



Staff memo

Banking and climate-related risks, implications for financial stability in Sweden

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Abstract

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In this paper, using Credit Registry data (KRITA) and industry level CO₂ equivalent emissions data from Statistic Sweden (SCB), I study how exposed the Swedish banking system was to high-emission industries in 2020. Then, I investigate how much of this exposure was represented by financially vulnerable firms defined as firms that, even before the economic crisis in 2020, were struggling with paying the interest on their debt. I find that, in December 2020, the banks reporting to KRITA lent a total of more than SEK 2 trillion to the firms in this study. Of this amount, circa SEK 250 billion went to firms in high-emission industries. Importantly, a large part of this money (a total of about SEK 57 billion) went to financially vulnerable firms. These results confirm the need to further investigate the impact that the realization of climate-related risks, and transition risks in particular, together with existing vulnerabilities, may have on the Swedish banking system. Yet, to be able to perform these analyses, all firms should not only start to consistently report data about their emissions, but also be more transparent about how climate-related risks may affect them.

Keywords: climate change, climate-related risks, transition risks, greenhouse gases (GHG) emissions, corporate sector vulnerabilities, financial stability.

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Abstract in Swedish

Med utgångspunkt i information från kreditdatabasen KRITA och Statistiska centralbyråns data på växthusgaser, undersöker jag här i vilken utsträckning det svenska banksystemet under 2020 var exponerat mot branscher med höga koldioxidutsläpp. Jag undersöker därefter i hur stor utsträckning exponeringen gällde företag som redan innan pandemin hade en svag finansiell ställning, det vill säga företag som redan hade svårt att betala sina räntekostnader. Enligt studien gick ungefär 250 miljarder kronor, av totalt cirka 2 000 miljarder kronor i total företagsutlåning i december 2020, till företag i branscher med höga koldioxidutsläpp. Studien finner vidare att en stor del av dessa lån (57 miljarder) gick till företag med svag finansiell ställning. Resultaten visar hur viktigt det är att fortsätta undersöka vilken inverkan klimatrelaterade risker, och omställningsrisker i synnerhet, tillsammans med andra sårbarheter, kan ha på den svenska banksektorn. Men för att göra en sådan undersökning är det viktigt att företagen dels förbättrar sin rapportering av data om utsläpp, dels blir tydligare med hur de kan påverkas av klimatrelaterade risker.

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Staff Memo

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1 Introduction

This memo studies how exposed the Swedish banking system is to firms that may be affected by climate related risks, and, in particular, by transition risks, which are “the financial risks which could result from the process of adjustment towards a lower-carbon economy” (Carney 2015). In the analysis, I employ Credit Registry data (KRITA) and I identify the industries that produced the largest amount of carbon dioxide equivalent (CO₂e)¹ in 2019 (i.e. high-emission industries) using data from the Swedish office of national statistics, Statistics Sweden (SCB).

Importantly, I also consider that climate-related risks may affect the financial system by exacerbating existing financial vulnerabilities. Therefore, to better assess the potential consequences for the stability of the Swedish banking system, I do not only study how exposed the system is to high-emission industries but also how exposed it is to financially vulnerable firms in these industries. To do so, I identify firms’ financial vulnerabilities by building on my recent work on financial vulnerabilities in the universe of Swedish limited liability firms (Cella 2020a, 2020b and 2021).

For years now, we have known that climate change has the potential to affect every life on the planet with large consequences for the economy and the financial system (e.g. Giglio et al. 2020 and BIS 2021).² The effects on the ecosystem are in fact already visible.³ To save the planet (and the economy),⁴ important change is needed: firms (and households) have to drastically reduce their emissions of greenhouse (GHG) gases. However, as usual with change, together with opportunities, risks could also arise. These risks need to be quantified and managed in a timely fashion.

Broadly speaking, banks and the banking system are exposed to climate change through macro- and microeconomic transmission channels that arise from two distinct components of climate-related risk: physical risks and transition risks (BIS 2021). Physical risks result directly from how changes in the climate (e.g. natural disasters) affect economic activity. Transition risks instead cover a broader range of effects on firms’ operations and business models that come from the transition to a low-carbon economy. These risks can materialize together or separately, and can have very different, even opposite, effects (see Giglio et al. 2020 for a comprehensive discussion).

¹ In the text, I use the words CO₂ equivalents (CO₂e) and greenhouse gases (GHG) interchangeably. This is because carbon-dioxide equivalents (CO₂e) describe different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO₂e signifies the amount of CO₂ which would have the equivalent global warming impact (Brander and Davis 2012). SCB reports the total of emissions from stationary and mobile sources. This total roughly maps into the total of scope 1 and scope 2 emissions as defined by the GHG Protocol Corporate Standard. Please, see Appendix A.1 for more details and specific references.

² Giglio et al. 2020 provides a review of the literature on the interactions between climate change and financial markets. The report from BIS (BIS 2021) reviews the effects of climate-related risk drivers on banks and the banking system.

³ For example, Portugal, California and Australia have been affected by raging wild fires in the past few years that can be directly connected to climate change (Borunda 2020). Glaciers are also melting with large consequences for the ecosystem: the level of the sea is rising, more fresh water in the sea is changing the gulf stream with consequences for the weather all over the planet. Also less fresh water will be available as the glaciers melt into the oceans (Glick 2018).

⁴ In 2008, leading economist Nicholas Stern started his Richard T. Ely lecture with this sentence: “Greenhouse gas (GHG) emissions are externalities and represent the biggest market failure the world has seen.” (Stern 2008).

While both types of risks are relevant from a financial stability point of view, in this study, because of the nature of the data, I mostly focus on transition risks.

The speed of the transition to a low carbon economy can be influenced by public policy, technology, investor preferences and, even physical events (Carney 2015). Policy makers in Sweden aim for the country to be climate neutral by 2045 and for the transportation industry (one of the highest-emission industry in 2019) to become fossil-free by 2030. To meet these goals, Swedish firms need to move away from fossil fuels toward greener sources of energy quite quickly.⁵ Moreover, these changes should not only be made rapidly but should also be done in an orderly way so to avoid exacerbating the potential risks from the transition itself.

To help the transition, large investments in green technologies have already started.⁶ The issuance of financial instruments to invest specifically in projects to help the transition to a green economy (so-called 'green bonds') is picking up (Ferlin and Sternbeck Fryxell 2020) and both institutional investors and retail investors have become more engaged in climate-risk-related questions.⁷ In fact, in the long run, firms have a lot to gain from greening their operations and becoming more sustainable. Yet, in the short run, these changes may increase the probability of default for all firms in the economy because of the impact they may have on the firms' business models and economic growth more generally.⁸

More directly related to high-emission industries, as the discussion about climate change intensifies,⁹ firms with high emissions could also be affected by consumer movements (for example, boycotts, protests, and reputational risks), shareholder activism,¹⁰ and litigation risks (for example, lawsuits over environmental damage).¹¹ Moreover, as greener technology becomes available, carbon-intensive assets (so-called 'stranded assets') will become obsolete. Therefore, these assets, usually largely financed by debt originated by banks,¹² could be repriced with substantial losses. Importantly, this asset re-evaluation may not necessarily happen at the same pace as the transition. In fact, asset managers can already reduce the carbon footprint of their portfolios (and move away from carbon-intensive assets) rebalancing toward firms

⁵ To achieve the climate neutrality goals, firms must emit drastically less than what they have done in the past 10 years (Swedish Climate Policy Council 2021).

⁶ For example, some of the largest Swedish firms are investing in producing fossil-free steel. See Reuters (2021) and Carpenter (2020).

⁷ For example, Alecta (2020), one of the largest Swedish pension funds, in the spring 2020 published its first climate report in accordance with the principles of the Task Force on Climate-related Financial Disclosure (TCFD).

⁸ For example, even though many firms may be willing to transition toward using more green energy, renewable energy may not be available in the necessary quantities. Even in Sweden capacity has to be enhanced substantially to fully substitute fossil fuels (Sweden.se 2021). This suggests that, at least in the short run, green energy could be substantially more expensive than fossil-based energy, at the margin. The potentially higher cost of green energy could then negatively affect both the demand and supply of goods and services.

⁹ Harvey (2020) and Gordon and Look (2020).

¹⁰ Cardwell (2017), Lemos Stein (2018) and McCormick (2021).

¹¹ Viglione (2020).

¹² In 2016, in the EU, the majority of the fossil-fuel activities were financed with debt. More than half of this debt was originated by banks (Gros et al. 2016).

that emit less (Bolton and Kacperczyk 2021 and Jondeau et al. 2021b). This rebalancing alone could largely affect the stock value of high-emission firms and may have important consequences for financial stability (Jondeau et al. 2021a).

Importantly, as suggested above, there is large heterogeneity in the effects of transition risks on asset values and, subject to their current dependence on carbon-intensive assets, some firms may not be affected at all. Yet, it is still reasonable to believe that, because of the nature of their businesses and their current dependence on carbon-intensive assets, firms in high-emission industries may be the most sensitive to the realization of these risks. This study therefore maps how much of the lending portfolios of the banks reporting to KRITA consists of credit to firms in high-emission industries.

However, to better understand how transition risks may affect our financial system, I also argue that it is not enough to only study how exposed banks are to high-emission industries. In fact, from a risk management perspective, by looking at climate-related risks in isolation, one may paint a partial picture of the actual risks that could be building up in the financial system. This is because if many of the firms that need to green their operations are already financially vulnerable (for example, they can barely service their debt or already have quite high leverage), their existing vulnerabilities could be exacerbated by the realization of transitions risks.

As mentioned in the discussion above, a rapid transition to a greener economy may in itself exacerbate existing financial vulnerabilities by affecting firms' economic and financial costs and their probability of default. Moreover, to adapt to the change, firms may need to borrow to make the necessary investments to transition to a greener economy (away from fossil-fuel energy into environmentally friendly technologies). If these firms are already financially vulnerable, they may be unable to borrow more (debt overhang problem). If this is the case, then, there could be important consequences for the firms' ability to survive (and also for the effort to meet the goal of climate neutrality). On the other hand, if financially vulnerable firms are able to further increase their leverage, this may exacerbate their existing financial vulnerabilities, at least in the short run. Hence, to fully grasp the effect of transitions risks on the financial system, it is important to understand how these risks may interact with existing vulnerabilities.

To be able to fully analyse the interaction between transition risks and existing financial vulnerabilities, one would need to have firm-level information on emissions of greenhouse gases, on how much of the firm's total assets consist of carbon-intensive assets and, ideally, information on the firm's investment plans to green its operations. Unfortunately, none of this information is available to me. Yet, using the available data, I illustrate how financial vulnerabilities are distributed in high-emission industries and how much the banking system is exposed to these firms.

All of the main results of this study are illustrated in Section 2, while Section 3 concludes. CO₂e emissions data is described in the Appendix A.1.

2 Main results

To understand how dependent firms are on fossil fuels and how much they are expected to reduce their emissions to slow climate change, one would ideally like to know how much they emit (directly and indirectly), what the sources of their emissions are, and what plans they have to make their energy consumption more efficient and sustainable. Even better, one would like to know how much of the firms' total assets consist of carbon-intensive assets and how the value of these assets (and all assets) will be affected by climate-related risks and transition risks, in particular.

Unfortunately, none of this information is currently (publicly) available for the vast majority of the firms on the planet. Yet, in Sweden, the office of national statistics, Statistics Sweden (SCB), estimates industry-level data for the total amount of CO₂e gases emitted by Swedish firms sorted in 32 industries (SCB 2020b, 2021a and SCB 2021b).

The data has shortcomings (see the Appendix A.1 for a comprehensive discussion) but it is based on a clear methodology, is quite granular and easy to use and, although one cannot classify firms within the same industry, one can compare industries with different levels of emissions. Hence, using the data provided by SCB, I sort all industries in quartiles based on total CO₂e emissions in 2019: *High-emission* (the fourth quartile of the emissions distribution), *Medium-emission* (the third quartile of the distribution) and *Low-emission* (both the first and second quartile of the distribution).¹³ Descriptive statistics for the firms in each category can be found in Appendix A.1.

In the remaining part of this section, I study how exposed the banks reporting to KRITA are to firms in high-emission industries (Section 2.1), and then I show how much of the amount lent goes to *vulnerable firms* in these industries (Section 2.2). I introduce the other sources of data used in this study while discussing the results.

2.1 Bank exposure to high-emission industries

To study banks' lending to non-financial firms in high-emission industries, I match the emission data from SCB with data reported in KRITA. KRITA is a survey run by Statistic Sweden on behalf of the Riksbank to collect information on loans to companies and to the public sector.¹⁴ Eighteen monetary financial institutions are surveyed to compile the data collected in KRITA. The data covers about 95% of all loans to sectors other

¹³ The high-emission group contains the following industries: Wholesale and Retail Trade (WRT), Construction (CON), Plastic (PLAS), Petroleum (PETR), Metals (META), Electricity Gas and Water Supplies (ELGAG), Agriculture, Forestry and Fishing (AGRF), Transportation (TRAN). The medium-emission group consists of the following industries: Health (HEAL), Vehicles (VEHI), RE (REAL ESTATE), Consultancy (CONSUL), Administrative Support (ADMI), Food and Tobacco (FOOD), Mining (MINI), Wood (WOOD). Finally, all of the other industries are in the low-emission group: Computers (COMP), Transportation Equipment (TRA-EQ), Telecom (TEXT), Textiles (TELE), TV and Movies (TVMO), Electronics Equipment (ELEC-EQ), Social Work (SOCIO), Education (EDUC), Programming (PROG), Advertising (ADVE), Hotels and Restaurants (H&R), Other Services (OTHES), Furniture (FURN), Arts (ARTS), Machinery (MACH).

¹⁴ KRITA is still an ongoing project and is being continuously updated and improved. The results in this paper are based on a data extraction conducted on 4 March 2021.

than households. In KRITA, firms' organization numbers and primary industry codes (SNI07 industry codes) are also available.

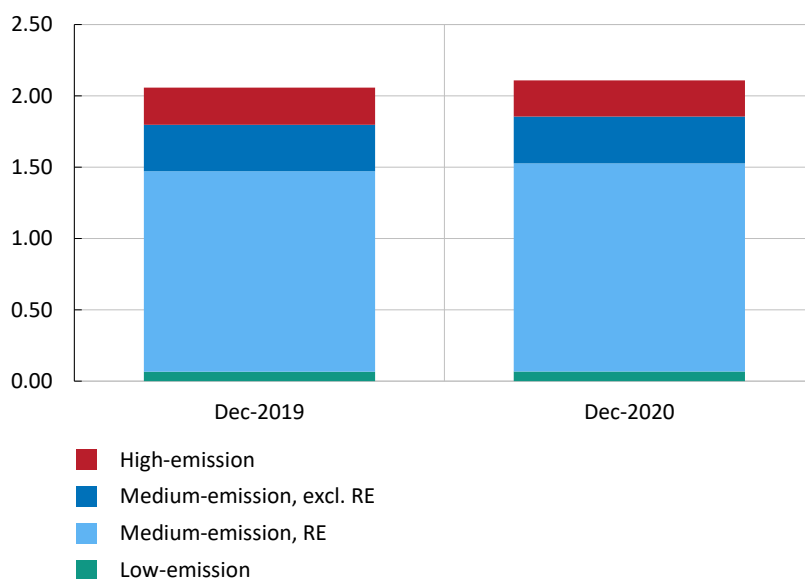
The SCB data on emissions is matched with KRITA using the firm's primary industry code. In December 2020, KRITA reported information for a total of about 199,000 firms (about 204,000 in December 2019). However, after matching with the emission data (firms with missing industry codes are dropped) and dropping firms in the financial and insurance activities industry (SNI07 64110-66309), about 192,000 (195,000) firm-observations remain in December 2020 (December 2019).

Using the data described above, for the month of December 2019 and December 2020, I start by showing the proportion that the firms in high-emission industries borrowed from the banks in the sample. Results are shown in Figure 1.

Figure 1 shows results also for medium and low-emission industries. Importantly, to be able to better describe potential exposure to climate-related risks, I decompose the total amount borrowed by medium-emission industries in two parts: the total borrowed by firms in the real estate industry (SNI07 68100-68320) and the total borrowed by firms in medium-emission industries, excluding real estate.

Figure 1. Loans to industries with different levels of CO₂e emissions

Total nominal amount in trillions of SEK, December 2019 and December 2020



Note: Figure 1 shows a decomposition of the total nominal amount borrowed in December 2019 and December 2020 by non-financial firms for which data is available in KRITA. For each period, results are reported by industries grouped on the total amount of CO₂ emissions in 2019. All firms with missing SNI and firms in the financial and insurance activities industry (SNI07 64110-66309) are excluded. Emissions data is described in the Appendix A.1.

Source: KRITA and SCB

Figure 1 shows the total amount lent by the banks operating in Sweden for which data is available in KRITA in December 2019 and December 2020. For each year, the graph

shows the total lent to firms in four different groups: all firms in high-emission industries (the red part of the bar), all firms in medium-emission industries excluding real estate (the dark blue portion of the bar), all real-estate firms alone (clear blue portion of each bar) and firms in low-emission industries (in green).

In December 2020, the firms in this study borrowed a total of more than SEK 2 trillion. Of this amount, about SEK 69 billion was lent to firms in low-emission industries, more than SEK 1.7 trillion was lent to firms in medium-emission industries and about SEK 250 billion to firms in high-emission industries. Therefore, around 12% of the total amount lent in December 2020 by the banks reporting to KRITA went to firms in high-emission industries.

Figure 1 also shows that, collectively, the banks reporting to KRITA have very limited exposure to firms in low-emission industries (circa 3% of the total amount lent went to these firms in December 2020) but a substantial exposure to medium-emission industries and in particular to the real estate industry. Firms in medium-emission industries, excluding real estate (the dark blue bars), in December 2020, accounted for almost 16% of total lending to all of the firms in KRITA, while firms in the real estate industry (the clear blue bars) have borrowed almost 70% of the total amount recorded.

Figure 1 also reports results for December 2019 to show whether exposure to high-emission industries, and other industries, has decreased in 2020, for example because of the economic crisis or because banks themselves have started greening their portfolios in earnest. I do not find any evidence of this. In fact, very little has changed between 2019 and 2020.

The results above have important implications for financial stability. To begin with, Figure 1 shows that the Swedish banking system is largely exposed to high-emission industries and to medium-emission industries excluding real estate. Since we do not know how the firms in these industries may be affected by transition risks and we do not have the data to assess the impact that such risks may have on these firms, one cannot ignore the potential consequences of such exposure. Second, Figure 1 shows that the Swedish banking system is substantially exposed to firms in the real estate industry. Data from SCB (see appendix A.1) show that real estate is one of the industries that emits the least among medium-emission industries, thus, one can argue that the firms in this industry may not be largely affected by transition risks per se. Yet, one needs to remember that this industry could be largely affected by physical risks. Therefore, even from a climate-related risk perspective this industry appears to be a key one for financial stability.

Results in Figure 1 then confirm two important facts. First, they substantiate the need to obtain more transparent and timely data from firms (and financial institutions) about their exposure to climate-related risks. Second, they reiterate the importance of the real estate industry for the stability of our financial system and reinforce the importance of closely monitoring developments in this industry.

Finally, in unreported analysis, I find large heterogeneity in banks' exposure to high- and medium-emission industries. This suggests that greening the banking system will

affect banks differently. In particular, this process will affect banks differently depending on the composition of their portfolios within those industries. Therefore, it will be important to monitor the transition closely and to do so, again, more data (and better data) is necessary.

The results in this section show that both high- and medium-emission industries are particularly important in the portfolio of the banks reporting to KRITA. Therefore, to better understand the potential risks for our financial system, I focus in the next section on the firms within these industries and study how much of the total amount lent in 2020 was allocated to financially *vulnerable firms*.

2.2 Decomposition of bank lending

2.2.1. Definition of financially vulnerable firms

I employ data from KRITA also to study lending to vulnerable firms in high-emission industries. In this case, the firms in KRITA are matched with the CO₂e data from SCB and the Serrano database provided by Bisnode in November 2020. The Serrano database contains detailed financial statement information for all Swedish limited liability companies (aktiebolag) that reported to the Swedish Companies Registration Office (Bolagsverket) in 2019.

Following my work on financial vulnerabilities, (Cella 2020a, 2020b and 2021) and building on the existing literature (see for example, International Monetary Fund 2019 and Altman et al. 2019), I use financial statement information for the entire universe of limited liability firms in Serrano in 2019, to identify firms that may be more exposed to the risk of financial distress (i.e. financially vulnerable firms).¹⁵ In particular, I try to capture as many potentially vulnerable firms as possible by employing a broad definition based on leverage, return on assets (ROA) and interest coverage ratio.¹⁶ Using these variables, I sort all firms into the following categories:

1. **ICR (interest coverage ratio) ≤ 1 :** This category includes all firms that in 2019 had an ICR below or equal to 1 and firms that have filed for bankruptcy or restructuring in either 2019 or 2020 and for which the bankruptcy process was not yet concluded by October 2020.
2. **High leverage-poor performance:** This category contains firms with leverage above the median in their industry-size category and profitability (ROA) below the median in their industry-size category.

¹⁵ Financial distress usually precedes bankruptcy, however the definition of financial distress is less rigorous than the definition of bankruptcy. For example, the International Monetary Fund (2019) defines firms with ICR below 1 as firms with imminent risk of distress since these firms are technically insolvent (they are unable to pay the interest on their debt). However, the literature does not only use this definition to identify firms at risk of distress. See Platt et al. (2006) for a discussion of the differences between financial distress and bankruptcy. For more information about the Swedish legal system for bankruptcies and re-organization, see Cella (2020b).

¹⁶ A firm's leverage is calculated as the ratio between its debt and the sum of its debt and equity. A firm's performance is calculated by its return on assets (ROA) obtained as the ratio between its earnings before interest and taxes (EBIT) and its total assets. A firm's ICR is obtained as the ratio between a firm's earnings before interest and taxes (EBIT), and (the absolute value) of its interest expenses.

3. **High leverage-good performance:** This group contains all firms with leverage above the median in their industry-size category.
4. **Other firms:** This category contains all firms that could not be otherwise classified.

The classification described above suffers from short-comings that are common in this literature (see Appendix A.2 for a discussion). Importantly though, descriptive statistics, reported in Table 1.a in Appendix A.3, suggest that firms with $ICR \leq 1$ are not only at risk of insolvency but, on average, are also highly levered and perform quite poorly. Because of these characteristics, the firms in this category may be more sensitive to financial distress (Altman et al. 2019).¹⁷ Therefore, in the rest of the study, unless otherwise specified, I refer to firms with $ICR \leq 1$ as “vulnerable firms” and I use the terms “firms with $ICR \leq 1$ ” and “vulnerable firms” interchangeably.

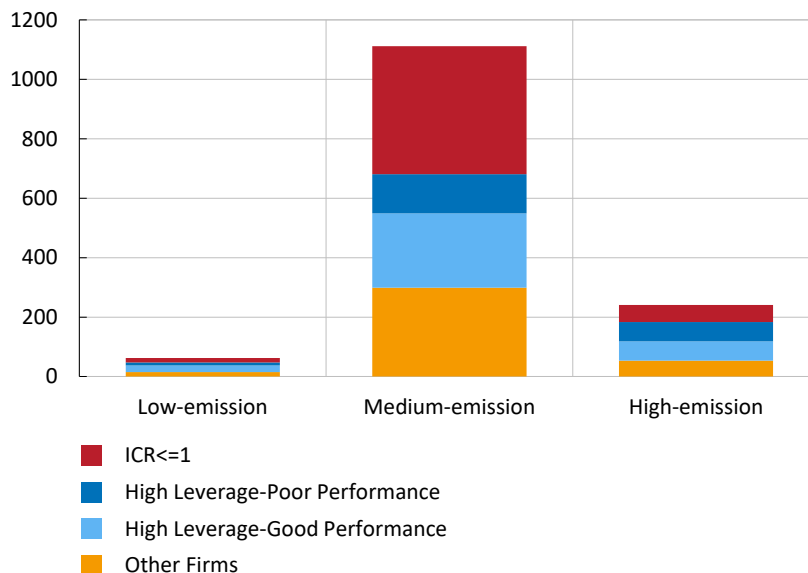
2.2.2. Lending to vulnerable firms in high-emission industries

In this section, using the matching between KRITA and Serrano, I calculate how much, in December 2020, the banks reporting to KRITA lent to the firms that could already be identified as vulnerable firms in 2019. Then, employing emissions data from SCB, I show how lending to vulnerable firms is allocated within industries with different levels of emissions. Results are reported in Figure 2.

¹⁷ Altman et al. (2019) indicates poor performance, high financial leverage and liquidity issues as factors that contribute to a firm’s distress.

Figure 2. Loans to firms with ICR \leq 1 in industries with different levels of CO₂e emissions

Total nominal amount in billions of SEK, December 2020



Note: Figure 2 shows a decomposition of the total monthly amount borrowed in December 2020 by non-financial limited liability firms for which data is available in KRITA and Serrano. Results are reported by industries grouped on the total amount of CO₂ emissions in 2019: high emissions, medium emissions, and low emissions industries. The total amount lent to each one of these groups is then further decomposed by firms classified in different categories in 2019. All firms with missing SNI and firms in the financial and insurance activities industry (SNI07 64110-66309) are excluded. A description of the firms' categories can be found in section 2.2.1 while emissions data is described in the Appendix A.1.

Source: KRITA, Bisnode and SCB.

After matching KRITA with Serrano and with the emissions data from SCB, in December 2020, I am left with 147,150 non-financial limited liability firms.¹⁸ In Figure 2, firms are first grouped into industries sorted according to total amount of CO₂e emissions: high-emission (high), medium-emission (medium), and low-emission (low). Then, the total amount lent in December 2020 to each one of these groups is further decomposed by type of firm: firms with ICR \leq 1 (red portion of each bar), firms with high leverage and poor performance (blue portion of each bar), firms classified as high leverage and good performance (clear blue portion of each bar) and other firms (orange portion of each bar). While Figure 1 shows that, in December 2020, a large amount of money was lent to firms in high-emission industries, Figure 2 shows that a substantial

¹⁸ Matching between Serrano and KRITA is based on each firm's unique organization number. Data is then matched with the SCB emissions dataset using the firm's primary industry code. It is important to notice that because of the matching with Serrano to identify financial vulnerabilities, the total amount of firms employed in this section is smaller than that employed to construct Figure 1, since I now only employ data for non-financial limited liability (AB) firms while Figure 1 was built using all firms that were available in KRITA, after matching with the emissions data. Nevertheless, this smaller sample of firms has received in December 2020 a large chunk of the credit extended by the banks in this study. Please, see Figure 1 and Figure 2 for details.

part of this money went to non-financial limited liability firms that were already quite financially vulnerable in 2019 (firms with $ICR \leq 1$).

Figure 2 shows that, in December 2020, out of the total of more than SEK 2 trillion reported in Figure 1, a total of around SEK 1.4 trillion went to the non-financial limited liability firms that are both in KRITA and Serrano, after matching with SCB emission data. Of this total, about SEK 62 billion was borrowed by firms in low-emission industries, more than SEK 1.1 trillion was lent to firms in medium-emission industries and about SEK 240 billion was borrowed by firms in high-emission industries. If we focus on vulnerable firms only, it appears that they received a considerable part of these loans in each of the emissions categories.

Figure 2 shows that almost 36% of the total 1.4 trillion SEK lent out by the banks in KRITA in December 2020 went to firms that, already before the economic crisis in 2020, appeared to be struggling with paying the interest on their debt. In fact, firms with $ICR \leq 1$ in 2019 received about SEK 500 billion in total, and of this, circa SEK 57 billion went to vulnerable firms in high-emission industries, SEK 413 billion went to vulnerable firms in medium-emission industries and approximately SEK 15 billion went to vulnerable firms in low-emission industries. Therefore, firms with $ICR \leq 1$ in high-emission industries received 24% of the total lent to all firms in these industries (57 out of 240 billion SEK). Vulnerable firms in medium-emission industries borrowed almost 39% of the total allocated to these industries (413 out of 1.1 trillion SEK). And, even in low emissions industries vulnerable firms account for almost 24% of the total lent to these industries (15 out of 62 billion SEK). These results suggest that the large concentration of loans to vulnerable firms together with the potential materialization of climate-related risks, and transition risks in particular, could have important implications for the stability of the Swedish banking system, at least in the short run.

To summarize, the results in Section 2 clearly show that, in December 2020, a large part of the lending portfolio of the banks reporting to KRITA was exposed to firms in industries with high and medium emissions (Figure 1). Moreover, a large part of this money was allocated to firms that with an $ICR \leq 1$ (Figure 2). These results further corroborate the idea that to fully understand the impact of transition risks, and more in general climate-related risks, on the financial stability of the Swedish banking system, it is important to continue monitoring the evolution of firms' financial vulnerabilities and study how the materialization of transition risks may exacerbate existing firms' vulnerabilities.

3 Conclusions

The COVID-19 pandemic has taught the world how hard nature can hit us. Despite the continued effort to start seriously addressing climate change, we still have a long way to go. Nevertheless, the transition to a greener economy is necessary to insure a liveable future on our planet. Therefore, both firms and financial institutions (and households) should learn how to take advantage of the opportunities that this transition offers but should also learn how to deal with the potential risks involved.

To help assess the potential financial stability risks stemming from the realization of transition risks, and climate-related risks in general, this study shows how exposed the Swedish banking system is to industries that account for the majority of the CO₂e gases emitted directly in the atmosphere by Swedish firms. I find that 12% of the total amount lent in December 2020 by the banks reporting to KRITA went to firms in high-emission industries (around SEK 250 billion out of a total of about SEK 2 trillion). The analysis also shows that a large portion of this exposure (a total of about 57 billion SEK) went to non-financial limited liability firms that, in 2019, struggled with servicing the interest on their debt.

However, the aim of this study is not only to create more awareness about how exposed the Swedish financial system is to high-emission industries but also to highlight how difficult it is to clearly assess the consequences of climate-related risks for financial stability.

In Sweden, firms are not required by law to report their CO₂e emissions consistently. Complying with international regulations, firms that *choose to report* their emissions can, for example, decide how to report and change their reporting methods over time. Therefore, there is a clear need to improve reporting standards and transparency (see Ferlin et al. 2021 for a discussion). To be able to paint a complete picture of how climate-related risks may affect the stability of the Swedish banking system, we need better data: all firms should systematically and transparently report how their operations and the value of their assets are affected by climate-related risks, how much they emit (directly and indirectly) and what their plans are to reduce these emissions.

Reporting is expensive and exposes firms to reputational risks, yet both firms' customers and providers of capital have the right to know what firms are doing (or not doing) to help meet the goal of carbon neutrality and what risks this may pose to them, at least in the short run. A lot can already be done, but once this data is available, the way forward will be easier to pave and both private and public institutions will be able work more effectively towards greening the financial system and managing the risks in their portfolios.

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APPENDIX

A.1 Carbon dioxide equivalent data

In this study, I employ industry level carbon dioxide equivalent (CO₂e)¹⁹ emissions data estimated by Statistic Sweden (SCB) for the year 2019. For each of the 32 industries in their sample, SCB reports yearly total emissions from stationary and mobile sources (SCB 2020b, 2021a and 2021b).²⁰ All firms are assigned to a given industry using the firm's primary SNI code and are considered as stand-alone even if they belong to a group.²¹

Using the data provided by SCB, I sort all industries by total emissions and then divide all of them into quartiles based on emissions.²² I do this exercise using total industry emissions of CO₂e in 2019.²³ The industries in each quartile and their respective emissions are reported in Figure 1.a.

¹⁹ The carbon dioxide (CO₂) equivalent is the unit of measure that expresses the climate impact from emissions of different greenhouse gases by converting amounts of other gases into the equivalent amount of carbon dioxide with the same global warming potential. Emissions are converted into CO₂ emissions using a methodology provided by the UN climate panel, the IPCC. SCB.

²⁰ To the best of my knowledge, the total of emissions from stationary and mobile sources should roughly map into the total of scope 1 and scope 2 emissions as defined by the GHG Protocol Corporate Standard. The GHG Protocol defines three types of emissions: scope 1, 2 and 3. Scope 1 emissions are direct greenhouse (GHG) emissions from sources that are controlled or owned by an organization (e.g. emissions associated with fuel combustion in boilers, furnaces, vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly impacts in its value chain. These are not reported by SCB. See Greenhouse Gas Protocol (2015a and 2015b), U.S. Environmental Protection Agency (2015) and SCB (2021a and 2021b).

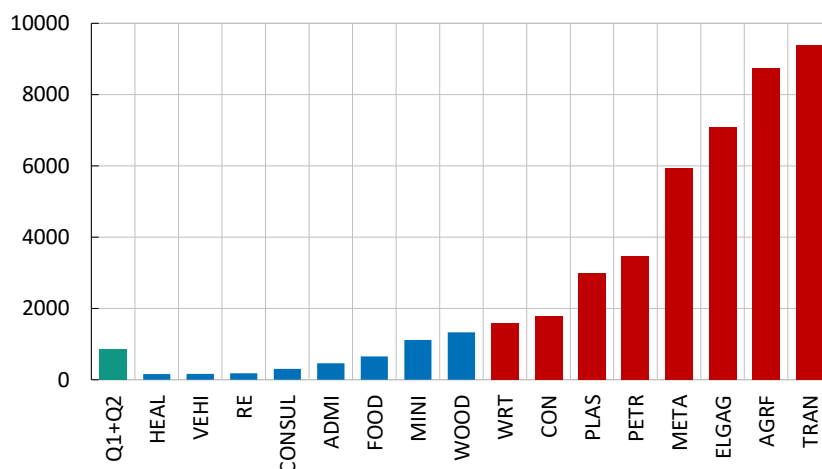
²¹ SCB's yearly emissions data is based on the survey on industry yearly energy use (SCB 2021a). To give a practical example of how emissions are imputed from the firm level to the industry level, assume that firm A belongs to a group of firms composed of firms A and B. Firm A's primary SNI code shows that this firm is in the manufacturing industry, while firm B is a holding company classified in the consulting service industry. The emissions of firm B are estimated based on the energy use in the manufacturing industry. Firm B would be allocated some emissions but only at SNI-level (consulting industry), based on what can be found in the yearly energy balance for the service sector in combination with information from the National accounts data on energy expenditure for that specific SNI. In other words, even though firms A and B belong to the same group, their emissions are never added together. Full documentation can be found in SCB (2021a and 2021b).

²² Notice that in May 2021 data have been revised and some differences have arisen with respect to the data employed in this study which have been downloaded in November 2020. First, using the data extracted in November 2020, I classify the Health industry (HEAL), Q86 human health activities, as a medium-emission industry, but using data revised in May 2021 this industry should have been classified as a low emissions industry. Similarly, the industry Arts (ARTS), R90-R93 arts entertainment and recreation, was classified as a low-emission industry with data obtained in November 2020. Yet, revised data, show that this industry should have been classified as a medium-emission industry. Finally, within high emitting industries in Figure 1.a, the most polluting industry appears to be the Transportation (TRAN), H49-H53 transport and storage. Yet, employing the revised data in May 2021, the most polluting industry appears to be Agriculture, Forestry and Fishing (AGRF), A01-A03 agriculture, forestry and fishing. Importantly, none of these changes affect the main results of this study.

²³ Even though emissions in Sweden have decreased in 2020 with respect to 2019 (SCB 2020a), that result was most likely driven by the reduction in economic activity due to the pandemic (Le Quéré, Jackson, and Jones et al. 2020). Therefore, emissions in 2019 are also more similar to what emissions may have looked like if the pandemic had not happened since in the last 10 years total emissions have not dramatically changed even though much effort has been put into fighting climate change.

Figure 1.a Total CO₂ Equivalent Emissions in 2019, by industry

Thousand tonnes



Note: Figure 1.a shows for each industry the total amount, in thousands of tons, of CO₂ equivalent emissions estimated by Statistic Sweden for the year 2019. Results are reported by industry sorted by the total amount of CO₂ emissions, from those that emit the least to those that emit the most. All industries are grouped in quartiles based on emissions. The fourth quartile is represented by the red bars. The third quartile is represented by the blue bars. Since the industries in the first and second quartile emit very little, I have collated them into one large group: Q1+Q2. The industries are the following: Computers (COMP), Transportation Equipment (TRA-EQ), Telecom (TEXT), Textiles (TELE), TV and Movies (TVMO), Electronics Equipment (ELEC-EQ), Social Work (SOCIO), Education (EDUC), Programming (PROG), Advertising (ADVE), Hotels and Restaurants (H&R), Other Services (OTHES), Furniture (FURN), Arts (ARTS), Machinery (MACH), Health (HEAL), Vehicles (VEHI), Real Estate (RE), Consultancy (CONSUL), Administrative Support (ADMI), Food and Tobacco (FOOD), Mining (MINI), Wood (WOOD), Wholesale and Retail Trade (VS.), Construction (CON), Plastic (PLAS), Petroleum (PETR), Metals (META), Electricity Gas and Water Supplies (ELGAG), Agriculture, Forestry and Fishing (AGRF), Transportation (TRAN). Emissions data were downloaded in November 2020.

Data sources: SCB.

In Figure 1.a, I have collected all industries in quartiles based on the amount of total emissions in 2019. The red bars represent all the industries in the fourth quartile of the emissions distribution (*High-emission*). The blue bars represent industries in the third quartile of the distribution (*Medium-emission*). Finally, the green bar represents the industries in both the first and second quartile of the distribution (*Low-emission*) since collectively these industries pollute less than the industry of Mining (MINI) alone.

The industries in each group are as follows. The *high-emission* group contains the following industries: Wholesale and Retail Trade (WRT), Construction (CON), Plastic (PLAS), Petroleum (PETR), Metals (META), Electricity Gas and Water Supplies (ELGAG), Agriculture, Forestry and Fishing (AGRF), Transportation (TRAN). The *medium-emission* group consists of the following industries: Health (HEAL), Vehicles (VEHI), Real Estate (RE), Consultancy (CONSUL), Administrative Support (ADMI), Food and Tobacco (FOOD), Mining (MINI), Wood (WOOD). Finally, all of the other industries are in the

low-emission group: Computers (COMP), Transportation Equipment (TRA-EQ), Telecom (TEXT), Textiles (TELE), TV and Movies (TVMO), Electronics Equipment (ELEC-EQ), Social Work (SOCIO), Education (EDUC), Programming (PROG), Advertising (ADVE), Hotels and Restaurants (H&R), Other Services (OTHES), Furniture (FURN), Arts (ARTS), Machinery (MACH).

Unfortunately, the data provided by SCB is not perfect to fully comprehend how climate-related risks may affect firms and, as a consequence, the stability of the financial system. Yet, given the current lack of detailed data provided by the firms themselves, it is a good enough proxy to at least gauge the overall severity of the problem.

To begin with, the emission data only depicts a partial picture of how much Swedish firms contribute to global CO₂e emissions since it only refers to the total of emissions from mobile and stationary sources. Nevertheless, to meet its neutrality target, Swedish institutions need Swedish firms to reduce emissions in Sweden. Thus, the data estimated by Statistic Sweden is a good enough proxy for the collective effort that is needed by all the firms in a given industry to help reduce air pollution. Nevertheless, even within high-emission industries, some industries are going to be more affected than others,²⁴ and even within the same industry firms will be affected differently. Unfortunately, with the current data it is impossible to capture within industry dynamics. In fact, the data overlooks the effort of firms to reduce emissions and does not identify firms that are already employing green sources of energy or more sustainable technology and therefore may be less affected by transition risks.

The data though has also some clear advantages. To begin with, it is estimated over a large set of Swedish firms and this makes the total more representative than estimates based only on a small sub-sample of firms that choose to report emissions. Second, it covers a large array of industries. This allows for more granularity in the analysis and for a better understanding of industries that contribute the most to direct emissions in Sweden. This is important because stranded-assets may be more concentrated in industries that are currently greatly dependent on fossil-fuels technologies. For example, within the manufacturing industry (SNI07 10111-33200) sub-industries do not contribute all in the same way to the total emitted by all firms in manufacturing.²⁵ If one would add together the direct emissions of all firms in the manufacturing industry, regardless of their sub-activities, one may overestimate the potential impact of transition risks for those firms that within the manufacturing industry belong to

²⁴ For example, although both need to make substantial changes, the petroleum industry (refinery of oil products) may be more affected in the end than the transportation industry, even though, in Sweden, this latter industry currently emits far more than the petroleum industry.

²⁵ To be more concrete, the manufacturing industry covers sub-industries in all quartiles of the emissions distribution. In the high-emission quartile I classify the following sub-industries: Plastic (PLAS), Petroleum (PETR), Metals (META). In the medium-emission quartile there are instead the sub-industries of Vehicles (VEHI), Food and Tobacco (FOOD), Wood (WOOD). Finally, the first and second quartile contains the sub-industries of Computers (COMP), Transportation Equipment (TRA-EQ), Textiles (TELE), Electronics Equipment (ELEC-EQ), Furniture (FURN), Machinery (MACH). Therefore, while collectively all of the firms in these industries emit a lot, it is reasonable to believe that firms in the sub-industries that belong to the high-emissions quartile may be the most affected by the realization of transition risks.

sub-industries that emit the least. The granular definition of industries is then a clear advantage of this data from a risk management perspective.

Next, I provide a description of the firms in each of the emissions categories. To do so, I match the emissions data from SCB with the Serrano database provided by Bisnode. This database contains detailed financial statement information for all Swedish limited liability companies (aktiebolag) that reported to the Swedish Companies Registration Office (Bolagsverket) in 2019. Using each firm's primary SNI code, I can assign, exactly as SCB does, firms to the industry for which SCB produces emissions statistics. Firms with missing SNI codes cannot be matched.

After dropping firms with missing primary industry codes and firms in the financial and insurance activities industry (SNI07 64110-66309), in Serrano there is a total of 436,329 non-financial limited liability firms that can be matched with the emissions data. Out of the latter total, 153,025 firms are in the high-emission group. The average firm in this group is almost 16 years old, has about SEK 30 million in total assets (the median firm has little less than SEK 2 million in assets) and 8 employees. The medium-emission group contains a total of 175,202 firms. These firms, on average, are larger (circa SEK 59 million in total assets but also in this group the median firm has again around SEK 2 million in total assets), employ less people (about 5) and are younger (13 years) than firms in high-emission group. Finally, the low-emission group contains a total of 108,102 firms. The average firm in this latter group has about SEK 17 million in total assets (the median is less than SEK 1 million), employs about 7 people and has been registered for almost 12 years. The low-emission group therefore contains the smallest and youngest firms in the sample.

A.2 Discussion of firms' classification

The classification I employ in this study suffers from short-comings that are common in this literature. To begin with, by solely employing accounting data reported by the firms themselves, it is impossible to fully gauge how financially vulnerable firms really are (see Cella 2020a for a discussion). Therefore, some firms may be classified as financially vulnerable even if they are not vulnerable and vice-versa. Second, 35% of the firms in the sample belong to a group. However, because of data limitations and the way CO_{2e} emissions are computed by SCB (see Appendix A.1), I consider all firms as independent firms (also referred to as stand-alone firms). By doing so, I do not take into considerations group-level synergies and the fact that these firms have access to the internal capital market of the group. Therefore, I may be overestimating the amount of vulnerable firms among firms that belong to groups. Finally, a firm's liquidity can change quite quickly. For example, firms with very good ICR could be hit by a sudden negative shock to their operating income and become quickly insolvent, while firms that struggle to service their debt may experience the opposite. This suggests that the way firms are classified is not only strictly related to the definition employed but also to the time at which the variables are calculated.

Because of the issues described above, misclassification could occur for a number of firms. Yet, since I already employ all the data available to me, I am unable to further

understand how these shortcomings may affect the results of this study. Nevertheless, to reduce concerns, when defining vulnerable firms, I follow the existing literature as closely as possible and I calculate all variables at the end of the year 2019, the last available year of accounting data, and discuss at length the characteristics of the firms in each group (see Appendix A.3). Additionally, as a robustness check, I try to understand whether the firms' classification is stable and how it may have been affected by the economic crisis that has followed the COVID-19 pandemic. To do so, I use data from the Swedish National Institute of Economic Research (Konjunkturinstitutet, KI) and employ a simulation methodology similar in spirit to the one used by Banerjee et al., (2020). I find that the firms' classification stays stable. In particular, firms that were classified as vulnerable ($ICR \leq 1$) using data in 2019, would have been classified as vulnerable even using the simulated data for the year 2020. Full-fledged analyses are reported in Cella (2021).

A.3 Firm level descriptive statistics

After matching KRITA with Serrano and with the emissions data from SCB, in December 2020, I am left with 147,150 non-financial limited liability. Simple descriptive statistics for these sub-samples are reported in Table 1.a.

Table 1.a Descriptive statistics

Descriptive statistics

	(1)	(2)	(3)	(4)	(5)	(6)
	Firms	Total Assets	Age	Leverage	ROA	ICR
All firms	147,150	69,984	15	60%	9%	6
Firms with $ICR \leq 1$	33,944	117,317	16	70%	-11%	-5
High leverage-poor performance	21,049	70,286	14	78%	1%	3
High leverage-good performance	42,495	41,361	13	72%	20%	17
Other firms	49,662	61,997	17	36%	17%	34

Note: Table 1.a shows descriptive statistics for selected variables. Table 1.a starts by reporting statistics for all of the firms in the sample, then these firms are split in 4 groups: Firms with $ICR \leq 1$, high leverage-poor performance firms, high leverage-good performance firms and other firms. Column (1) shows that total number of firms in each category. Columns 2-4 show averages while column 6 reports the median. Column (2) reports firm's total assets (in SEK thousands) while column (3) shows the average firm age. Firm age is the number of years from the firm's registration. Column (4) shows results for the firm's leverage. A firm's leverage is calculated as the ratio between its debt and the sum of its debt and equity. Column (5) shows results for profitability. A firm's profitability is calculated by its return on assets (ROA) obtained as the ratio between its earnings before interest and taxes (EBIT) and its total assets. Column (6) reports the median interest coverage ratio for all firms in each group. A firm's ICR is obtained as the ratio between a firm's earnings before interest and taxes (EBIT), and (the absolute value) of its interest expenses. Variables are calculated in 2019. Details about the classification of firms can be found in Section 2.2.1 and Appendix A.2.

Source: Bisnode.

The average firm in the sample had, in 2019, about SEK 70 million in total assets, leverage around 60% and ROA around 9%. These firms had a median ICR around 6 suggesting that the median firm in the sample could pay the interest on its debt 6 times over just using its operating earnings (EBIT). Out of the 145,150 firms just described, 33,944 are in the group of firms with $ICR \leq 1$ and 21,049 are classified as firms with

high leverage and poor performance with respect to their industry peers. In addition, the group of high leverage and good performance contains about 42,495 firms while about 49,662 firms are classified as other firms.

The firms in the group with $ICR \leq 1$ were, on average, 16 years old and had around SEK 117 million (median around SEK 3.7 million) in total assets, leverage of about 70% and ROA around -11% while the median ICR is around -5. Hence, compared with the average firm in the sample, the average firm with $ICR \leq 1$ was, in 2019, not only older (16 vs 15 years), larger (SEK 117 million vs SEK 70 million) and at risk of insolvency (-5 vs 6) but also more levered (70% vs 60%) and less profitable (-11% vs 9%).

Table 1.a also shows that firms in the category high leverage-poor performance were, on average, similar in age and size to those in the entire sample (with median total assets of circa SEK 3 million). As expected, these firms had, on average, higher leverage (78% vs 60%) and poorer performance (1% vs 9%) than the average firm in the sample. Importantly though, they also had a worse median ICR (3 vs 6). Yet, if we directly compare firms with $ICR \leq 1$ with high leverage-poor performance firms, those in the first group appear to be larger (on average) and in a worse financial position, given that on top of high leverage and poor performance they also had quite poor ICR (-5 vs 3).

The firms in the category of high leverage- good performance appear to be, on average, the smallest (SEK 41 million vs SEK 70 million) and youngest in the sample (13 vs 15 years). And, although almost by definition, these firms had, on average, high leverage (70% vs 60%) and perform better than the sample average (20% vs 9%), they also show much higher median ICR than the entire sample (17 vs 6). Finally, the set of "other firms" seems to contain firms that are, on average, older (17 vs 15 years), slightly smaller (around SEK 62 million vs SEK 70 million), substantially less levered (36% vs 60%), better performing (17% vs 9%), and, in median, very solvent (34 vs 6). These latter two categories of firms therefore contain firms that were smaller, more liquid, less levered and better performing than the rest of the firms in the sample.



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