Liquid assets in relation to fixed costs, including interest expenses. Specifically, cash in hand, central bank balances, bank balances and cheques in relation to fixed costs and interest expenses, with staff costs, business start-up and expansion expenses and other operating expenses reported outside of cost of sales, selling expenses, and general and administrative expenses counting as fixed costs.
5. **Altman Z-score:** A type of Z-score used to predict the chances of bankruptcy (Altman, 1968). This methodology can be used to predict the probability of a business organisation entering into bankruptcy within a given time, which is mostly about two years, and encompasses several risk dimensions (working capital, retained earnings, profitability, and capitalisation).¹⁸ In this model, if the Z value is greater than 2.6, the firm is said to be in the “safe zone” and has a negligible probability of filing for bankruptcy. If the Z value is between 2.6 and 1.1, the firm is said to be in the “grey zone” and has a moderate chance of bankruptcy. If the Z value is below 1.1, it is said to be in the “distress zone” and has a very high probability of reaching the stage of bankruptcy.
6. **IRB PD:** The probability of default (PD) reported by IRB banks in the credit register starting in 2008.

The first two borrower-specific risk measures, namely the debt overhang and equity ratio, represent to some extent medium to longer-term risk measures. Deterioration here does not necessarily indicate imminent default, especially in the case of the equity ratio. In other words, in a credit stress-test framework, the debt overhang ratio would be interpreted as more of a proxy for the (medium-term) PD, whereas the equity ratio would be more of a proxy for the loss given default (LGD) or the recovery rate. That is, the former would help to answer the question “How likely is it to see a borrower filing for bankruptcy?” whereas the latter would help to answer the question “What is the amount of money the creditor might lose?” – or, the other way around, “How much can a bank recover after the borrower’s default?” By contrast, the next two borrower-specific risk measures, namely the interest coverage and cash ratio, might signal imminent default risks – i.e. serve as a proxy for a short-term PD – if a borrower does not have enough reserves to cover payments falling due, e.g. fixed costs and interest expenses. Hence, the need for swift and sufficient public liquidity support and credit relief measures in response to the COVID-19 pandemic.¹⁹ The last two measures can be interpreted as PDs (more) directly, with the Altman Z-score proxying the probability of a company entering into bankruptcy within the next two years and the reported IRB PDs the probability of a company entering into bankruptcy within one year.

To assess the real economic stress that the COVID-19 pandemic might have placed on borrowers’ and banks’ (credit) risk over and above rapid liquidity shortfalls, the following assumptions are made. In the case of the debt overhang ratio, the paper considers two stress scenarios: in the first, only borrowers’ debt levels increase, and in the second, income also decreases. To compute conservative stress outcomes, debt levels increase by the maximum of the positive values of Δ credit and negative values of Δ gross value added taken as absolute

¹⁸ In particular, the Altman Z-score is calculated as equal to $3.25 + 6.56 * \text{working capital}/\text{total assets} + 3.26 * \text{retained earnings}/\text{total assets} + 6.72 * \text{EBIT}/\text{total assets} + 1.05 * \text{equity}/\text{total liabilities}$, in line with Altman et al. (2017).

¹⁹ For detailed information, see, for example, <https://www.bmwi.de/Redaktion/DE/Coronavirus/informationen-fuer-selbstaendige-und-unternehmen-zu-corona-hilfen-des-bundes.html>

values (Table 1). For instance, in 2020 stressed debt levels increase by 4.73% as $4.73 > |-0.70|$ in the case of sector A (agriculture, forestry and fishing) and by 43.70% as $12.43 < |-43.70|$ in the case of sector I (accommodation and food service activities). By contrast, to stress income, only negative changes in gross value added are used, as they correlate more to the deterioration in real sector activity, especially sales, for which information is not available for most sectors of economic activity.²⁰ To assess the sensitivity of the various data series to stressed debt levels, the equity ratio is calculated in three different stress scenarios: in the first, debt increases by the positive values of Δ credit; in the second, debt increases by the negative values of Δ gross value added taken as absolute values; and in the third, similarly to the debt overhang ratio, the maximum of both values is taken. These stressed debt levels are then added to total assets, consequently decreasing borrowers' equity ratio. Lastly, to stress interest expenses, the paper uses scenarios underlying the Basel interest risk coefficients. This involves an increase in interest rates, e.g. due to a higher risk premium, by 100 and 200 basis points, respectively.²¹ However, it is assumed that only 25.4% of those higher interest rates are passed through for existing interest expenses on the underlying debt, which corresponds to the amount that borrowers need to refinance within one year based on the MFI interest rate statistics.²² For additional (stressed) borrowing due to the COVID-19 pandemic, higher interest rates are passed through in full. Moreover, as borrower-specific interest rates are not directly reported in the JANIS data, they are approximated by the ratio of interest expenses to total debt.²³ Accordingly, stressed interest expenses are the product of these approximated interest rates and total debt. The final two borrower-specific risk measures, namely the Altman Z-score and the reported IRB PDs, are not stressed, mainly because of their multidimensional nature.²⁴

Figure 2.1 depicts the distribution of the borrower-specific debt overhang ratio, which can be interpreted roughly as the time (in years) that a company needs to repay its debt. Panel A shows the distribution over time, whereas Panel B compares the distribution within each risk bin in 2000 and 2020. Though the measure seems to be fairly stable over time, hovering at around 600% – which can be roughly translated into a repayment period of six years – Panel B shows that the debt overhang ratio improved for less risky borrowers (risk bins one to five) between 2000 and 2020, whilst it deteriorated for the riskier ones (risk bins six to ten). Especially in risk bin ten, i.e. the worst 10th percentile, the debt overhang ratio deteriorated considerably, i.e. the median increased by roughly 33% between 2000 and 2020. This is to some extent surprising given the overall favourable macroeconomic development prior to the COVID-19 pandemic. On the other hand, markedly lower interest rates and presumptions of “low for long” might have promoted higher absolute debt levels. Indeed, for the median borrower, total debt increased by over 5.2% in absolute numbers from 2000, whilst EBITDA increased by 1.6%. On aggregate, total debt for all borrowers present in the sample period increased by 237.5%, whilst aggregate EBITDA increased by 154.7%.²⁵ Hence, the fact that the debt overhang ratio remained relatively stable on average does not mean that there was no movement in the measure's components. The higher profits towards the end of the period under review were not used to scale back debt. To the contrary, total debt increased, both for the median borrower and on aggregate, over the last two decades. All in all, the stark difference between median and aggregate numbers translates into Panel B, which shows, first, that the

²⁰ Taking changes in German GDP into account does not change the results quantitatively or qualitatively.

²¹ These stressed interest rates correspond roughly to the change in the 75th and 95th percentile of the projections of the risk-free rate in the next three years prepared by the Deutsche Bundesbank's Directorate General Economics (not reported).

²² Going into detail, it is assumed that residual maturity equals half a year for maturity bucket “up to one year”, three years for bucket “one up to five years”, eight years for bucket “more than five years” and zero years for overdraft facilities. For detailed information, see [MFI interest rate statistics \(amounts outstanding, new business\) | Deutsche Bundesbank](#).

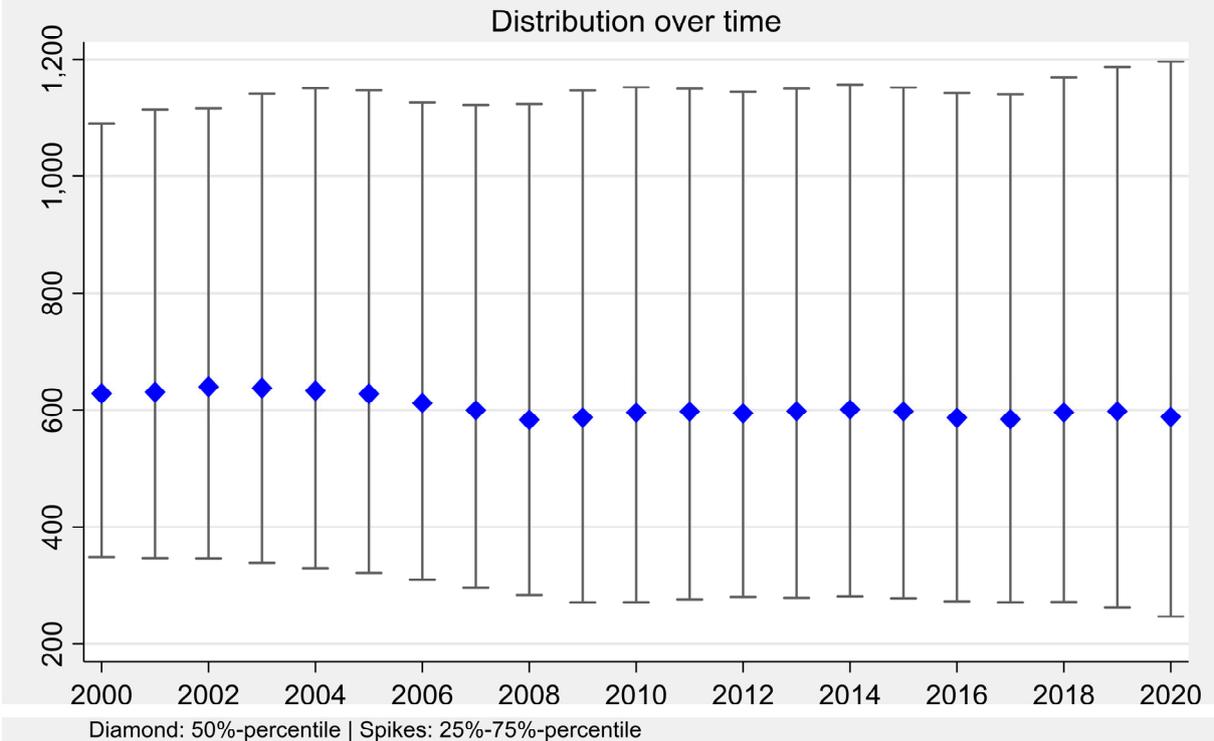
²³ At the end point, these calculated interest rates match the effective interest rate of German banks on loans to non-financial corporations (new business; see MFI interest rate statistics).

²⁴ Unreported robustness checks indicate that the results of a stressed Altman Z-score co-move with those of the stressed debt overhang ratio, in particular.

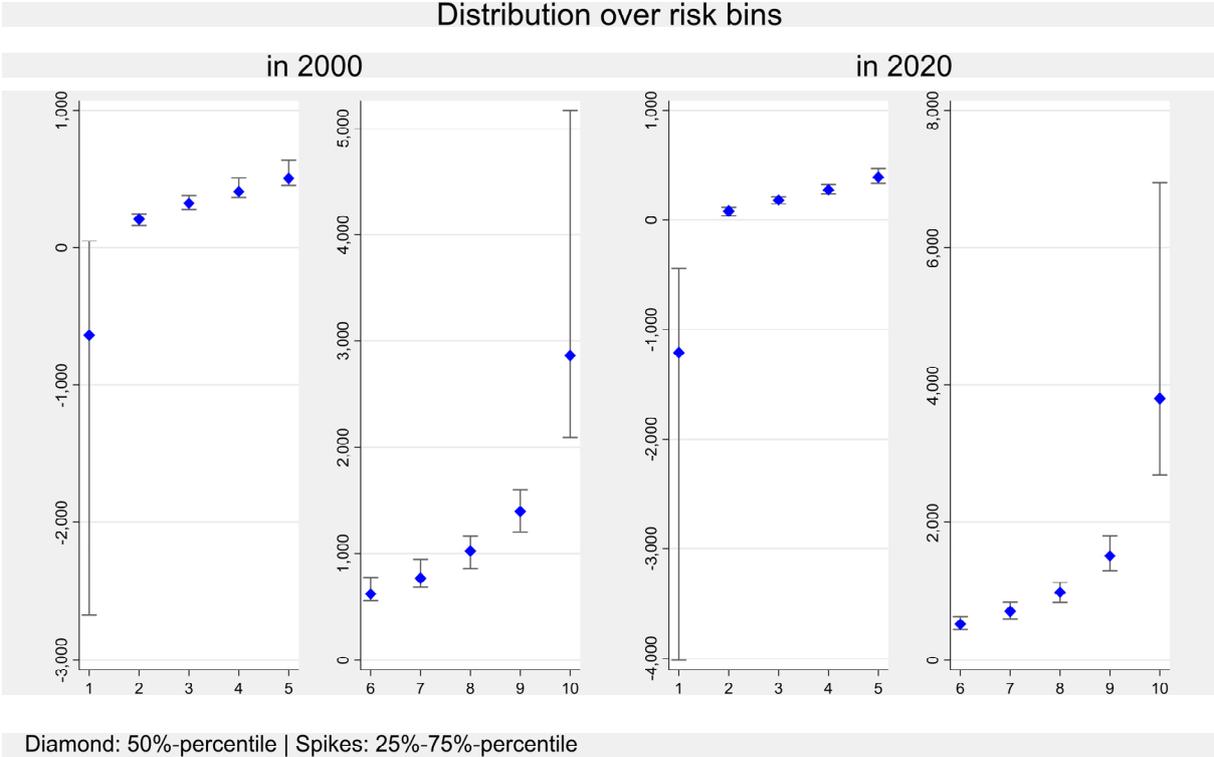
²⁵ Numbers refer to a totally balanced panel.

distribution across varying risk clusters widened and, second, that tail risks increased. Panel C shows the outcome of two stress scenarios for the median borrower, with, as described previously, debt levels increasing in the first scenario and income also decreasing in the second. At the maximum, the debt overhang ratio for the median borrower increases by around 8% in 2020 compared with 2019. In other words, for the median borrower, the debt overhang ratio would fall back to values seen in the early 2000s.

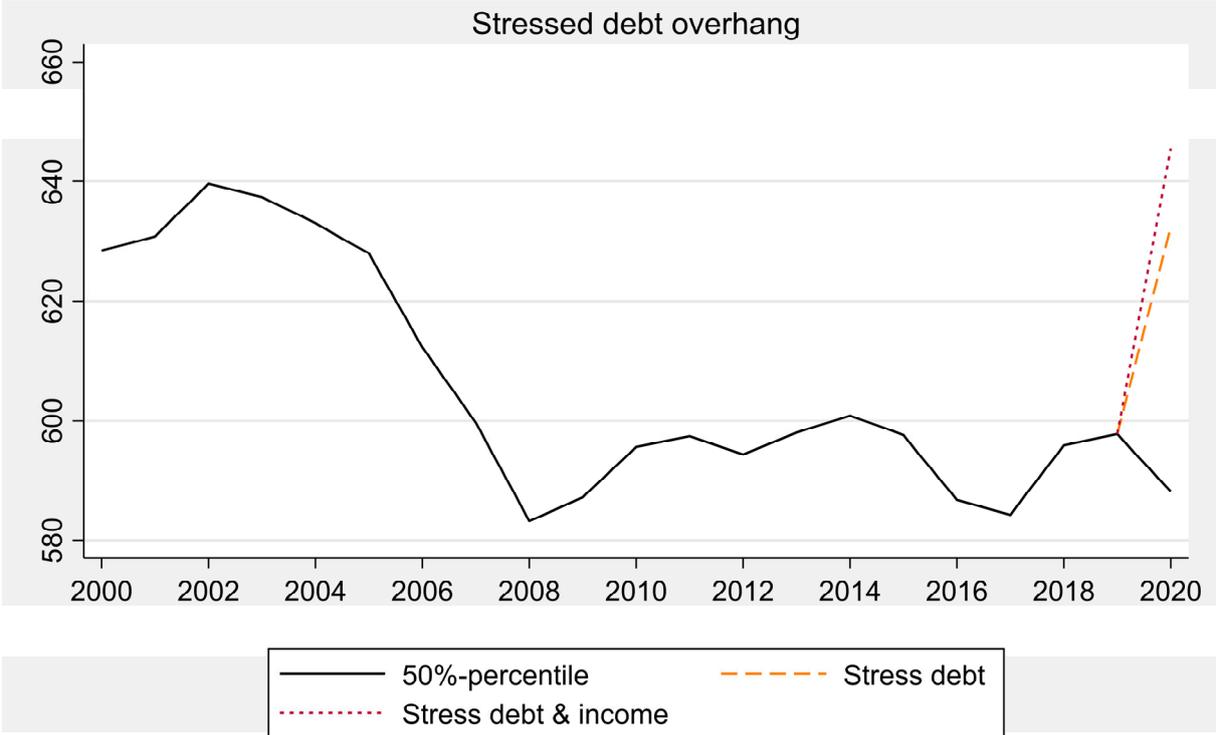
Figure 2.1: Debt overhang ratio, %
 Panel A



Panel B



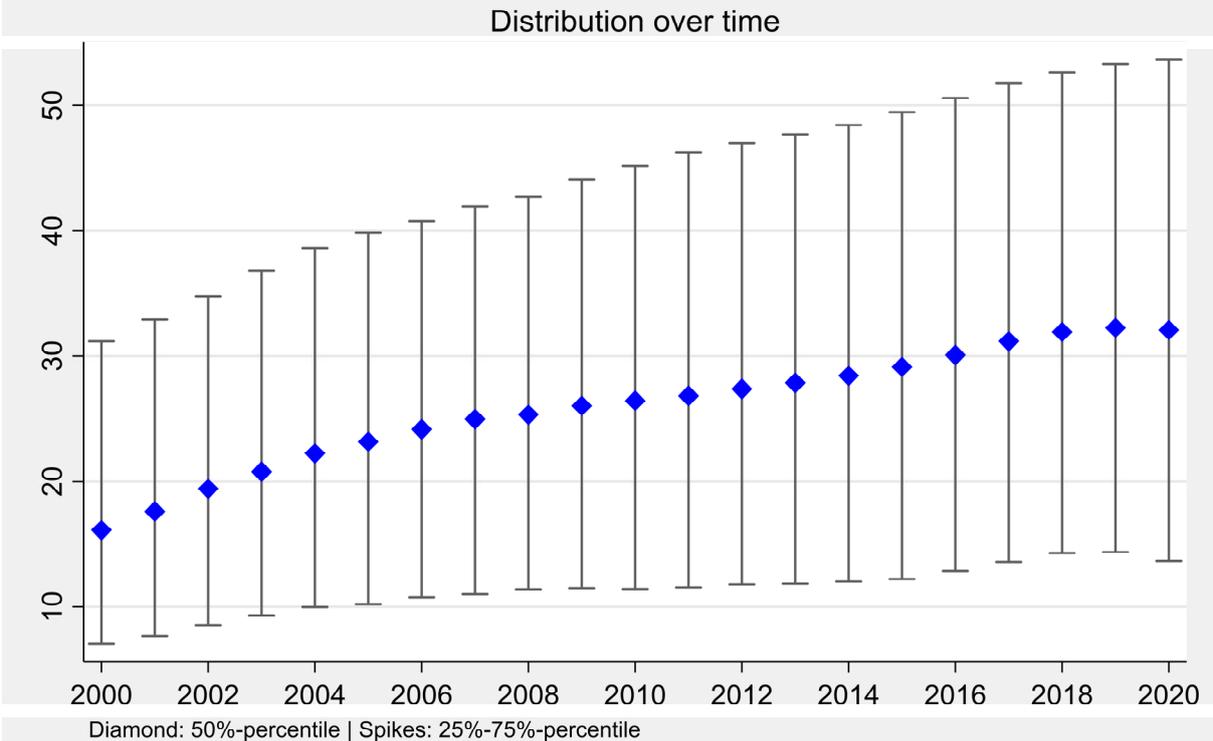
Panel C



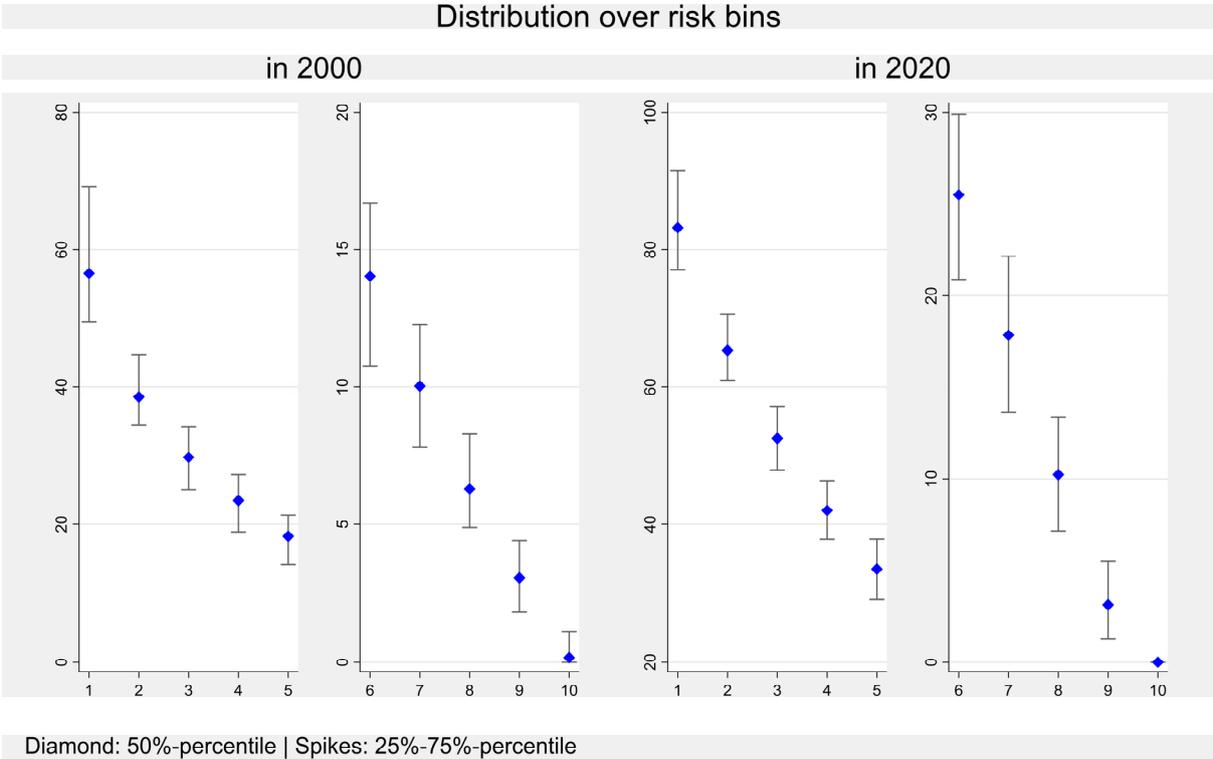
The debt overhang ratio is defined as the ratio of total debt to EBITDA.

The effect of higher debt levels on borrower-specific risk is also presented in **Figure 2.2**, which depicts the distribution of the borrower-specific equity ratio. Panel A shows the distribution over time, while Panel B compares the distribution within each risk bin in 2000 and 2020, and Panel C shows the results for different levels of stressed debt. Even in the case of scenario three, in which debt levels increase by the maximum of the positive values of Δ credit and negative values of Δ gross value added taken as absolute values, the equity ratio of the median borrower only decreases to the values seen in 2016-17. The strong resilience of equity ratios is due to the fact that although debt increased over the last two decades, so did equity levels. In other words, between 2000 and 2020 equity increased by 155.8% for the median borrower and by 137.4% on aggregate, i.e. for all borrowers present in the sample. As a result, the equity ratio increased from 16% to 32% for the median borrower over the last two decades (Panel A). Borrowers could therefore rely on comparably favourable equity levels by the start of the COVID-19 pandemic across all parts of the distribution (Panel B), which could be used to cover cash shortfalls, amongst other things. Or, from the banks' perspective, even if a borrower were likely to default, LGDs would still probably be relatively low.

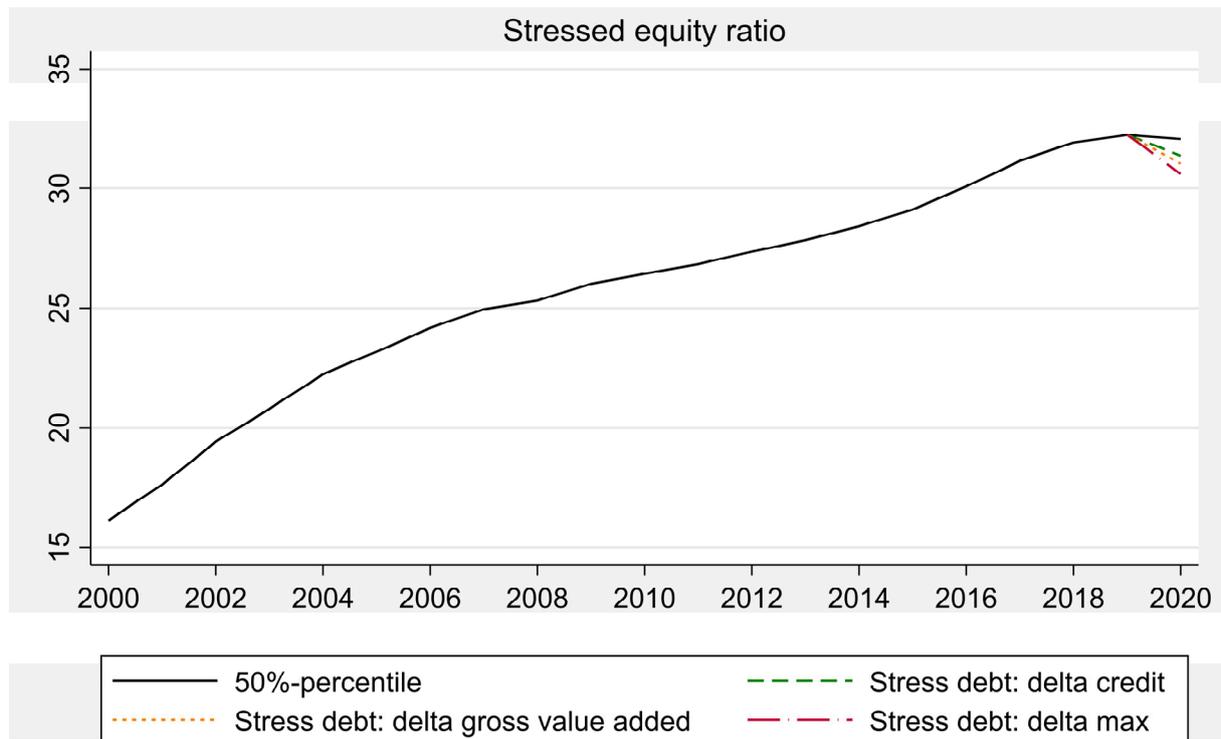
Figure 2.2: Equity ratio, %
 Panel A



Panel B



Panel C

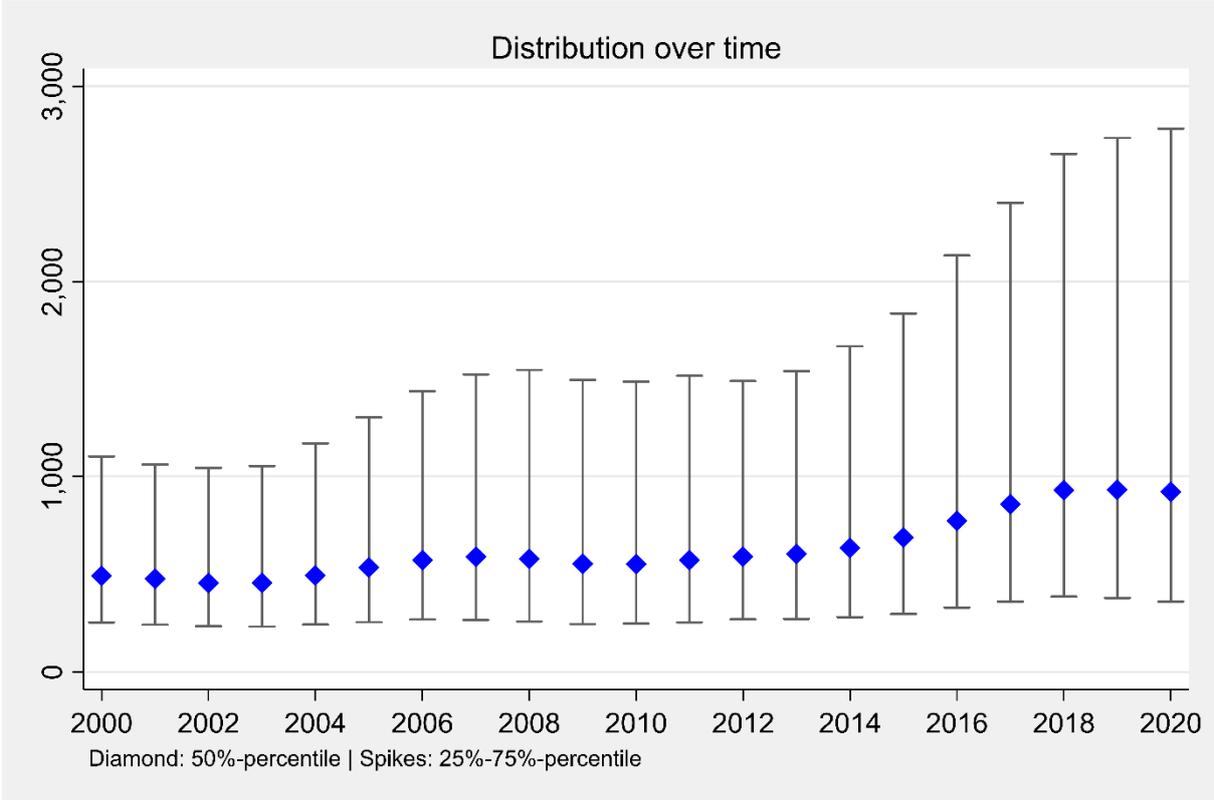


The equity ratio is defined as equity in relation to total assets.

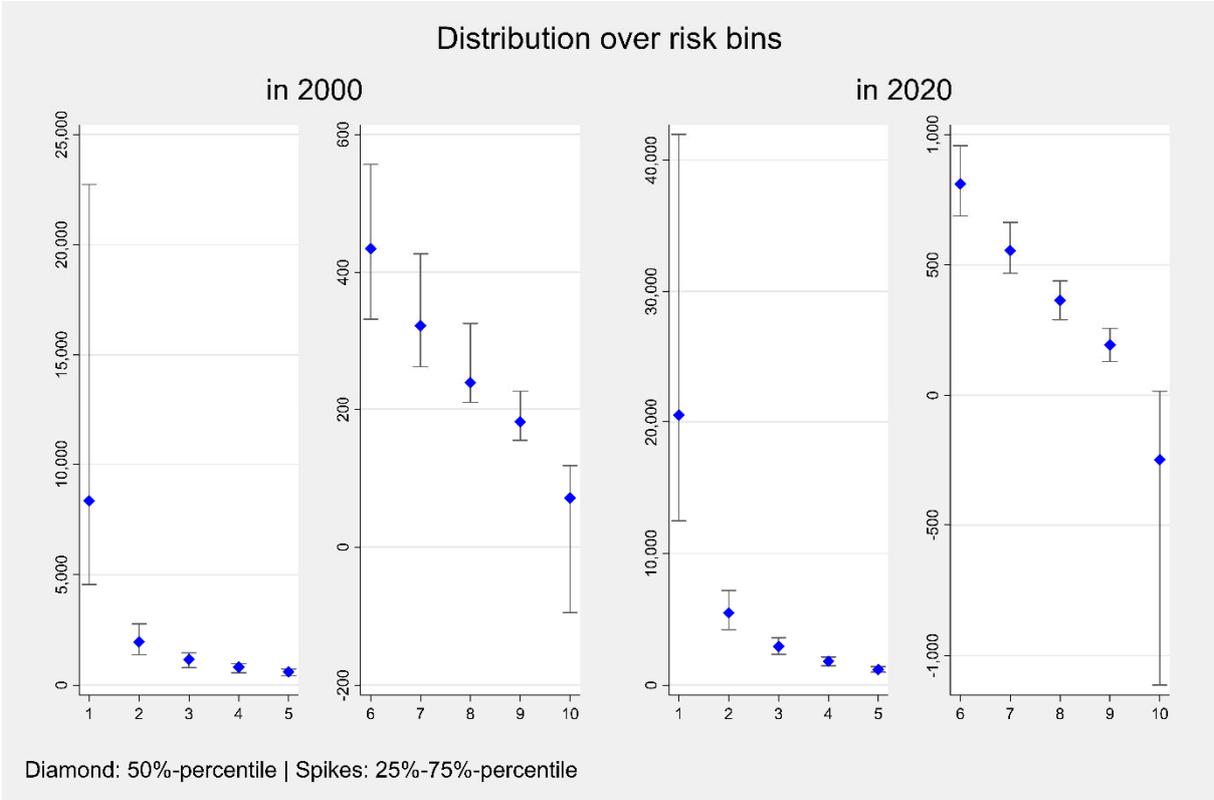
Figure 2.3 depicts the borrower-specific interest coverage ratio, which can be interpreted roughly as the amount of times a company can pay its interest expenses via its profits. Panel A shows that, in contrast to the debt overhang, the interest coverage ratio itself improved dynamically over time, nearly doubling over the last two decades. Specifically, in 2020 the median company has an interest coverage ratio of 920%, i.e. it is able to pay 9.2 times the amount of its interest expenses. This is to a large extent due to the fact that, for the median borrower, interest rates on total debt decreased by nearly 58% (from 3.16% to 1.35%) between 2000 and 2020. But, similarly to the debt overhang ratio, Panel B shows, first, that the distribution across varying risk bins widened and, second, that tail risks increased considerably. Whereas the median interest coverage ratio in risk bin ten is 71% in 2000, it goes so far as to venture into negative territory in 2020.²⁶ In contrast to stressed debt levels, Panel C depicts stressed interest expenses for the stock of old debt that has to be rolled over as well as for additional (stressed) debt stemming from the COVID-19 pandemic. As for the debt overhang ratio, stressed income impacts the borrower-specific interest coverage ratio to a considerably lesser extent. But if borrowers needed to pay interest rates on their total debt that were 1 percentage point higher due, for example, to a higher risk premium – which in turn would make them equal to interest rates in the mid-2000s – the median interest coverage ratio would deteriorate by 18.7% in 2020 compared with 2019, and by 30.5% in the case of an interest rate increase of 2 percentage points. Assuming borrowers take on additional debt to cover expenses and cash shortfalls in 2020, the interest coverage ratio would deteriorate by 26.4% and 39.1%, respectively.

²⁶ In other words, companies experience negative EBITDA.

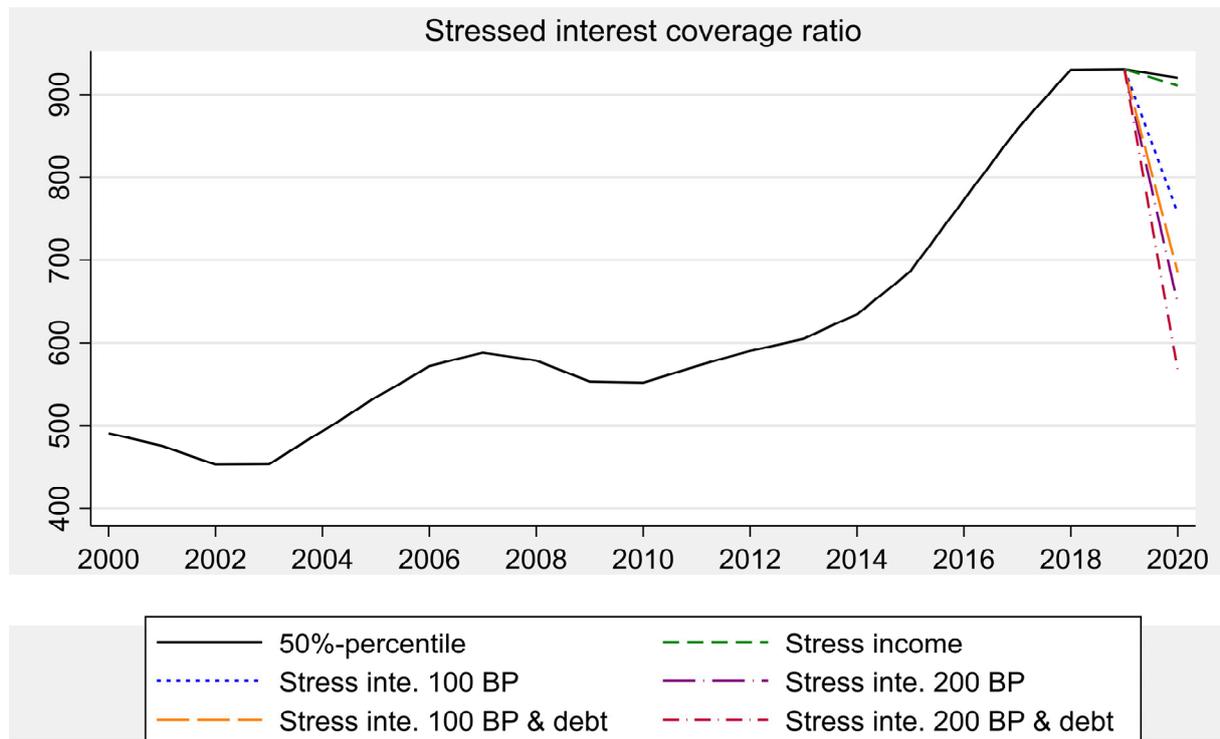
Figure 2.3: Interest coverage ratio, %
 Panel A



Panel B



Panel C



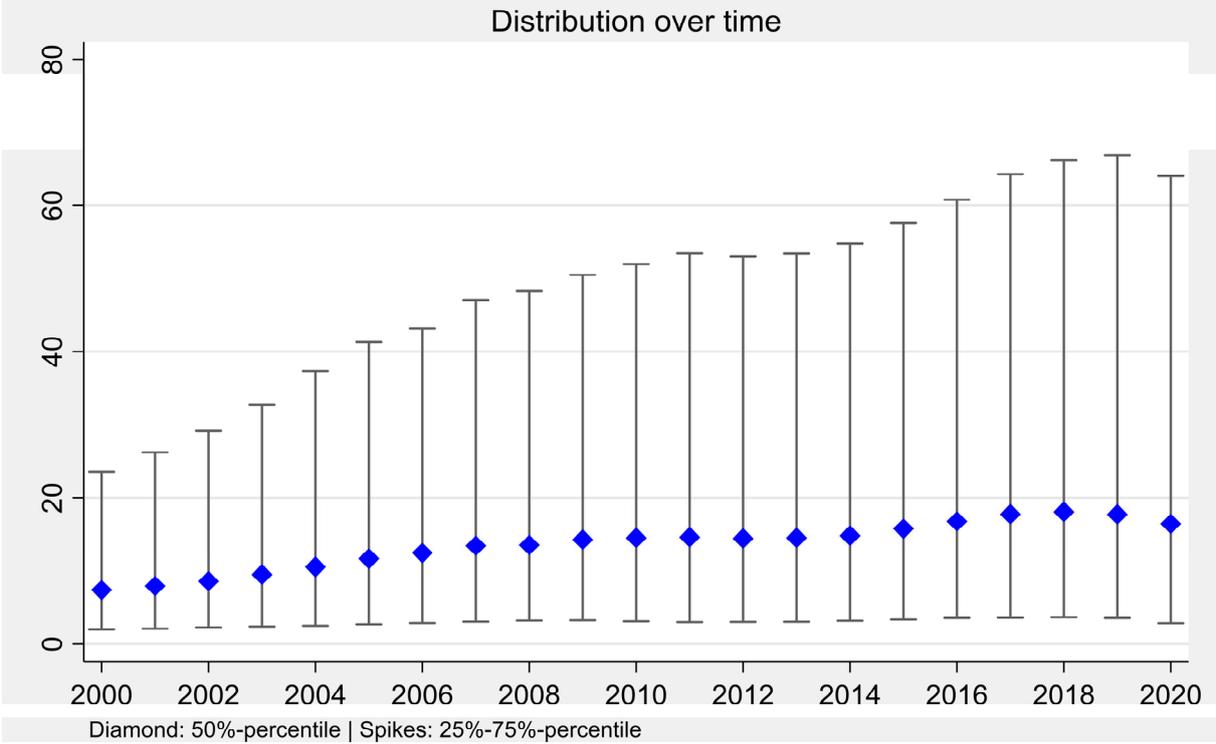
The interest coverage ratio is defined as the ratio of EBITDA to interest expenses.

Figure 2.4 depicts the borrower-specific cash ratio. Similarly to the interest coverage ratio, Panel A shows that the cash ratio of borrowers more than doubled over the last two decades. Borrowers were therefore able to rely on improved cash positions by the start of the COVID-19 pandemic across all parts of the distribution (Panel B). Nevertheless, borrowers in risk bins seven to ten, i.e. the worst 40% of borrowers, have a median cash ratio of below 8.3%, which can be translated into an approximated time of less than one month before running out of cash if cash inflows were to abruptly stop.²⁷ Hence, the need of swift and sizeable liquidity support measures. Higher interest rates and additional debt would diminish cash ratios at the most by 10.8% in 2020 compared with 2019. Moreover, it is important to note that the cash ratio is stressed solely via the denominator. The numerator is not stressed, mainly due to the scarce availability of information on how public liquidity support measures effectively impacted borrowers' cash positions. Inferring from the low and improving insolvency figures in 2020, immediate cash needs were sufficiently covered.²⁸

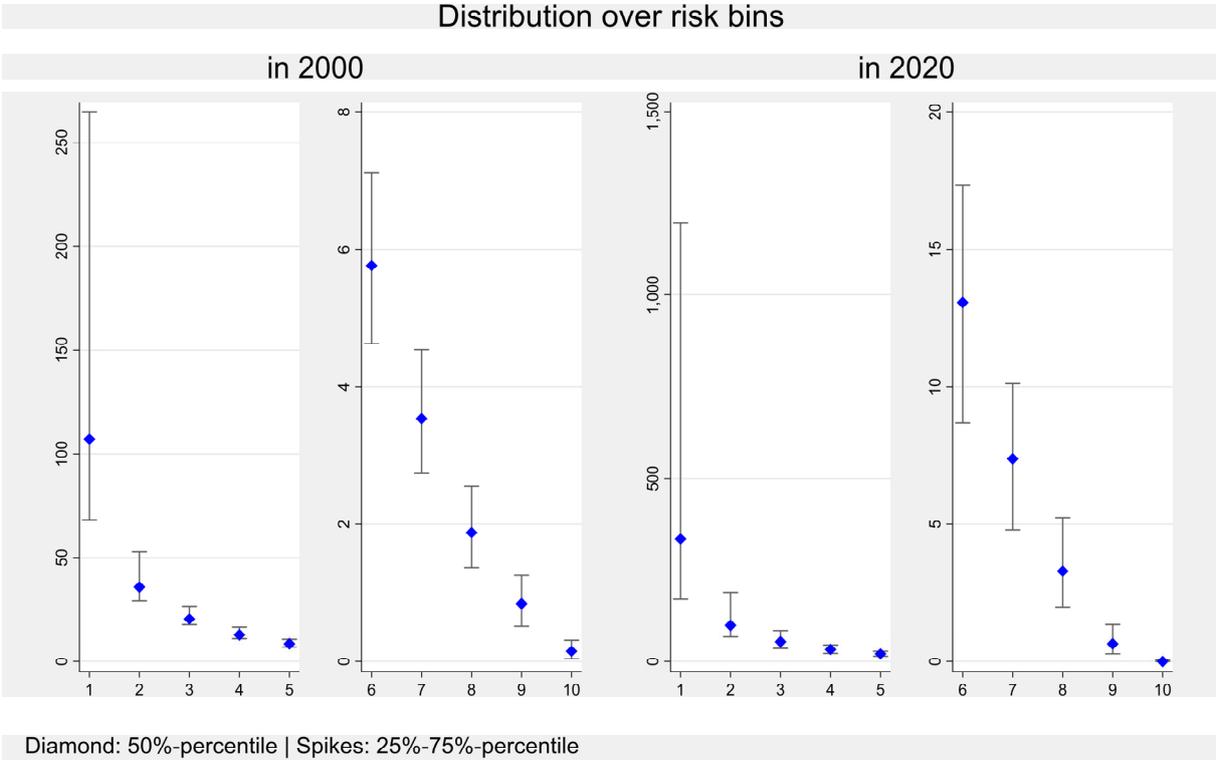
²⁷ Assuming a ratio of 100% covers cash outflows for one year and cash outflows are distributed equally over the year.

²⁸ This is corroborated by the Deutsche Bundesbank's internal assessment "Einschätzung des Finanzierungsbedarfs und Verschuldungsgrads deutscher Unternehmen in der aktuellen Krise (Jueppner (Vo 31-11), 2021)", which states that liquidity support measures will be sufficient in 2021 as well.

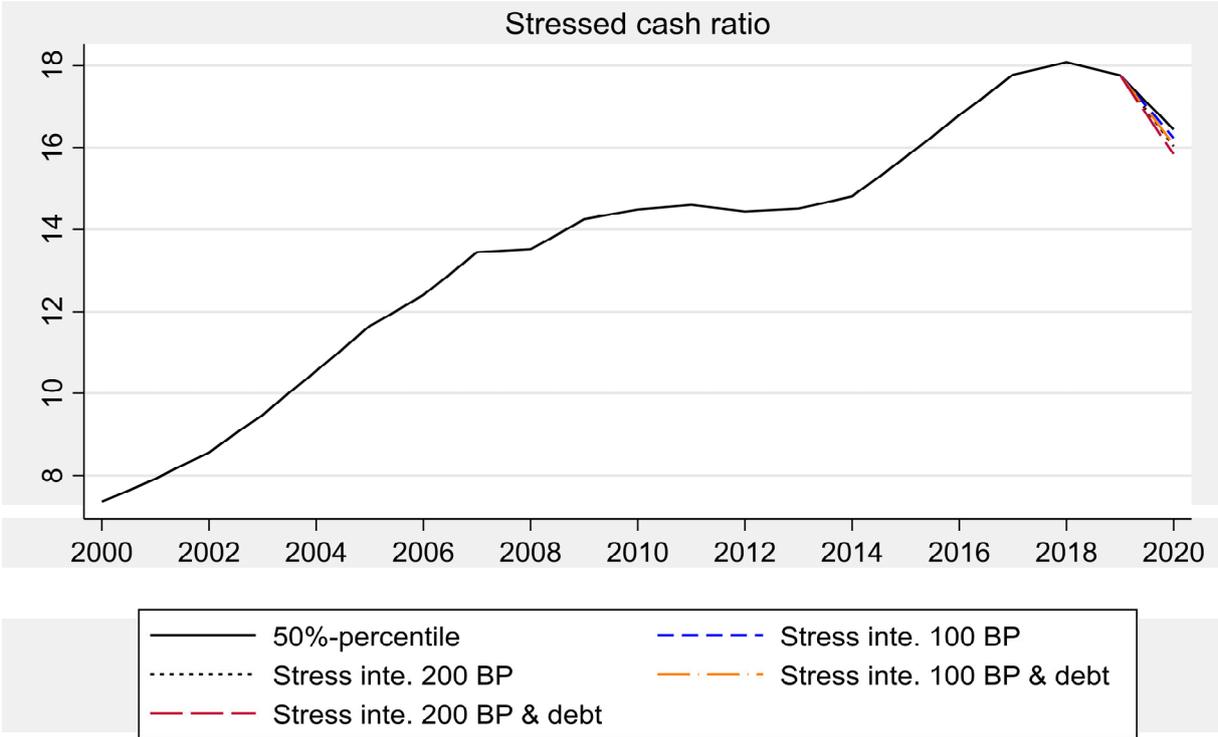
Figure 2.4: Cash ratio, %
Panel A



Panel B



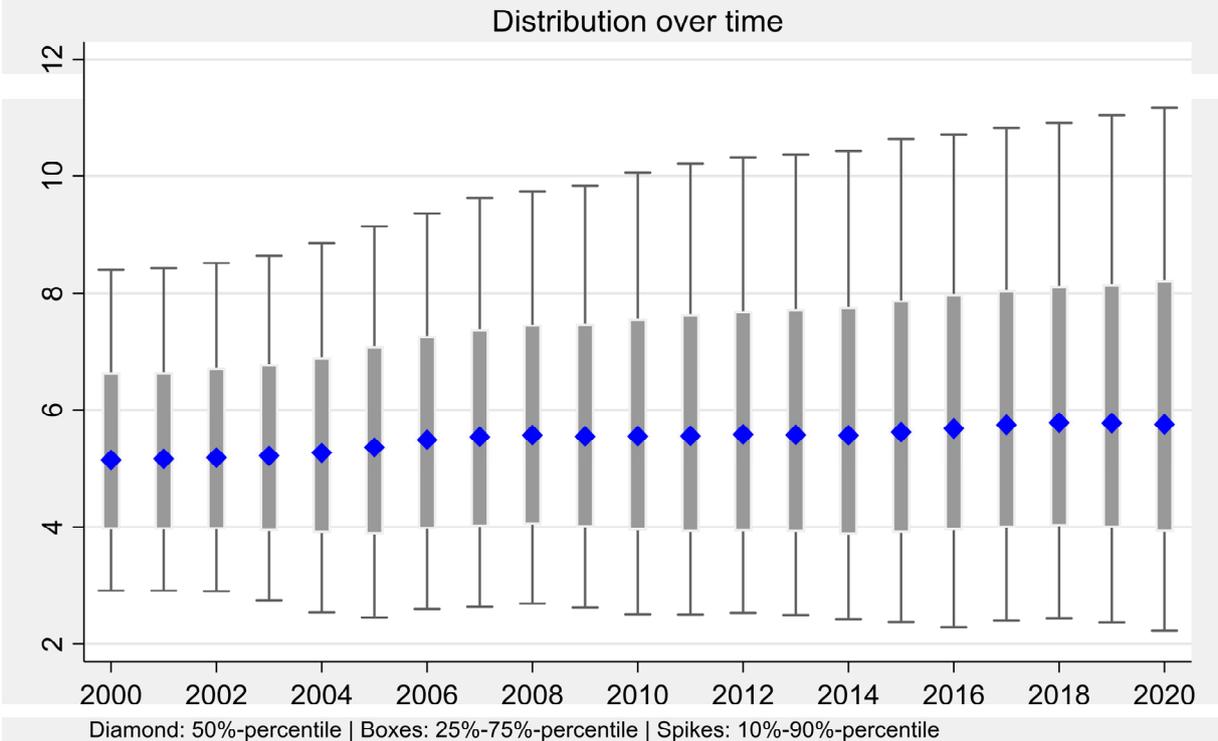
Panel C



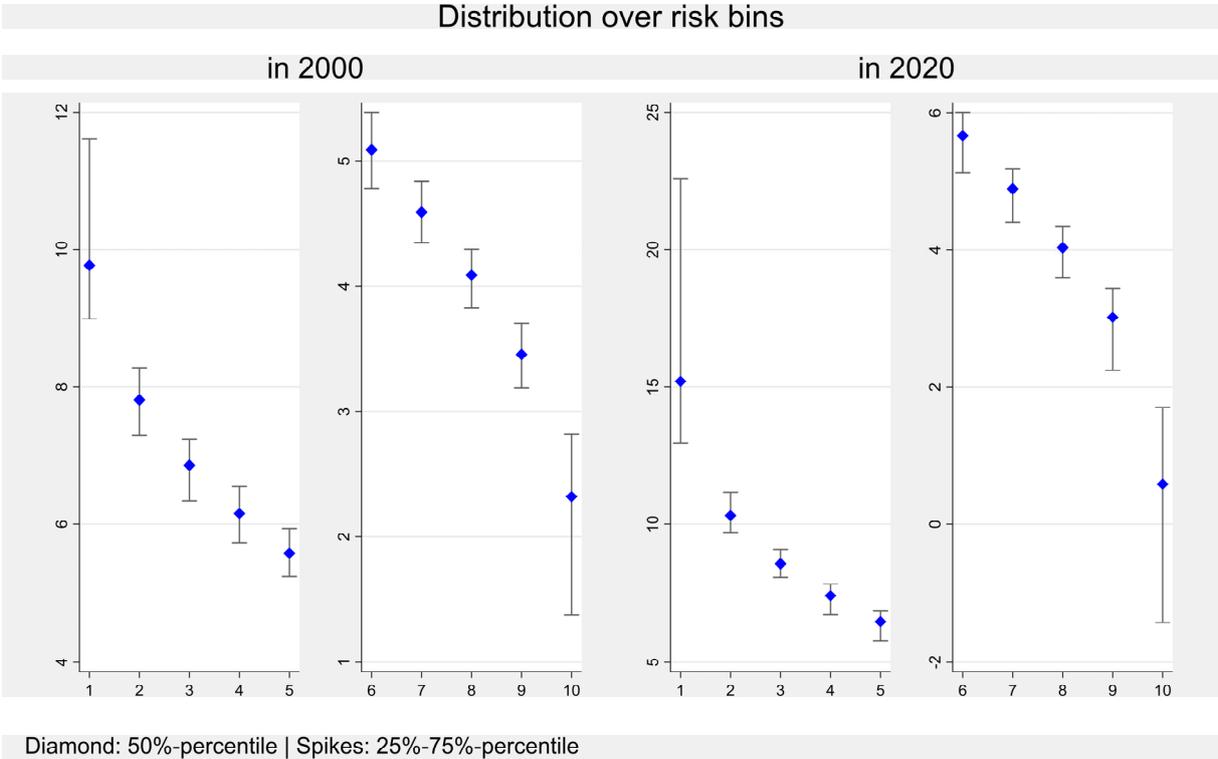
The cash ratio is defined as liquid assets in relation to fixed costs, including interest expenses. Specifically, cash in hand, central bank balances, bank balances and cheques in relation to fixed costs and interest expenses, with staff costs, business start-up and expansion expenses and other operating expenses reported outside of cost of sales, selling expenses, and general and administrative expenses counting as fixed costs.

Figure 2.5 depicts the borrower-specific Altman Z-score. In contrast to previous borrower-specific risk measures, Panel A depicts the distribution over time of the 10th and 90th percentiles as well. It shows that the Altman Z-score improved by 11.8% for the median borrower between 2000 and 2020. But, similarly to the debt overhang and the interest coverage ratio, Panel B shows, first, that the distribution across varying risk bins widened and, second, that tail risks increased. Specifically, whereas the median Altman Z-score in risk bin ten is 2.3 in 2000, it deteriorates to 0.6 in 2020. In other words, for borrowers exhibiting the highest risk, it moves out of the “grey zone” and down into the “distress zone”, which indicates a very high probability of reaching the stage of bankruptcy within the next two years. Due to its multidimensional nature, the Altman Z-score is not stressed. In general, according to this measure, roughly the bottom 5% of borrowers have Altman Z-scores placing them in the “distress zone” over the sample period.

Figure 2.5: Altman Z-score
Panel A



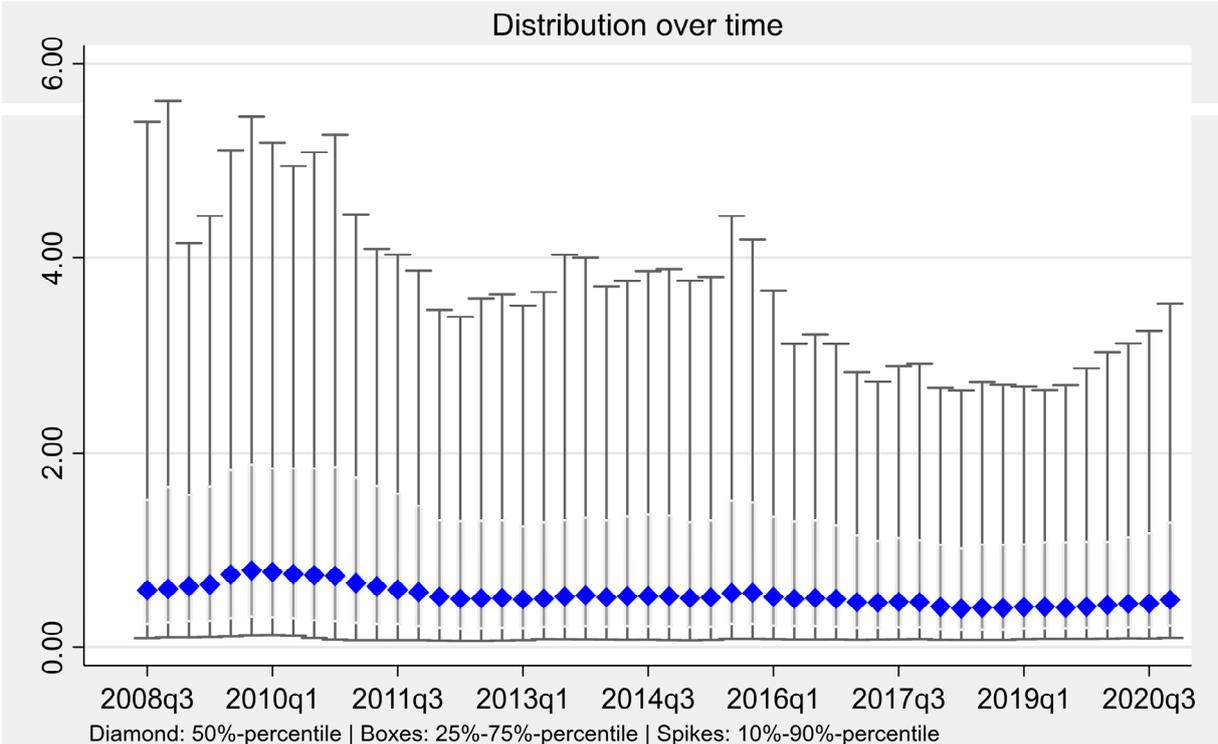
Panel B



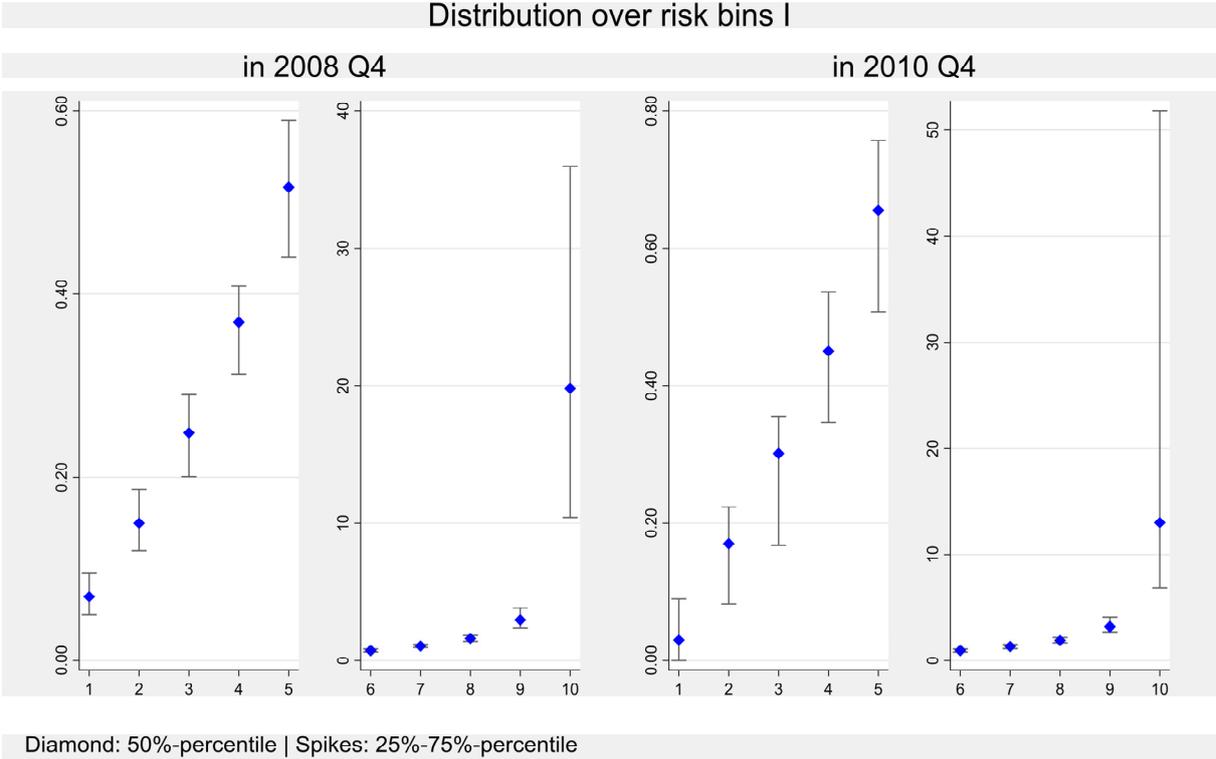
In this model, if the Z value is greater than 2.6, the firm is said to be in the “safe zone” and has a negligible probability of filing for bankruptcy. If the Z value is between 2.6 and 1.1, it is said to be in the “grey zone” and has a moderate chance of bankruptcy. If the Z value is below 1.1, it is said to be in the “distress zone” and has a very high probability of reaching the stage of bankruptcy.

Figure 2.6 depicts the borrower-specific PD reported by IRB banks. Due to the narrow values of the IRB PDs, Panel A also displays the 10th and 90th percentiles, as in Figure 2.5. In contrast to previous borrower-specific risk measures, Panel A shows a tightening of PDs up to the end of 2019. Thereafter, IRB PDs start to increase in all percentiles, but they do not reach levels seen in periods such as the end of 2009 in the aftermath of the global financial crisis. Though the COVID-19 pandemic triggered a recession on a scale similar to the one observed in 2009, PDs in 2020 – even in the 90th percentile – are not higher than those at the end of 2015, one year following the end of the European debt crisis. Due to the reporting of IRB PDs starting during a crisis period, Panel B depicts the risk bins’ distribution for 2008 and 2010 and Panel C the distribution for 2012 and 2020. Irrespective of the starting point, the 2020 figures do not exhibit any signs of severe distress comparable to the global financial crisis. Additionally, it is important to note that these are actual figures. In other words, at this stage, either the fall-out from the COVID-19 pandemic was assessed by IRB banks as being negligibly small or the true fall-out had not been incorporated into the PDs. It is only compared with 2012 that median PDs in 2020 are worse across risk bins one to five, but this is only by a small margin. Compared with 2008 and 2010, median IRB PDs for all risk bins are markedly lower in 2020.

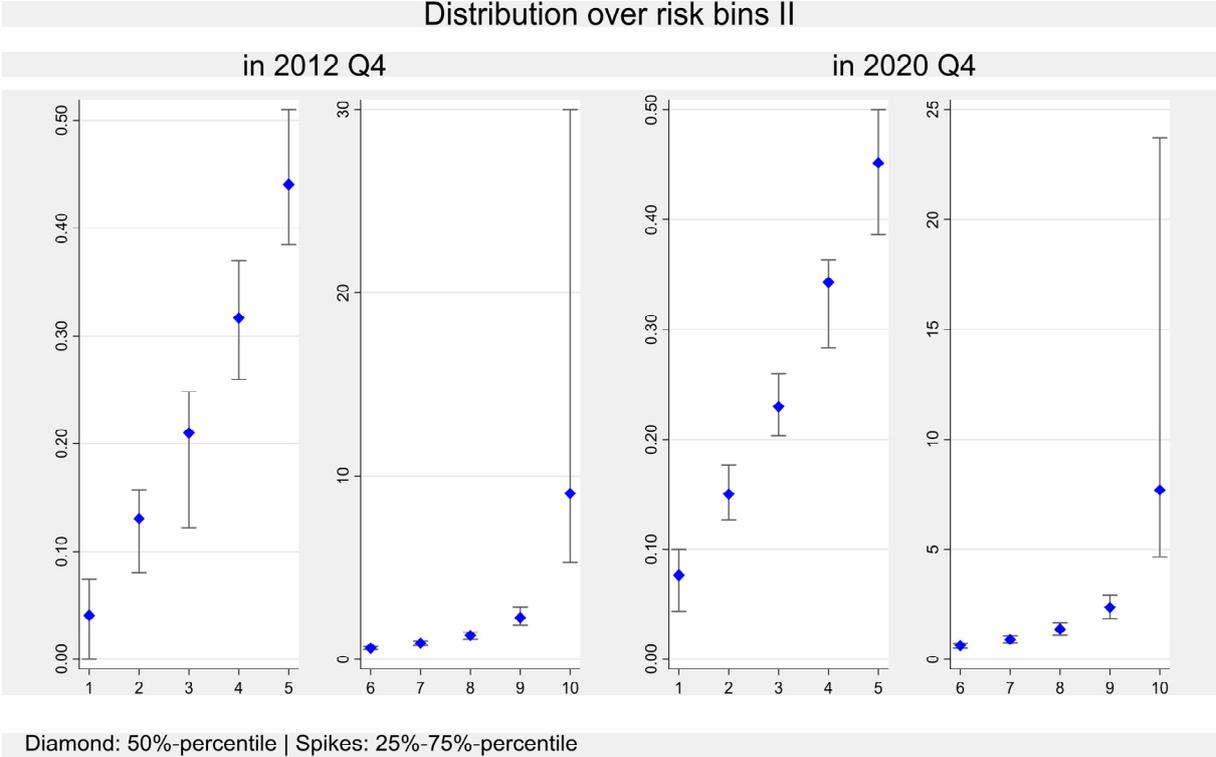
Figure 2.6: Probability of default (PD), %
Panel A



Panel B



Panel C



PDs are derived from IRB banks.

3. Aggregate allocation risk

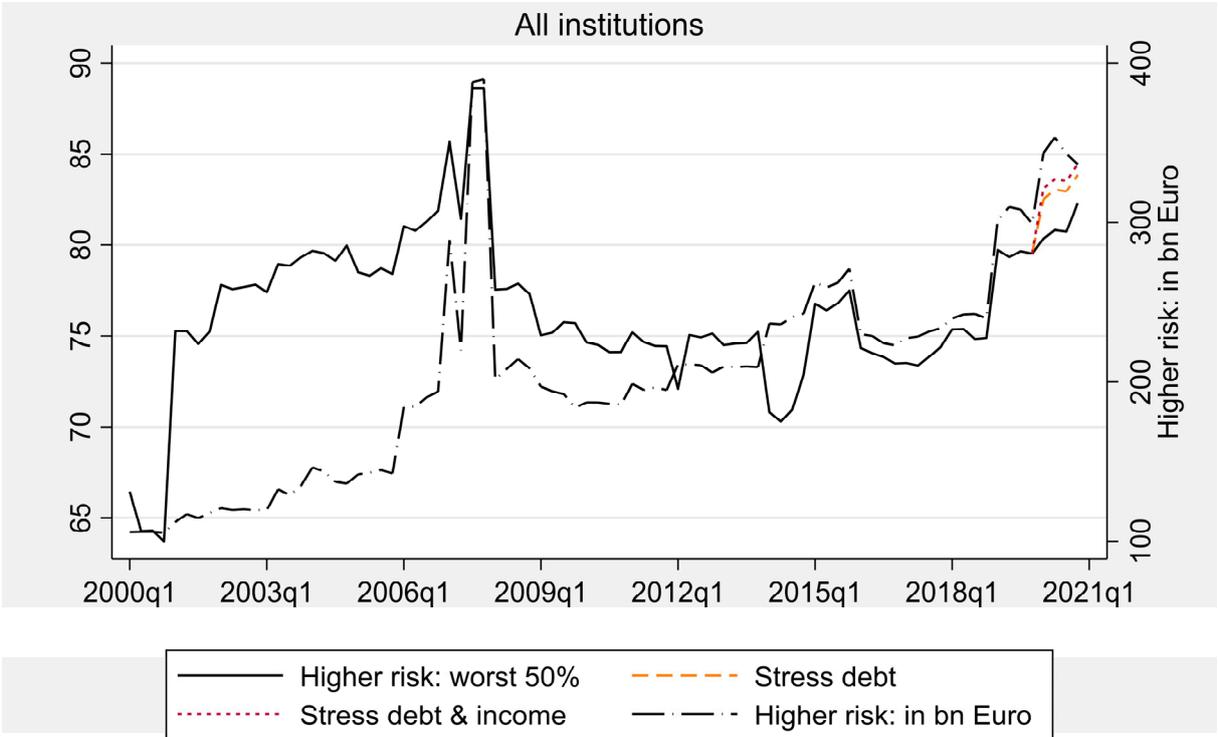
Section 3 explores how aggregate allocation risk develops over time for different risk clusters as well as in the various stress scenarios discussed in Section 2. Aggregate allocation risk is calculated by aggregating banks' exposure to borrowers in each risk bin (one to ten) for a distinct borrower-specific risk measure, both across all banks and across O-SIIs and L-SIIs. Aggregate allocation risk can therefore take values between 0% and 100%, i.e. banks can exhibit zero exposure or all of their exposure to borrowers within a specific risk bin or cluster of bins. Moreover, risk bins for the stressed variables are calculated by comparing the stressed outcome of a given variable to its distribution in the case of no stress (baseline). In other words, the subject of analysis is the number of risk bins in which a borrower-specific risk measure deteriorates due to the underlying stress scenario and, accordingly, how much exposure is potentially at risk.

To assess aggregate allocation risk, the exposure across various risk bins is condensed into the following four risk clusters. First, the level of exposure outstanding to borrowers in risk bins six to ten compared with all borrowers is analysed. Borrowers in these risk bins are in the worse half of the distribution, and are referred to as borrowers exhibiting "higher (or elevated) risk". The stress outcomes, as well as the amount of exposure in euro billion, are plotted for this cluster. Second, the level of exposure outstanding to borrowers in risk bins eight to ten compared with all borrowers is analysed for all bank groups. Borrowers in these risk bins are in the worst 30th percentile of the distribution, and are referred to as borrowers exhibiting "high risk". Third, to highlight tail risks, the level of exposure outstanding to borrowers in risk bin ten compared with all borrowers is analysed. Borrowers in this risk bin are in the worst 10th percentile of the distribution, and are referred to as borrowers exhibiting the "highest risk". Fourth and lastly, the level of exposure outstanding to borrowers in risk bins four to seven compared with all borrowers is analysed. Borrowers in these risk bins are between the 30th and 70th percentile and are referred to as borrowers exhibiting "medium risk".

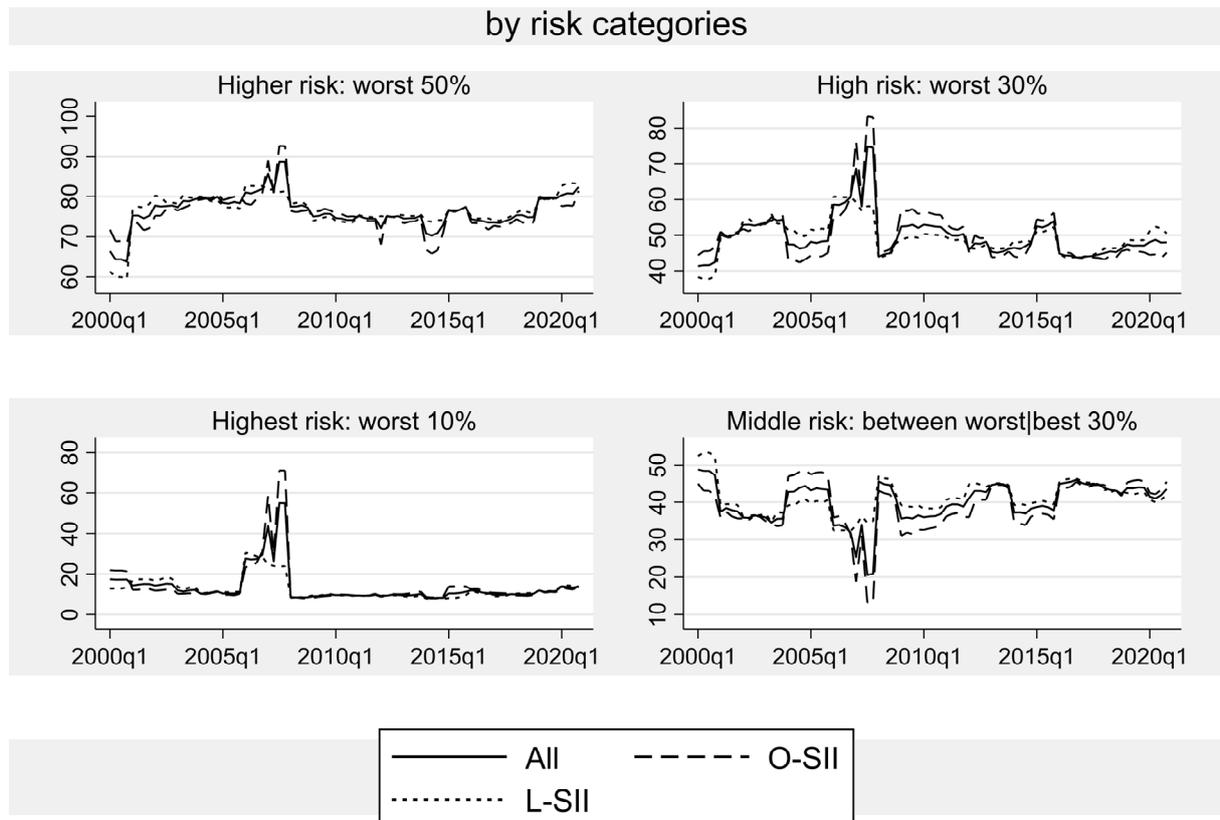
Figure 3.1 depicts allocation risk to higher-risk borrowers (cluster one), i.e. borrowers in the worse half of the distribution, based on the debt overhang ratio in Panel A. It shows an upward trend starting at the end of 2014, with allocation risk to this cluster amounting to more than 82% in 2020. In other words, the worse 50% of borrowers based on the debt overhang ratio make up more than 82%, or €336.5 billion, of the aggregate portfolio of German banks. If these borrowers were affected by stress scenarios that translated into higher total debt, aggregate allocation risk would be about 1.6 percentage points higher, or about 2.1 percentage points higher if borrowers' income also decreased. Hence, in the most severe stress scenario, allocation risk based on borrowers' debt overhang ratio would increase moderately, by around 2.6%, vis-à-vis the borrowers in the worse half of the distribution compared with the baseline scenario with no stress. By contrast, aggregate allocation risk would increase by nearly 13%, from 13.9% to 15.7%, vis-à-vis the worst 10% of borrowers (cluster three). The reason why the 8% increase in the stressed debt overhang ratio depicted in Section 2 does not translate more broadly into banks' allocation risk but is rather seen in the tails is that although aggregate allocation risk is elevated and increases in 2020, banks have fewer credit relationships with borrowers most affected by the COVID-19 pandemic in terms of debt increases and/or income decreases. As a reminder, while for some borrowers, especially in sector I (accommodation and food service activities) or sector R (arts, entertainment and recreation), macroeconomic conditions deteriorated considerably due to the COVID-19 pandemic, conditions deteriorated to a far lesser extent for most sectors, especially those with a large share of the total number of borrowers and, more importantly, credit relationships (Table 1). Panel B shows that the upward trend for allocation risk is mirrored in different risk clusters as well. Even the worst 10% of borrowers (cluster three), for which tail risks increased over time (Section 2), make up more than 10% of the banks' aggregate credit portfolio, irrespective of the bank group. Consequently, banks' tail risks increased twofold: first, because the borrowers in the tail of the

distribution became riskier and, second, because banks steadily increased their exposure to those borrowers following the global financial crisis. As a result, aggregate allocation risk in this risk cluster would increase more compared with the other risk clusters should those stress scenarios materialise. Aggregate allocation risk to borrowers exhibiting medium risk (cluster four) is fairly stable, fluctuating over time at values mostly between 30% and 45%. All in all, in a PD-LGD stress-test framework, these results imply two things. First, the banks' aggregate credit portfolio has a disproportionately high and soaring level of exposure to borrowers exhibiting elevated risk based on the debt overhang ratio, which proxies to some extent the probability of a borrower filing for bankruptcy in the medium term. Second, the amount of this exposure at risk would grow only moderately if borrower debt levels increased and income levels decreased.

Figure 3.1: Aggregate allocation risk based on borrowers' debt overhang ratio, percentage total exposure
 Panel A



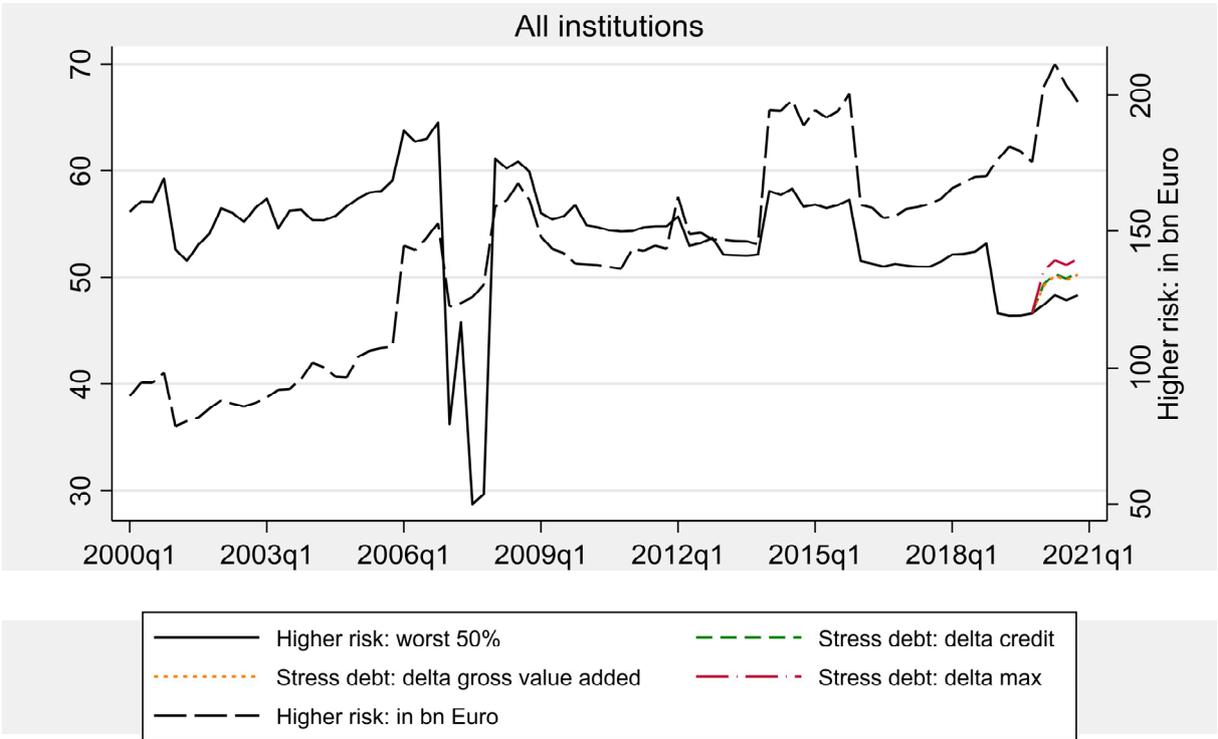
Panel B



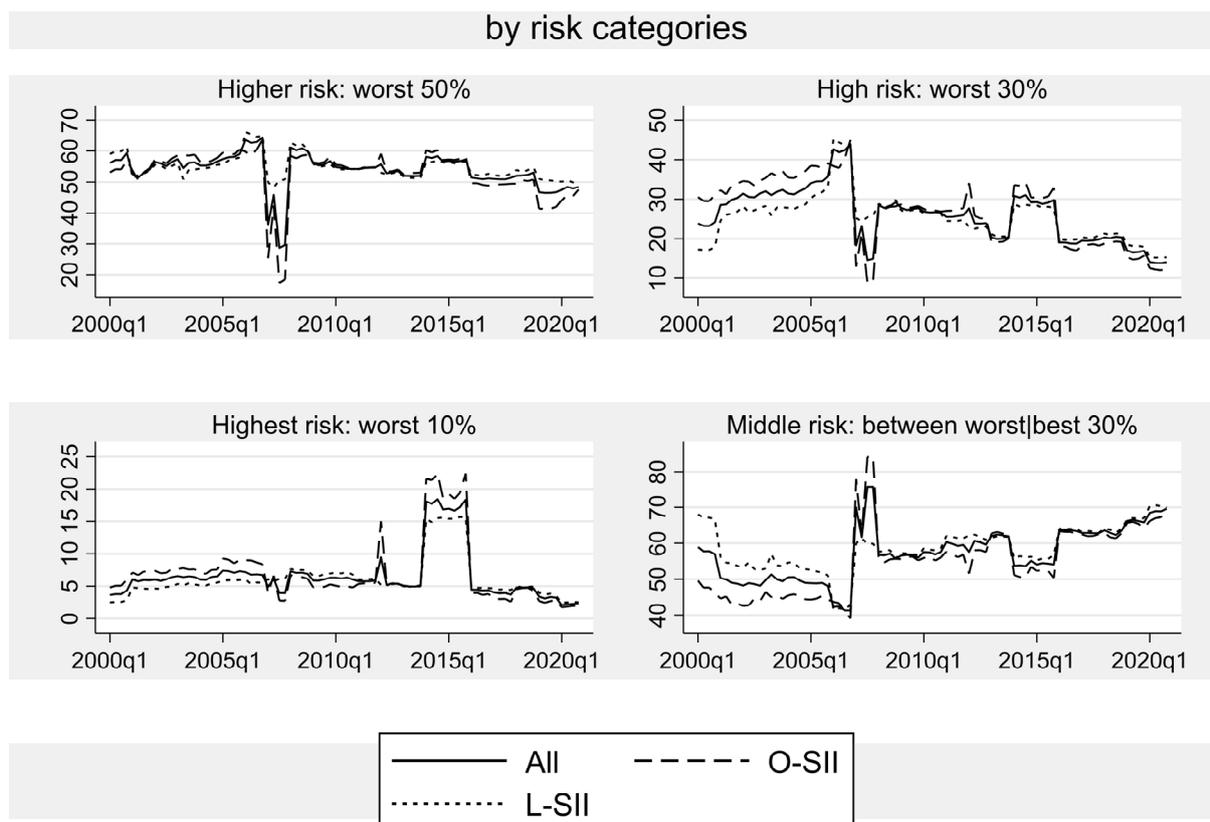
The debt overhang ratio is defined as the ratio of total debt to EBITDA. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

Panel A of **Figure 3.2** depicts allocations risk to higher-risk borrowers (cluster one), i.e. borrowers in the worse half of the distribution, based on the equity ratio. Though exposure in absolute terms steadily increases to up to €200 billion in 2020, the ratio fluctuates for higher-risk borrowers. However, the ratio increases quarter on quarter starting in 2016:Q1, except for the first quarter of 2019, which incidentally corresponds to the point in time at which changes to the reporting of credit register data were introduced. Moreover, in the most severe scenario, aggregate allocation risk increases by around 3.4 percentage points, or 7%, to 51.7%. In contrast to allocation risk based on the debt overhang ratio, the banks' aggregate credit portfolio does not appear to be heavily skewed in the direction of higher-risk borrowers in terms of the equity ratio. The reason for this is revealed in Panel B, which shows that banks shifted credit to borrowers exhibiting medium risk (cluster four). Those 40% of borrowers make up roughly 70% of the aggregate credit portfolio. On the flip side, aggregate credit exposure to borrowers in best 10th percentile (not reported) decreased to only 1.1%. Nevertheless, in a PD-LGD stress-test framework, these results imply two things. First, the banks' aggregate credit portfolio does not have a disproportionately high level of exposure to borrowers exhibiting elevated risk based on the equity ratio – which proxies to some extent the borrowers' recovery rate – and, second, the amount of this exposure at risk would grow only moderately should borrower debt levels increase.

Figure 3.2: Aggregate allocation risk based on borrowers' equity ratio, percentage total exposure
 Panel A



Panel B



The equity ratio is defined as equity in relation to total assets. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

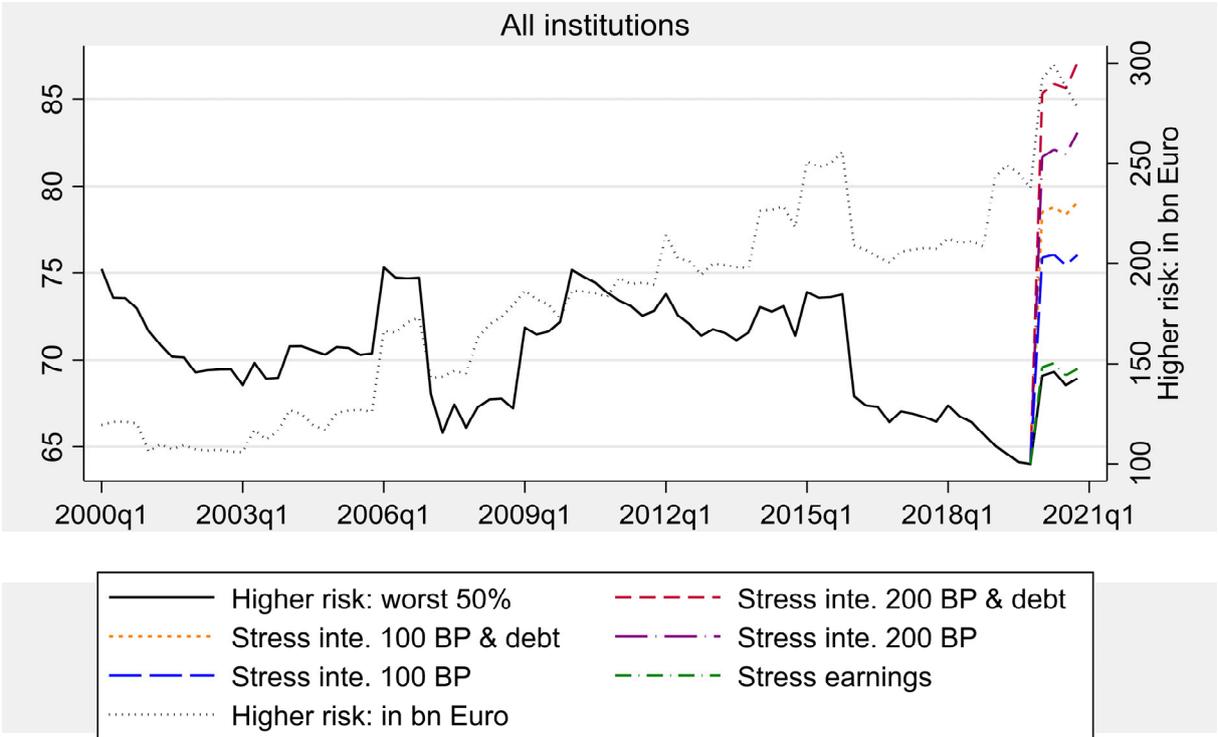
Panel A of **Figure 3.3** depicts aggregate allocation risk to higher-risk borrowers (cluster one) based on the interest coverage ratio. Exposure in absolute terms steadily increases to €280 billion by the end of 2020, while the ratio shows a downward trend between 2010:Q2 and 2019:Q4 and an increase in 2020:Q1, i.e. the beginning of the COVID-19 pandemic. All in all, at around 69%, aggregate allocation risk is elevated, i.e. banks are disproportionately exposed to borrowers with low interest coverage ratios. The potential implications for the stability of the banking system become clear when examining the outcome of stress scenarios that use higher interest rates to stress interest expenses. Allocation risk based on the interest coverage ratio increases by around 7 percentage points to 76% in the case of a 1 percentage point increase in the average interest rate. This increase in the stressed interest rate corresponds to the average in-sample interest rates seen in 2011 as well as aggregate, out-of-sample figures from the MFI interest rate statistics²⁹ in the same period. If interest rates increased by 2 percentage points, i.e. to over 3% for the median borrower, aggregate allocation risk would increase to around 83%. If borrowers further increased their debt levels due to the COVID-19 pandemic, aggregate allocation risk would amount to 79% and more than 87%, respectively. In other words, nearly 90% of the banks' aggregate portfolio would consist of borrowers exhibiting elevated risk based on the interest coverage ratio. Moreover, similarly to the debt overhang ratio, the increase in stressed aggregate allocation risk vis-à-vis the worst 10% of borrowers – i.e. borrowers exhibiting the highest risk (cluster three) – would be higher than the increase for the median borrower.³⁰ Most importantly, it should be noted that the pass-through of the higher

²⁹ For detailed information, see [MFI interest rate statistics \(amounts outstanding, new business\) | Deutsche Bundesbank](#).

³⁰ In the case of an increase in the risk premium by 1 or 2 percentage points and no additional debt, aggregate allocation risk increases from 5.4% (baseline) to 6.3% and 6.9%, respectively, in 2020:Q4.

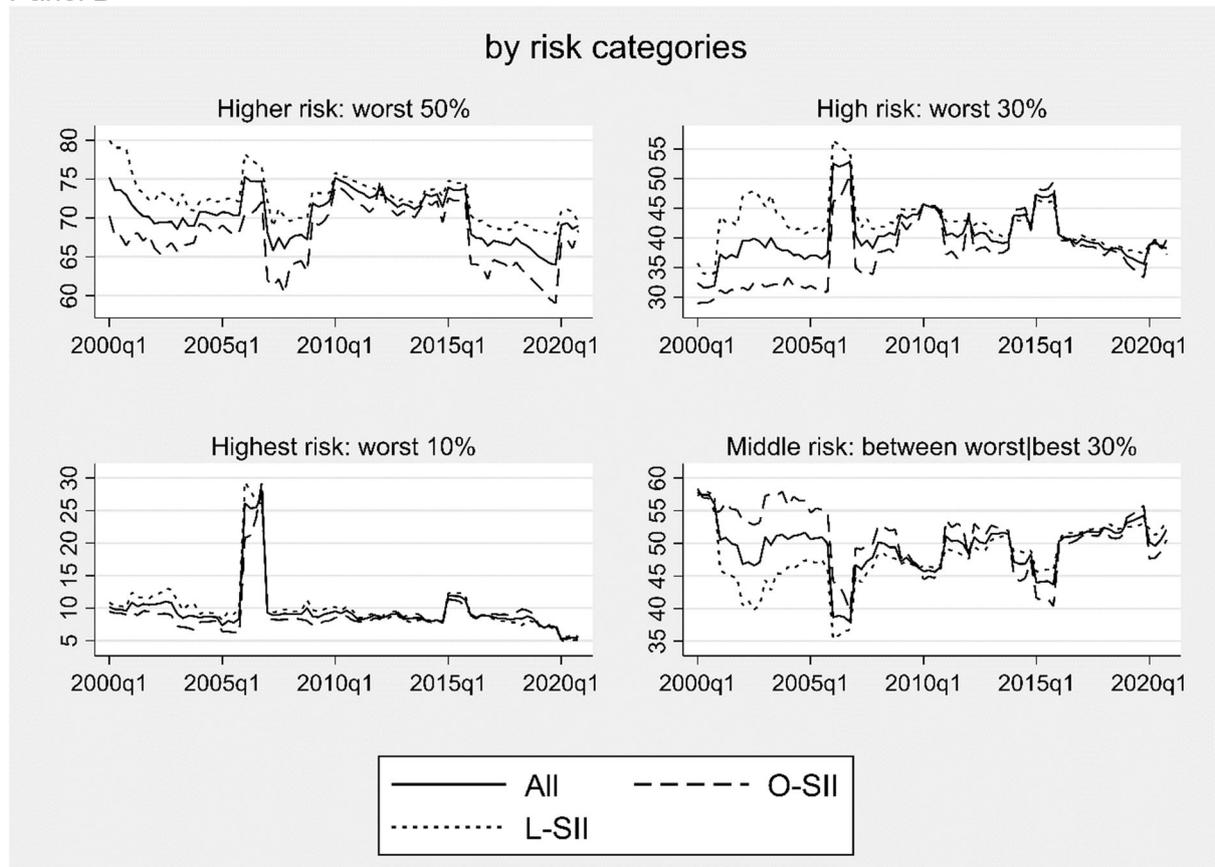
interest rates is assumed to be only 25.4%. If more debt became due during a period of elevated interest rates, aggregate allocation risk would be markedly higher.³¹ Regardless, even with an assumed pass-through of 25.4%, the increase in allocation risk is greater in the case of stressed interest rates than in the case of stressed debt levels (see Figure 3.1). The increase in the interest rate by 1 and 2 percentage points, respectively, is based on scenarios for the Basel interest coefficient, mirroring Bundesbank projections of the 75th and 95th percentile of the distribution for the increase in the risk-free rate in the next three years. Though it is presumably not the most likely outcome, an increase of such magnitude in risk premia, for instance, is not inconceivable. Even more so given that risk premia and risk-free rates do not exhibit a monotonic relationship. In other words, risk premia can rise at a faster and steeper rate than risk-free rates, especially in the short term, as seen during crisis periods in the past. Panel B shows that L-SIIs exhibit higher allocation risk vis-à-vis the worse half of borrowers (cluster one), whilst O-SIIs exhibit slightly higher allocation risk vis-à-vis borrowers in the worst three risk bins, i.e. high-risk borrowers (cluster two). Similarly to allocation risk based on the equity ratio, banks increased their exposure to medium-risk borrowers (cluster four) the most, i.e. to borrowers between the worst and the best 30th percentiles based on the interest coverage ratio. All in all, in a PD-LGD stress-test framework, these results imply two things. First, the banks' aggregate credit portfolio has a disproportionately high level of exposure to borrowers exhibiting elevated risk based on the interest coverage ratio – which proxies to some extent the probability of filing for bankruptcy in the short term – and, second, the amount of this exposure at risk would increase significantly should interest rates (i.e. risk premia) revert to levels seen in the mid-2000s.

Figure 3.3: Aggregate allocation risk based on borrowers' interest coverage ratio, percentage total exposure
 Panel A



³¹ The corner solution of all (existing) debt becoming due shows that aggregate allocation risk based on the interest coverage ratio would amount to 89% and 94%, respectively, in the case of an increase of an interest rate increase by 1 or 2 percentage points.

Panel B

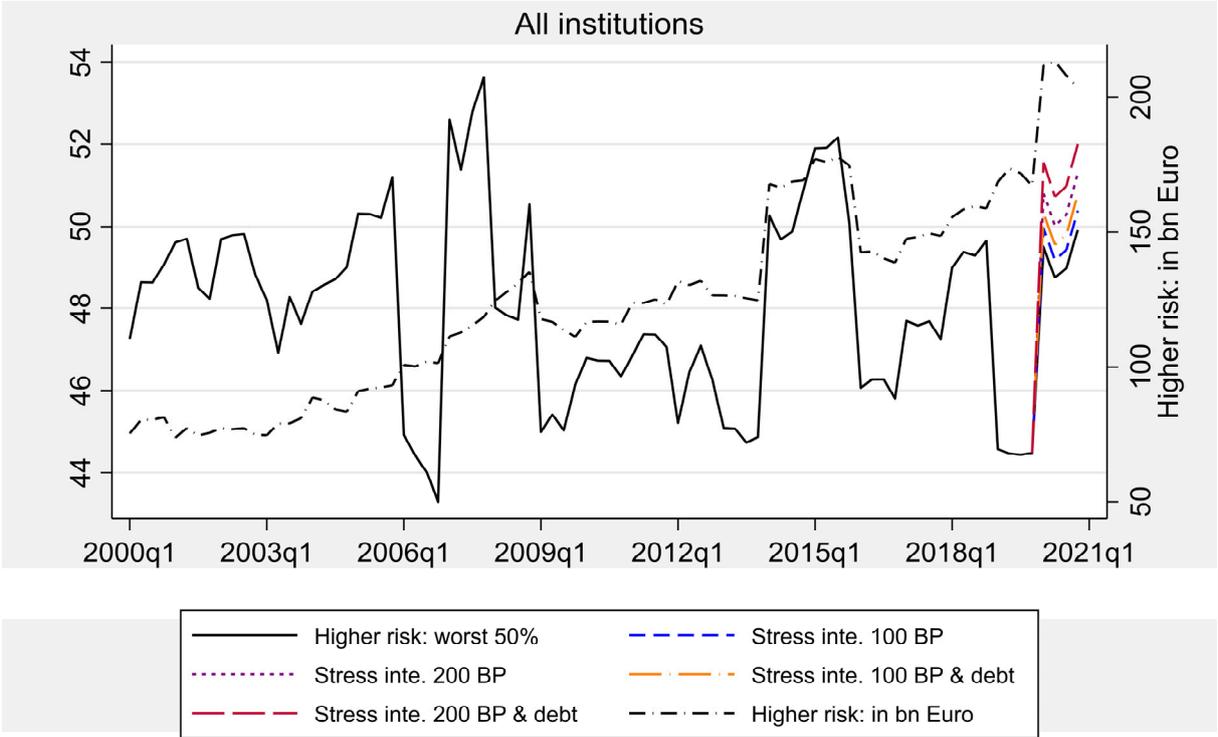


The interest coverage ratio is the ratio of EBITDA to interest expenses. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

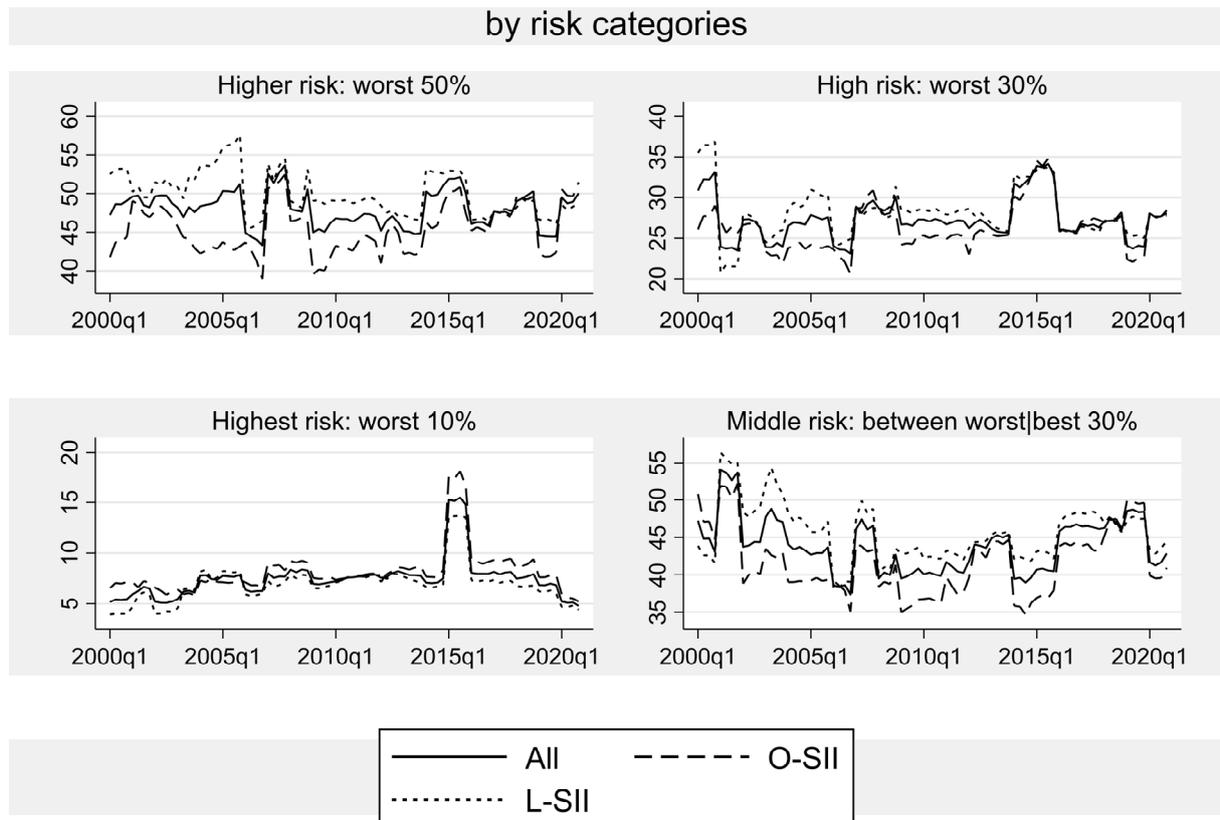
Figure 3.4 depicts allocation risk to higher-risk borrowers (cluster one) based on the cash ratio in Panel A. Though the ratio fluctuates between roughly 45% and 50%, it shows an increase of 5 percentage points, or €45 billion, in 2020:Q1. Whether this is due to the public credit guarantee schemes incentivising banks to grant more loans to companies most affected by the dry-up of cash inflows due to the lockdowns imposed in response to the COVID-19 pandemic is an open question. Nevertheless, should interest expenses increase by 1 or 2 percentage points, respectively, due to higher interest rates, and should borrowers need to service additional debt, aggregate allocation risk based on the cash ratio would increase at the most by nearly 2% and more than 4%, respectively. In other words, allocation risk would increase to 51% in scenario three and to 52% in scenario four. Interestingly, Panel B shows that banks did not increase their aggregate exposure to borrowers exhibiting the highest risk (cluster three), i.e. borrowers in the worst 10th percentile of the distribution of the cash ratio. To the contrary, aggregate exposure decreased by nearly 30%. On the other hand, aggregate exposure to high-risk borrowers (cluster two), i.e. borrowers in the worst 30th percentile, increased by 16%. Hence, if the public credit guarantee schemes did play a role, the picture is to some extent mixed as they might have supported cash-strained borrowers, but not the most exposed ones. All in all, in a PD-LGD stress-test framework, these results imply two things. First, the banks' aggregate credit portfolio does not have a disproportionately high level of exposure to borrowers exhibiting elevated risk based on the cash ratio, which proxies to some extent the probability of filing for bankruptcy in the short term. Second, should interest rates increase, e.g. due to a higher risk premium, the amount of this exposure at risk would grow to only moderate levels. However, it should be kept in mind that, even in the baseline scenario, borrowers in the 40th percentile have a median cash ratio below 8.3%, which can be translated

into an approximated time of one month before running out of cash if cash inflows were to abruptly stop.

Figure 3.4: Aggregate allocation risk based on borrowers' cash ratio, percentage total exposure
 Panel A



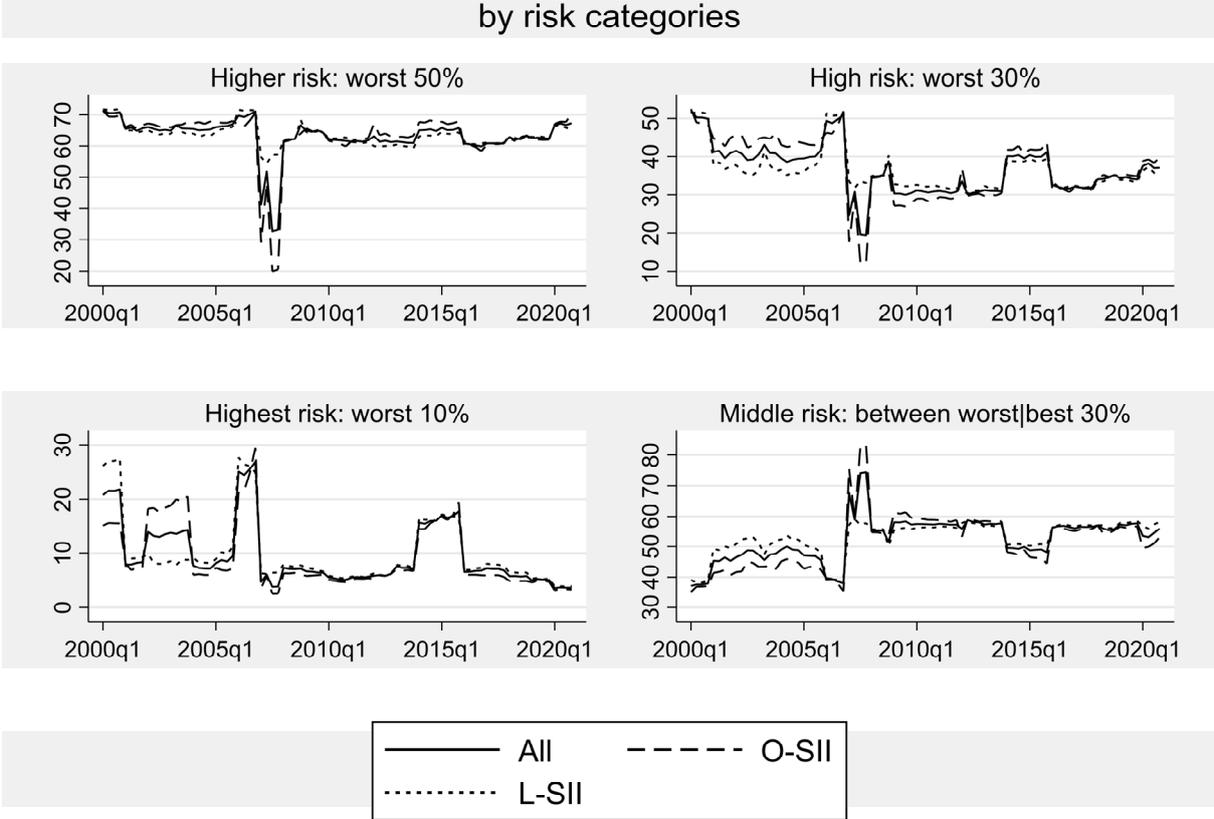
Panel B



The cash ratio is defined as liquid assets in relation to fixed costs, including interest expenses. Specifically, cash in hand, central bank balances, bank balances and cheques in relation to fixed costs and interest expenses, with staff costs, business start-up and expansion expenses and other operating expenses reported outside of cost of sales, selling expenses, and general and administrative expenses counting as fixed costs. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

In contrast to previous risk measures, **Figure 3.5** only depicts the aggregate allocation risk based on the Altman Z-score for different risk clusters and bank groups. Similarly to aggregate allocation risk based on the debt overhang ratio, it shows that allocation risk increases for borrowers exhibiting higher risk (cluster one), amounting to €276 billion in 2020 (not reported), as well as for borrowers exhibiting high risk (cluster two) towards the end of the period under review. That is, the worse half of the borrowers in terms of their Altman Z-score account for 67% and the worst 30% for 37% of the banks' aggregate credit portfolio in 2020:Q4. Moreover, differences between O-SIIs and L-SIIs do not appear to be very pronounced. Exposure to borrowers exhibiting the highest risk (cluster three), i.e. the worst 10% of borrowers, amounts to 3.6% in 2020 down from 5.1% in 2019. As shown in Section 2, most borrowers in this risk cluster are categorised as already being in the "distress zone" and are likely to reach the stage of bankruptcy in the next two years. Lastly, exposure to medium-risk borrowers (cluster four) is fairly stable from 2008 onwards, amounting to around 56% in 2020. All in all, in a PD-LGD stress-test framework, these results imply that the banks' aggregate credit portfolio has a disproportionately high and increasing level of exposure to borrowers exhibiting elevated risk based on the Altman Z-score, which proxies the probability of filing for bankruptcy in the next two years. Hence, the results are in line with allocation risk based on the debt overhang ratio (Figure 3.1), which also proxies the borrowers' PD in the medium term to some extent.

Figure 3.5: Aggregate allocation risk in terms of borrowers' Altman Z-score, percentage total exposure



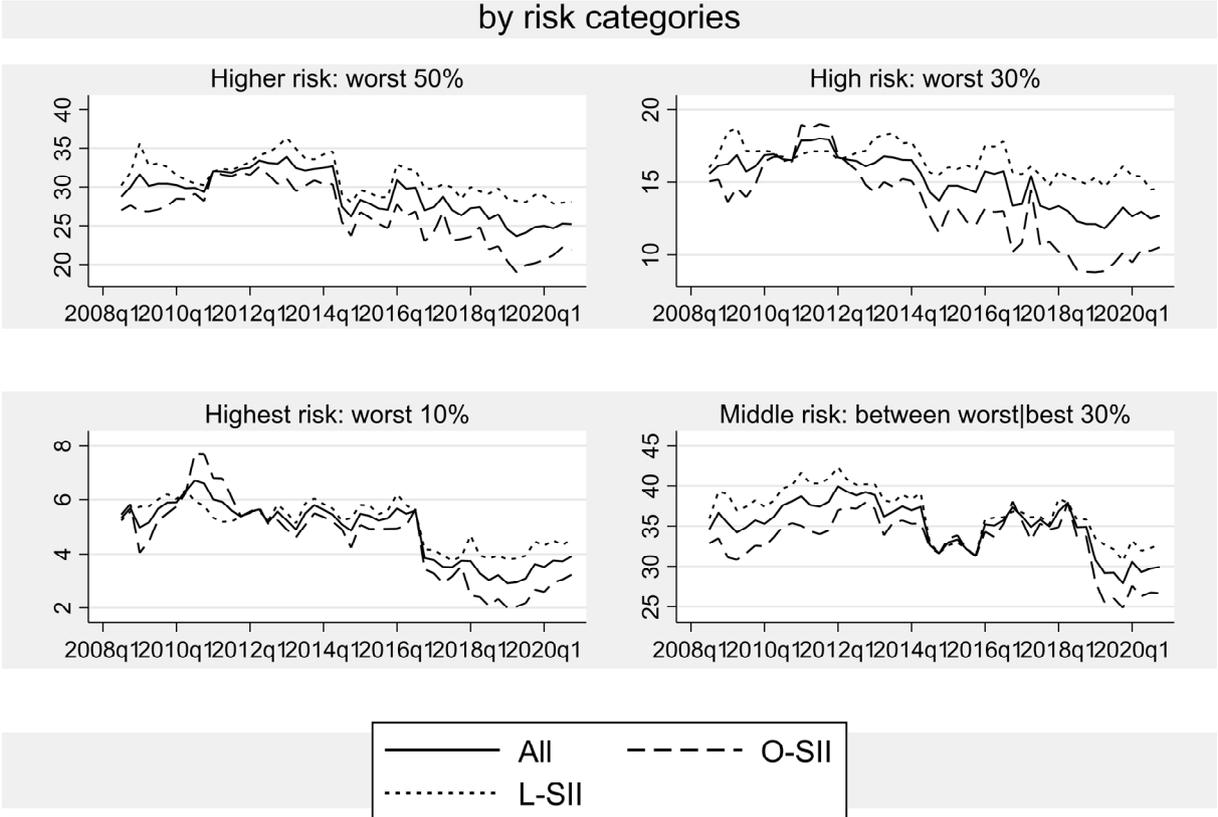
In this model, if the Z value is greater than 2.6, the firm is said to be in the “safe zone” and has a negligible probability of filing for bankruptcy. If the Z value is between 2.6 and 1.1, the firm is said to be in the “grey zone” and has a moderate chance of bankruptcy. If the Z value is below 1.1, it is said to be in the “distress zone” and has a very high probability of reaching the stage of bankruptcy. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

Similarly to Figure 3.5, aggregate allocation risk based on IRB banks’ PDs is only depicted for different risk clusters and bank groups in **Figure 3.6**. In contrast to allocation risk based on risk measures calculated using JANIS data, aggregate allocation risk based on self-reported IRB PDs does not indicate that risky borrowers are overrepresented in the banks’ credit portfolio. That is, the worst 50% of borrowers (cluster one) account for roughly 25.2% of the banks’ aggregate credit portfolio, or €97 billion (not reported), while the worst 30% of borrowers (cluster two) account for 12.7% and borrowers in the highest-risk cluster (three) account for 3.9%. Furthermore, whilst IRB PDs deteriorate slightly starting in 2019:Q4 and 2020:Q1 (Section 2), aggregate allocation risk also increases across all risk clusters mentioned, especially for borrowers exhibiting the highest risk (cluster three). By contrast, aggregate exposure to medium-risk borrowers (cluster four) plummets in 2018 to an all-time low. While the difference between O-SIIs and L-SIIs is fairly small in the cases of the previous risk measures based on the JANIS data, O-SIIs exhibit markedly lower aggregate allocation risk based on reported IRB PDs.³² At the same time, the increase since 2019 is all the more pronounced for this group of banks. As O-SIIs are IRB banks themselves, the pronounced difference in allocation risk based on reported IRB PDs raises the question of whether this difference is, amongst other things, due to significant differences in the banks’ risk assessment. And if so, why do the risk assessments of O-SIIs and L-SIIs differ significantly?

³² Note here that PDs refer here to borrower-specific PDs reported by IRB banks, i.e. the median value over all reporting banks (see Section 2). Hence, this risk-measure is not dependent on whether a bank uses an IRB approach, or a Standard one.

Allocation risk based on JANIS data does not appear to indicate that L-SIIs have a significantly greater disposition to relatively riskier borrowers than O-SIIs do, at least. All in all, in a PD-LGD stress-test framework, these results are in line with other allocation risk measures that proxy borrowers' PD in the sense that they show allocation risk to be increasing towards the very end of the period under review, at least in the case of clusters one and especially three.

Figure 3.6: Aggregate allocation risk in terms of borrowers' probability of default (PD), percentage total exposure
 Panel A



PDs are derived from IRB banks. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

4. Median allocation risk

Section 4 examines the extent to which the median, rather than the aggregate, exposure differs across the same risk clusters and groups of banks as in Section 3. Unlike aggregate allocation risk – which is indicative of the aggregate bank portfolio at risk – examining median allocation risk is indicative of a potential risk appetite.³³ That is, if relatively riskier borrowers receive larger loans on average over the long term than relatively less risky ones, aggregate allocation risk may build up over time. Median allocation risk can take values between 0% and “∞”%. In other words, if the median exposure to borrowers in a specific risk cluster is zero and the median exposure to borrowers that are not in that cluster is larger than zero, the median allocation risk of that risk cluster is zero. Conversely, if the median exposure to borrowers in a specific risk cluster is larger than zero and the median exposure to borrowers that are not in that cluster is (close to) zero, the median allocation risk of that risk cluster converges towards the median

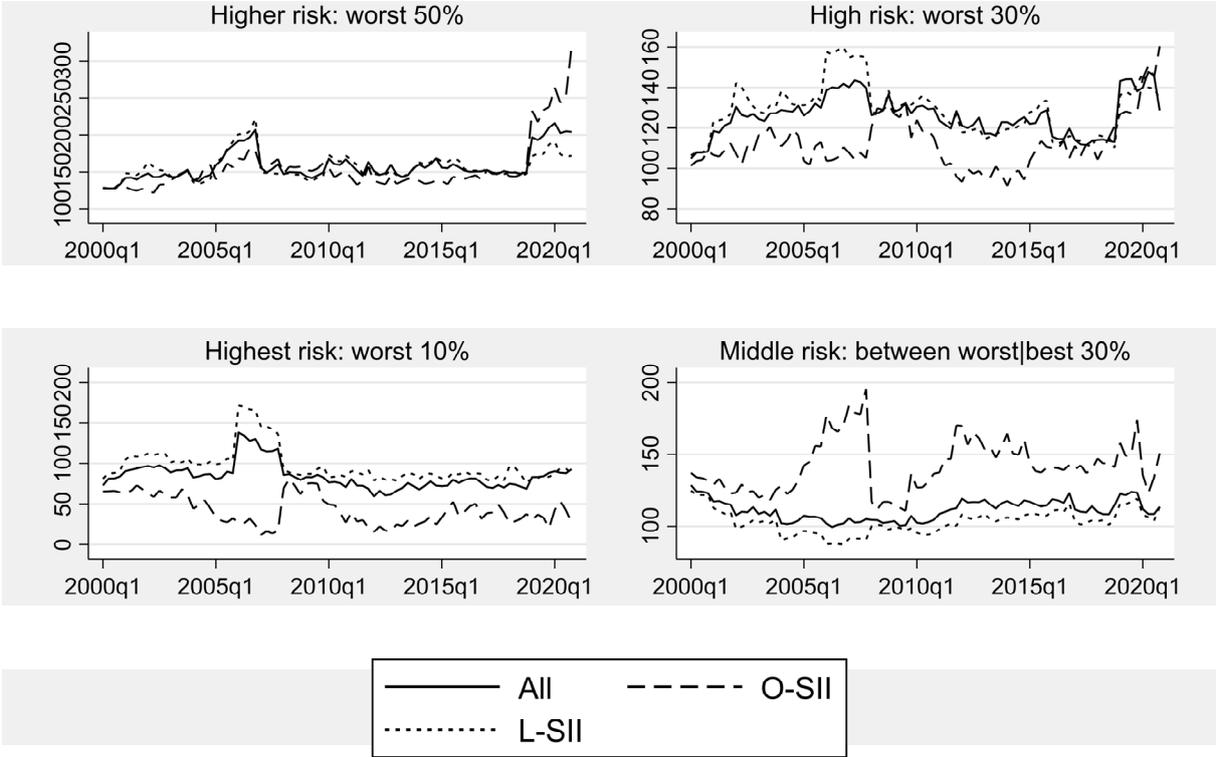
³³ Even if a bank charges higher interest rates due to a borrower's (relatively) higher default risk, the bank runs the risk of the expected loss being different from zero, i.e. of mispricing the risk. The greater the exposure, the greater the potential fallout from mispricing.

exposure in the risk cluster itself (in theory to “∞”). However, it should be noted that median allocation risk proxies the intensive margin only. In view of this, a decrease in the ratio could be due to the fact that while banks are funding a larger total number of relatively risky borrowers, the amount of funding provided to them is smaller. Hence, this risk-increasing effect at the extensive margin could reduce median allocation risk even though aggregate risk is increasing. Consequently, to draw meaningful conclusions, it is important to analyse aggregate and median allocation risk in tandem. Moreover, as it differs as a concept from aggregate allocation risk – for which the difference between the exposure at risk in the baseline and the stress scenarios can be meaningfully interpreted – median allocation risk is analysed for the baseline scenario only.

To assess median allocation risk, the various risk bins are condensed, similarly to Section 3, into the following four risk clusters. First, the median exposure of borrowers in risk bins six to ten – i.e. borrowers in the worse half of the distribution, which are referred to as borrowers exhibiting “higher (or elevated) risk” – in relation to the median exposure of borrowers in risk bins one to five – i.e. borrowers in the better half of the distribution – is analysed. The second, third and fourth risk clusters refer to equivalent ratios for borrowers exhibiting high, the highest and lastly medium risk. In the last case, the median exposure of borrowers in risk bins four to seven in relation to the median exposure of borrowers in risk bins one to three and borrowers in risk bins eight to ten is analysed.

Figure 4.1 depicts median allocation risk based on the debt overhang ratio. It shows that the extent to which loans received by borrowers in the worse half of the distribution are larger than those received by borrowers in the better half of the distribution (cluster one) is greater in 2020 than in 2000. Going into detail, the ratio of borrowers exhibiting higher (or elevated) risk to borrowers that do not is 128% in 2000:Q1, whereas in 2020:Q4 it is 204%. That is, in 2020 the median loan to a (relatively) higher-risk borrower is twice as large as the median loan to a (relatively) safer borrower. In the case of borrowers exhibiting high risk (cluster two), the ratio increases by roughly 23% between 2000 and 2020 to 128.6%, whilst in the case of borrowers exhibiting highest risk (cluster three), it increases by roughly 27% to 92.7%. Taken together, median allocation risk increases across all risk clusters and, with the exception of borrowers in the highest-risk cluster (three), loans to riskier borrowers are larger than those to safer ones. The median allocation risk for medium-risk borrowers (cluster four) is relatively constant, fluctuating between roughly 100% and 120%. In contrast to aggregate allocation risk presented in Section 3, the difference between O-SIIs and L-SIIs is more pronounced. During the global financial crisis, L-SIIs increase median lending to borrowers in all risk clusters by a greater amount. By contrast, O-SIIs appear to increase median lending to higher-risk borrowers (cluster one) and high-risk borrowers (cluster two) during the COVID-19 pandemic, in particular. This notwithstanding, O-SIIs exhibit an increase in median allocation risk in terms of high-risk borrowers (cluster two) starting at the end of 2014 already. All in all, based on the debt overhang ratio, median and aggregate allocation risk results are in alignment, confirming that the riskiness of the banks’ credit portfolio increases towards the end of the period under review.

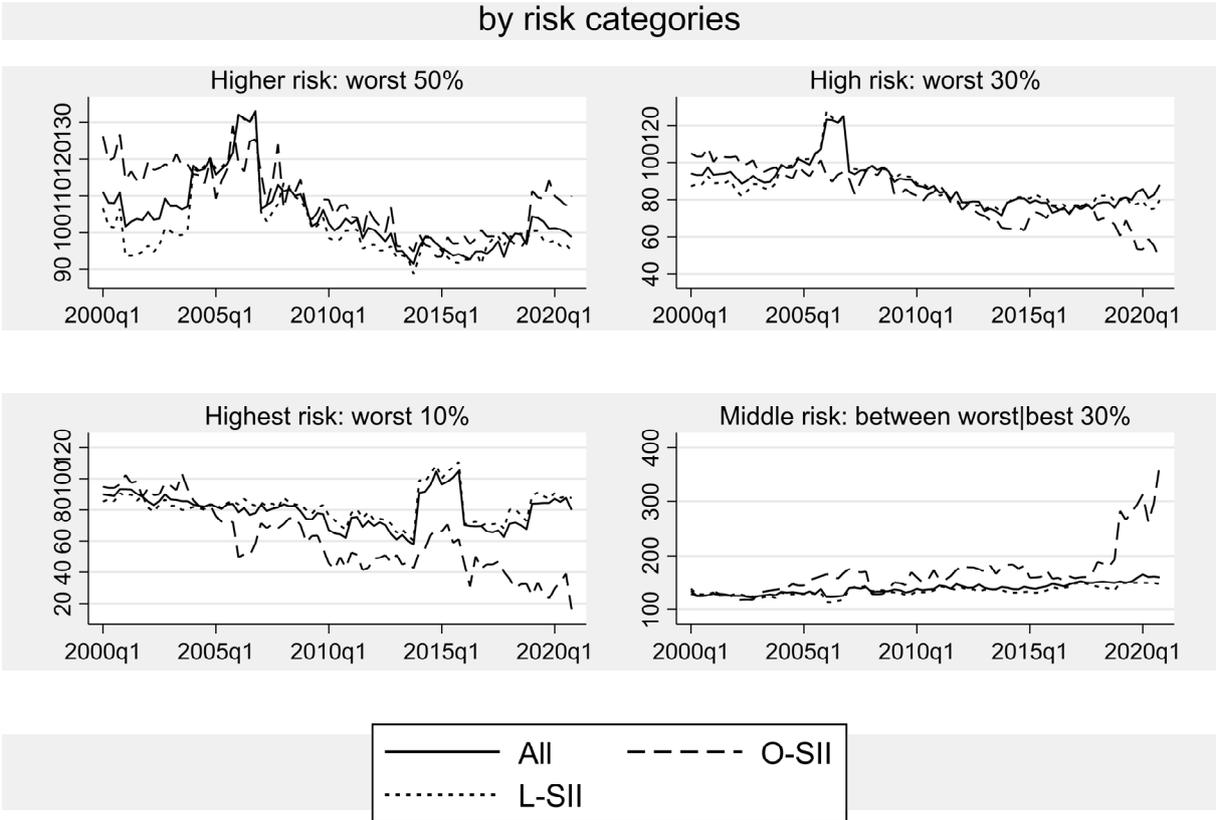
Figure 4.1: Median allocation risk in terms of borrowers' debt overhang ratio, percentage
by risk categories



The debt overhang ratio is defined as the ratio of total debt to EBITDA. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

Figure 4.2 depicts median allocation risk based on the equity ratio. Similarly to aggregate allocation risk based on the equity ratio (Figure 3.2), median risk does not appear to be very pronounced. That is, the ratio of borrowers exhibiting (relatively) higher (or elevated) risk to borrowers that do not (cluster one) amounts to 111% in 2000:Q1, whereas in 2020:Q4 it amounts to 99%. It is only in the case of borrowers exhibiting high risk (cluster two) that the ratio increases starting in 2014, but it still amounts to only 88%. Median allocation risk increases for O-SII in terms of higher-risk borrowers (cluster one) and especially medium-risk borrowers (cluster four), whilst at the same time it decreases in terms of high-risk borrowers (cluster two) and highest-risk borrowers (cluster three). All in all, based on the equity ratio – which can be interpreted to some extent as a proxy for the banks' recovery rate – median and aggregate allocation risk results are in alignment, indicating no increase in the riskiness of the banks' credit portfolio.

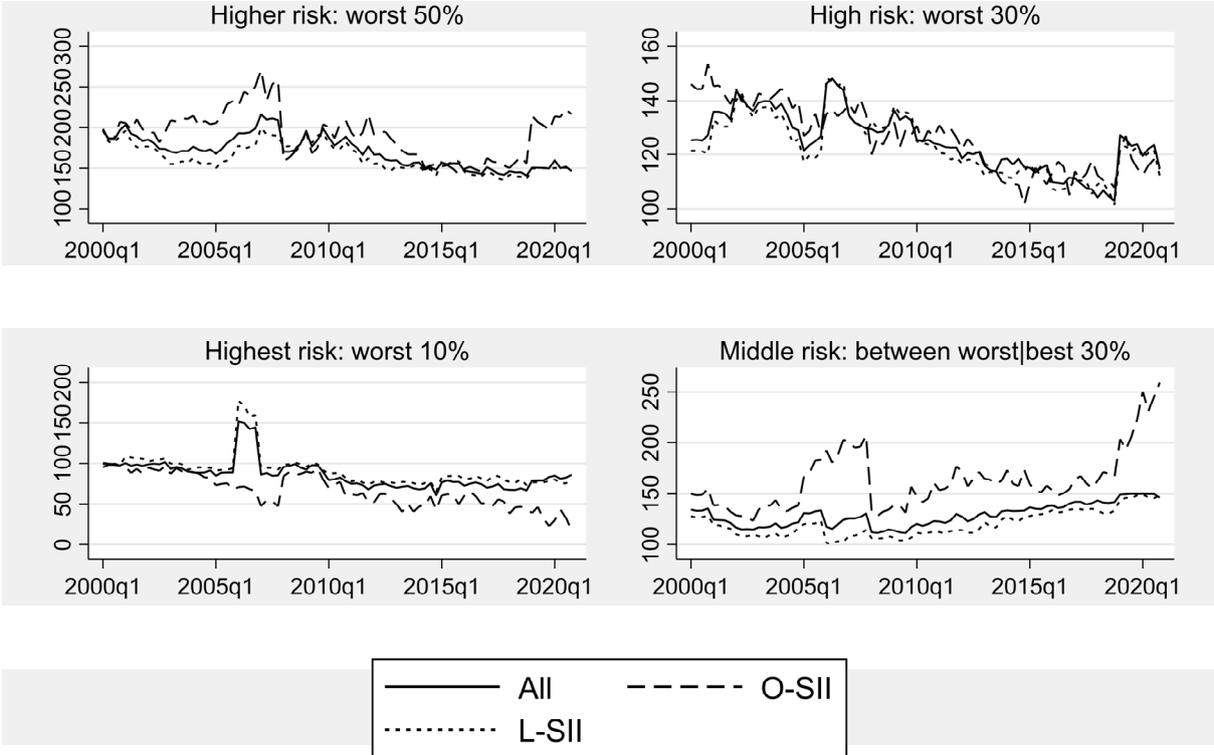
Figure 4.2: Median allocation risk in terms of borrowers' equity ratio, percentage



The equity ratio is defined as equity in relation to total assets. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

Figure 4.3 depicts median allocation risk based on the interest coverage ratio. The dynamics within the risk clusters are comparable to the ones for median allocation risk based on the equity ratio (Figure 4.2), though at a higher level. Median allocation risk vis-à-vis higher-risk borrowers (cluster one) and highest-risk borrowers (cluster three) is fairly stable towards the end of the period under review, while decreasing vis-à-vis high-risk borrowers (cluster two). Nevertheless, higher-risk borrowers (cluster one) and high-risk borrowers (cluster two) receive larger amounts of funding than safer ones, i.e. the ratio is larger than 100%. Going into detail, the median allocation risk for borrowers exhibiting higher (or elevated) risk (cluster one) amounts to 147%, while for high-risk borrowers (cluster two) it amounts to 115%. Similarly to the previous results, median allocation risk increases for O-SIIs in terms of higher-risk borrowers (cluster one) and especially medium-risk borrowers (cluster four), whilst at the same time it decreases in terms of high-risk borrowers (cluster two) and highest-risk borrowers (cluster three). Comparing the latter results to the equivalent aggregate allocation risk results (Figure 3.3), the decrease in median allocation risk in cluster two appears to be driven by the extensive margin, whilst in cluster three it is not. In other words, O-SIIs appear to lend to a larger total number of relatively risky borrowers but provide them with smaller amounts, consequently driving down median allocation risk whilst aggregate allocation risk remains constant. All in all, the results for median allocation risk based on the interest coverage ratio are mixed, especially for O-SIIs.

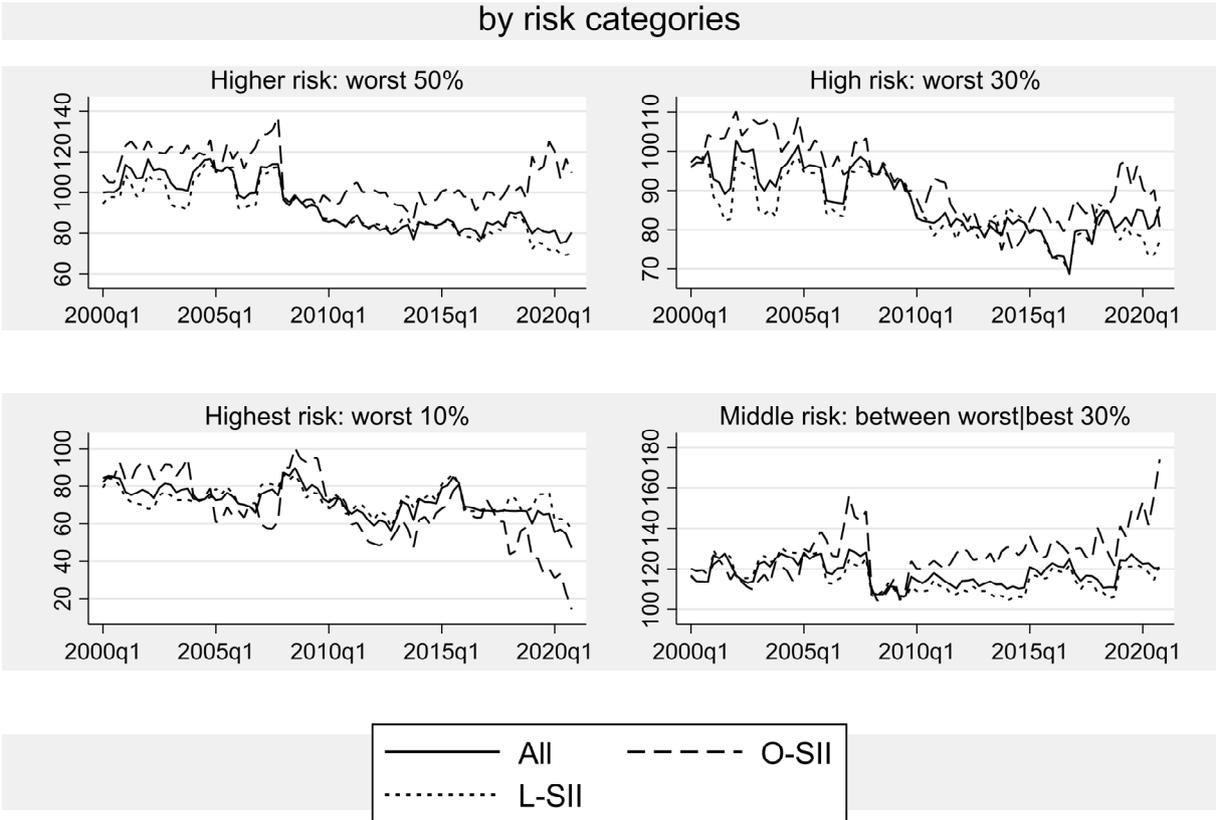
Figure 4.3: Median allocation risk in terms of borrowers' interest coverage ratio, percentage by risk categories



The interest coverage ratio is the ratio of EBITDA to interest expenses. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

Figure 4.4 depicts median allocation risk based on the cash ratio. The dynamics within the risk clusters are again comparable to the ones for median allocation risk based on the equity ratio (Figure 4.2). In general, borrowers do not receive more funding than safer ones. Moreover, O-SIIs exhibit increasing median allocation risk in clusters one and four, especially. In cluster two, however, O-SIIs are exposed to increasing median allocation risk up to the beginning of the COVID-19 pandemic and see a sizeable decrease from 2020:Q1. The sharp decrease in median allocation risk for O-SIIs is even more pronounced in cluster three, where the median exposure of borrowers exhibiting the highest risk falls from 67% in 2018:Q4 to 47% in 2020:Q4. While the sharp decrease in cluster three is corroborated by the aggregate allocation risk results (Figure 3.4), the decrease in cluster two for 2020 seems again to be due rather to O-SIIs lending to a larger number of relatively cash-strained (high-risk) borrowers but providing them with lesser amounts. All in all, the results for median allocation risk based on the cash ratio show that the banking system in general, but O-SIIs in particular, appear to have stepped in during the COVID-19 pandemic by providing additional loans to cash-strained borrowers, though not to the most strained ones.

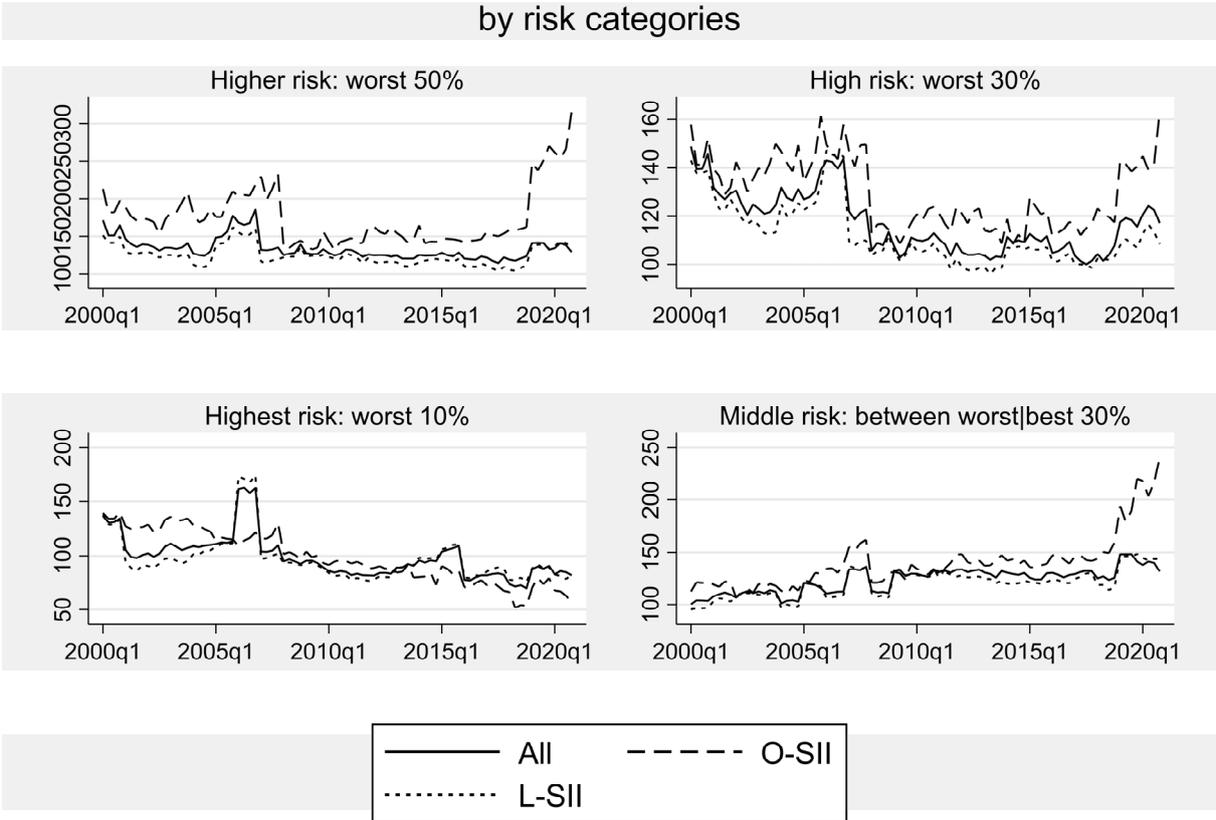
Figure 4.4: Median allocation risk in terms of borrowers' cash ratio, percentage



The cash ratio is defined as liquid assets in relation to fixed costs, including interest expenses. Specifically, cash in hand, central bank balances, bank balances and cheques in relation to fixed costs and interest expenses, with staff costs, business start-up and expansion expenses and other operating expenses reported outside of cost of sales, selling expenses, and general and administrative expenses counting as fixed costs. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

Figure 4.5 depicts median allocation risk based on the Altman Z-score. Similarly to the aggregate results (Figure 3.5), median allocation risk increases for borrowers exhibiting higher risk (cluster one) and high risk (cluster two), across all banks and especially at O-SIIs. That is, while both risk dimensions for all banks increase starting at the end of 2016, this increase is disproportionately large for O-SIIs. Going into detail, median allocation risk to borrowers exhibiting higher (or elevated) risk (cluster one) increases from 123% to 129% for all banks between 2016:Q4 and 2020:Q4. For O-SIIs, however, median allocation risk more than doubles – to an all-time high – from 154% to 316%. Similarly, median allocation risk to high-risk borrowers (cluster two) increases in the same time period from 101% to 117% for all banks and from 117% to 163% for O-SIIs – another all-time high. All in all, based on the Altman Z-score, allocation risk for all banks, but especially O-SIIs, soars from 2016-17 due, first, to a growing part of the banks' aggregate credit portfolio (Figure 3.5) consisting of exposure to relatively riskier borrowers and, second, to the median funding amount also increasing, except again for borrowers exhibiting the highest risk (cluster three).

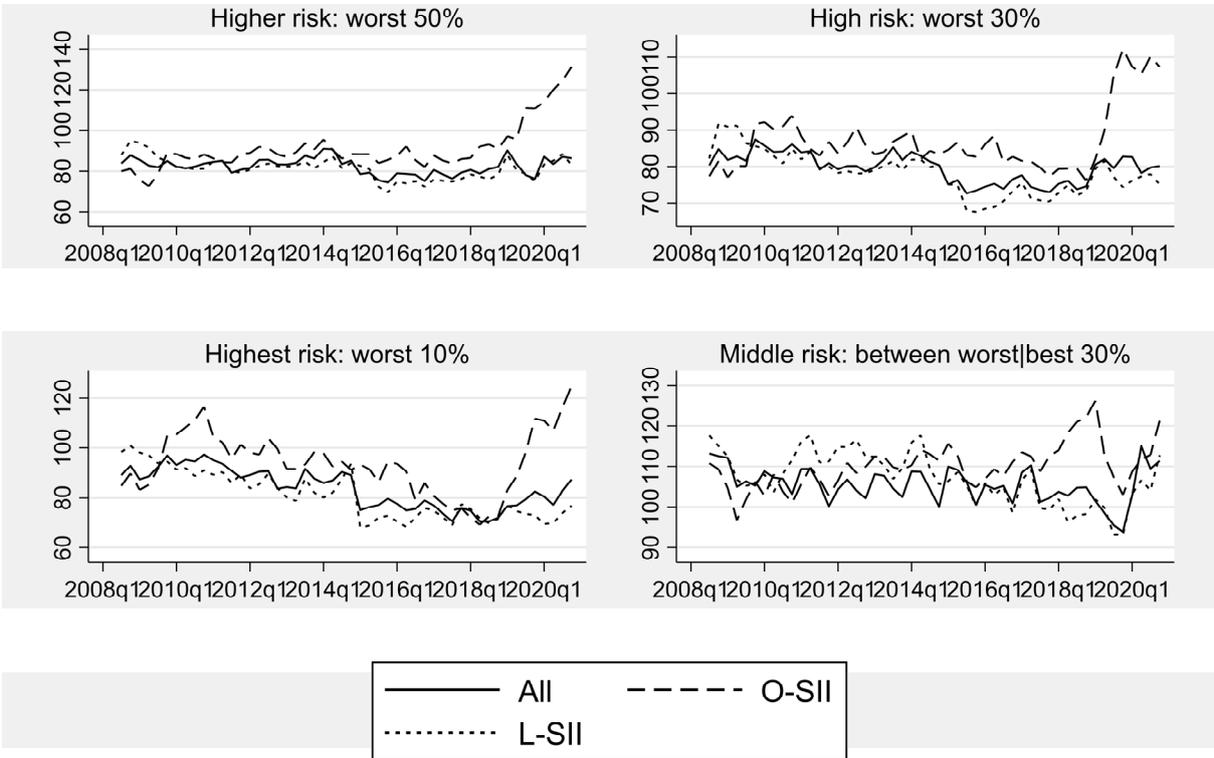
Figure 4.5: Median allocation risk based on borrowers' Altman Z-score, percentage



In this model, if the Z value is greater than 2.6, the firm is said to be in the “safe zone” and has a negligible probability of filing for bankruptcy. If the Z value is between 2.6 and 1.1, the firm is said to be in the “grey zone” and has a moderate chance of bankruptcy. If the Z value is below 1.1, it is said to be in the “distress zone” and has a very high probability of reaching the stage of bankruptcy. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

Figure 4.6 depicts median allocation risk based on the reported IRB PDs. Similarly to the Altman Z-score results (Figure 4.5), median allocation risk increases for borrowers exhibiting higher (or elevated) risk (cluster one), high risk (cluster two), but also the highest risk (cluster three), across all banks and again, most prominently, for O-SIIs. Moreover, for O-SIIs, the ratio across all risk clusters is not only soaring but is also greater than 100%. That is, even in the case of borrowers exhibiting the highest risk (cluster three), the ratio amounts to 125% for O-SIIs in 2020:Q4, meaning that the median exposure of borrowers in the worst 10th percentile in terms of the IRB PD distribution is 24% higher than the median exposure of the remaining 90% of borrowers. Together with aggregate allocation risk (Figure 3.6), which also starts to increase from 2019, soaring median allocation risk indicates a build-up of risk in the banks' portfolio.

Figure 4.6: Median allocation risk based on borrowers' probability of default (PD), percentage by risk categories



PDs are derived from IRB banks. Banks were designated as O-SIIs based on the list applicable from 1 January 2021.

5. Summary & conclusion

This paper analyses risks that arise from banks' credit portfolio composition and can be referred to collectively as allocation risk. That is, a potential increase in, or elevated levels of, allocation risk mean a larger exposure of banks to borrowers at the upper end of the risk distribution. In this sense, allocation risk does not concern a borrower's absolute risk, but rather its relative risk compared with other borrowers and whether banks have a disproportionately high level of exposure to those borrowers. To analyse allocation risk, data on the financial statements of domestic, non-financial corporations are merged with data from the German credit register. The period under review spans from 2000:Q1 to 2020:Q4 and covers a sizeable part of the banks' total exposure to the real economy. Moreover, the paper models possible real economic changes in 2020. Specifically, companies are exposed to various stress scenarios, e.g. an increase in interest expenses due to higher interest rates, an increase in debt levels and a decrease in income. A total of six borrower-specific risk measures are utilised: these are the debt overhang ratio, the equity ratio, the interest coverage ratio, the cash ratio, the Altman Z-score and, lastly, the banks' self-reported PDs. Though risk measures improved for the median borrower, some exhibited greater tail risks towards the end of the period under review.

The borrower-specific risk measures and stress scenarios translate into the banks' aggregate credit portfolio as follows. Measures that proxy borrowers' medium-term probability of going bankrupt show elevated or even increasing levels of allocation risk. First, the debt overhang ratio indicates not only an elevated but also increasing exposure to borrowers across various parts of the risk distribution. Consequently, the riskiness of the banks' aggregate credit portfolio

increased not only on average but also in the tails. Second, the Altman Z-score, which proxies borrowers' probability of reaching the stage of bankruptcy within the next two years, likewise indicates an elevated and increasing level of risk in banks' aggregate credit portfolio. By contrast, the results based on the banks' self-reported PDs do not give any indication of elevated risk in the aggregate bank portfolio at least, but rather at the intensive margin. The latter is measured by analysing banks' median lending instead of aggregate lending. Based on the equity ratio, which proxies the borrowers' long-term PDs, but more importantly the banks' recovery rate in the event of default, the results likewise give no indication of elevated or increasing allocation risk. Regarding stressed allocation risk, the debt overhang and equity ratio indicate, to some extent, resilience to scenarios stressing borrowers' debt and income levels. The results for allocation risk based on measures that proxy borrowers' short-term probability and immanent probability of reaching the stage of bankruptcy indicate heightened risks in various ways. Specifically, based on the interest coverage ratio, the results indicate elevated but not increasing risk levels in the banks' aggregate credit portfolio. By contrast, banks are not disproportionately exposed to borrowers with a relatively low cash ratio, which proxies a borrower's liquidity. However, it should be noted that, in absolute terms, a significantly large number of borrowers would use up their liquid assets after just one month in the absence of an inflow of funds. Against this background, the measures taken to support corporate liquidity in response to the COVID-19 pandemic appear all the more important with respect to the stability of both the real economy and the banking system. The results for stressed allocation risk based on these two measures indicate vulnerabilities to scenarios stressing borrowers' interest expenses, i.e. higher interest rates due, for example, to a higher risk premium.

6. Literature

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