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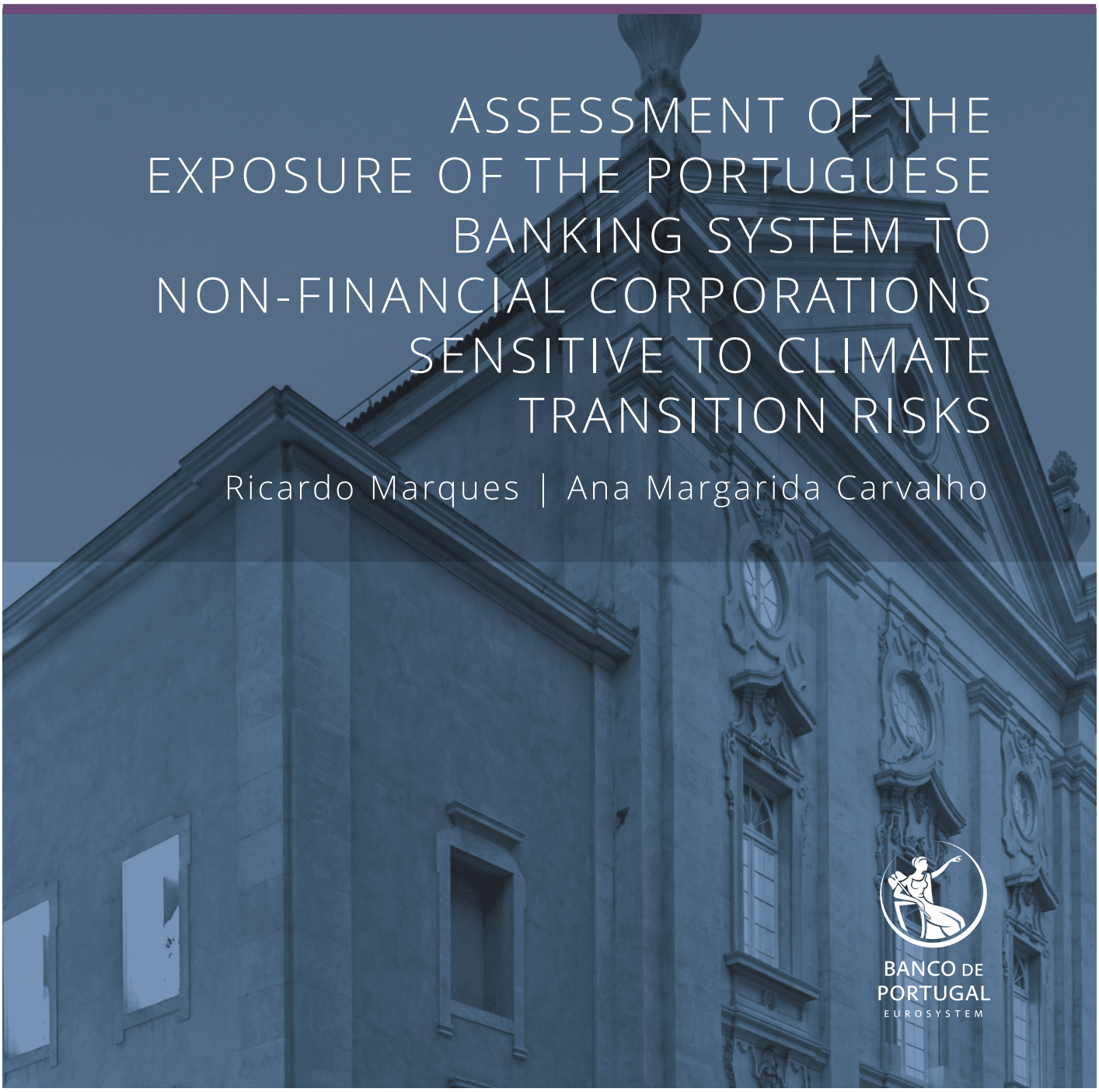

ASSESSMENT OF THE EXPOSURE OF THE PORTUGUESE BANKING SYSTEM TO NON-FINANCIAL CORPORATIONS SENSITIVE TO CLIMATE TRANSITION RISKS

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JUNE 2021

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Assessment of the exposure of the Portuguese banking system to non-financial corporations sensitive to climate transition risks

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Abstract
Climate change is a source of risk to financial stability. This article presents a quantification of the exposure of the Portuguese banking system to non-financial corporations (NFCs) sensitive to the risks arising from the transition to a low-carbon economy. The results suggest that about 60% of banks' exposures to NFCs are in climate-policy-relevant sectors (CPRS), chiefly in the sectors dedicated to construction, transaction and use of buildings and, to a lesser extent, in sectors associated with the production and use of means of transportation and in energy-intensive industries. This article also presents a methodology for estimating direct greenhouse gas (GHG) emissions, by sector of activity, from resident NFCs with bank financing. The calculation of carbon intensity on the basis of these estimates shows that around 60% of banks' exposures to NFCs is below the median of this indicator. This result is consistent with the higher concentration of exposures in climate-policy-relevant sectors with lower direct GHG emissions.

JEL: G21, Q54

Keywords: climate change, transition risks, banking system, financial stability.

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1. Introduction

In recent years, climate change has risen to the top of the international political agenda. The accumulation of scientific evidence on the impact of human activities on the climate, as well as the awareness of civil society of the consequences of inaction on the quality of life of current and future generations, has led to the prioritisation of the transition to a sustainable low-carbon economy. The urgency of fighting climate change resulted in the conclusion of the Paris Agreement at the end of 2015, in which most countries pledged to substantially reduce greenhouse gas (GHG) emissions. The Paris Agreement aims to limit, by the end of the century, global average temperature rise to well below 2 degrees Celsius above pre-industrial levels, while seeking to limit this increase to 1.5 degrees.

In December 2019, the European Commission (2019) presented the European Green Deal, a European Union (EU) transformation plan based on a sustainable and socially inclusive development model. On the climate front, the European Green Deal sets the target of reducing net GHG emissions[1] to zero in the EU by 2050 (carbon neutrality). The pursuit of this objective will call for structural changes in the way societies produce and consume energy. This process to transform the economy hinges on the cooperation between public and private sectors to disseminate the necessary technology and to provide appropriate economic incentives in order to direct investment towards the sectors relevant to energy transition. In this context, as acknowledged in the European Commission (2018)'s March 2018 Action Plan, the financial system should play an important role in mobilising the financial resources necessary to achieve the goals of the European Green Deal, while carrying out its activities within a risk-based prudential regulatory framework. It is therefore expected that the financial system, and in particular the banking sector, due to its preponderance in financing the EU economy, will take into account the risks inherent to climate change in its risk management and financing decisions.

From an economic and financial standpoint, the financial risks associated with climate change are typically grouped into two categories: physical risks and transition risks (NGFS (2019)). Physical risks relate to the economic and financial impacts of the increased frequency and intensity of extreme weather events (e.g. forest fires, floods), as well as long-term changes in weather patterns (e.g. rise in average sea water levels, changes in rainfall, higher temperatures). These phenomena have the potential to produce negative systemic effects on the economy, such as damaged physical capital, the reduction of labour supply and productivity and the increase in human health-related costs (Bolton *et al.* (2020), BIS (2021)). The estimation of the economic impacts of climate change in the long term is complex and surrounded by great uncertainty due to the very long

1. GHG emissions from human activities minus the GHG uptake by natural (e.g. soil, oceans, forests) or artificial sinks (e.g. carbon removal and storage technologies). These technologies are still under development.

forecast horizons, the non-linearities of climate-related events and the multiplicity of transmission channels between natural systems and human activities. However, existing studies point to very substantial economic costs by the end of the century (NGFS (2019)). The magnitude of these impacts proves the existence of potential risks to financial stability, such as those related to the costs with compensation payments, the significant reduction in the value of collateral, the devaluation of financial assets and the materialisation of credit risk in exposures to economic agents more vulnerable to the effects of climate change.

Transition risks reflect the possible impacts of structural changes to the economy and society from reducing GHG emissions. To a greater or lesser extent, these changes have the potential to bring about material changes to the financial system (e.g. through sudden variations in asset value), with such changes being greater the faster and more unexpected the process is. However, in a benign scenario, this transition will be gradual and predictable in such a way as to avoid disruptions to the financial system while guaranteeing that adjustment costs are bearable.

Physical and transition risks are not independent of each other. On the one hand, a longer or less coordinated transition period between countries will tend to increase the likelihood of physical risk materialisation. In this scenario, the adverse consequences of climate change can lead to an acceleration of the transition process, thus also increasing its inherent risks. On the other hand, a more ambitious climate policy (e.g. a policy leading to a rapid rise in carbon pricing) may reduce physical risks, but will increase the risk of a disorderly transition (ESRB (2020)).

Despite the economic and social impacts that may result from the materialisation of climate risks, empirical research on these impacts is still at an incipient stage (Banco de Portugal (2019)). The aforementioned specific nature of physical and transition risks, as well as the limited availability of adequate data (e.g. indirect GHG emissions by entity and sector of activity, classification of sectors of activity according to climate risks), are obstacles to research. Nevertheless, in recent years, some methodologies have been developed to address these shortcomings, focusing on two sequential tasks in risk analysis: (i) quantification of exposures to climate risks and (ii) the application of technical tools to assess the risk underlying these exposures. The first part of this article addresses the first of these steps, presenting a quantification of the exposures of the Portuguese banking system to non-financial corporations (NFCs) sensitive to transition risks and classifying them into climate-policy-relevant sectors. In the second part, estimates of GHG emissions from resident NFCs by sector of activity and emissions indirectly financed by the banking system are calculated.

The article is structured as follows. Chapter 2 examines the main transmission channels for climate transition risks to financial stability, focusing on the banking sector. Chapter 3 describes the methodology adopted. Chapter 4 presents the main results of the analysis. Chapter 5 presents the concluding remarks.

2. Transition risks to financial stability

The transition to a low-carbon economy that will make it possible to meet the GHG reduction targets set out in the Paris Agreement will require a rapid, cross-cutting transformation of the productive structure of economies. The estimated figures for the investments that will be needed over the coming decades to meet these goals are significant. In the EU, the European Commission (2020a) estimates that the additional public and private investments necessary to achieve a 40% reduction in GHG emissions by 2030 compared to 1990 levels amount to €260 billion a year, around 2% of the EU's nominal GDP in 2019. The revision of the GHG emissions reduction target to 55% by 2030 (European Commission (2020b)), as well as the carbon neutrality target in 2050, suggests that the investment needed will be higher.

The materialisation of these invstments should boost the growth of firms linked to renewable energy or low GHG emissions sectors, and also promote the adaptation of firms to new sustainability standards, wherefore their funding could provide an opportunity for the financial system. However, the transition process will also lead to the decline of some activities (e.g. extraction of fossil fuels and their use in energy production), thus prompting the disappearance of firms unable to meet the demands of a carbon-neutral economy. This could be a source of risk to financial institutions more exposed to sectors of activity adversely affected by the energy transition.

This process of adjustment of the economic fabric is fostered by three factors (NGFS (2019)): (i) tax and regulatory changes (e.g. taxes and limits on GHG emissions) with a view to internalising the social cost of carbon by emitters; (ii) technological progress that reduces the cost of producing renewable energy and increases the energy efficiency of production processes, or even permits the capture of GHG from the atmosphere; and (iii) change in consumer preferences by excluding products whose production or consumption is associated with high environmental costs (e.g. replacement of combustion-engine cars by others with electric engines). These factors may interact with and reinforce each other. For instance, a tax on GHG emissions could lower the relative price of electric vehicles, making them more attractive to consumers and encouraging more research in the field of electric mobility.

Technological progress and changing consumer preferences should gradually take effect as new technologies develop and infiltrate the economic fabric and consumers adhere to the new products. However, the change in climate policy, reflected, for example, in a significant increase in carbon pricing in a short period of time, could generate more abrupt changes in the value of assets, thus bearing higher economic costs than a scenario in which the transition takes place at a more gradual pace (ESRB (2016)).

The main economic impacts of the energy transition relate to the early obsolescence of physical capital (e.g. fossil fuel reserves, thermal power plants, combustion-engine vehicles, buildings with lower energy efficiency). The rapid depreciation, and consequent loss of value, of these fixed assets will result in the

recognition of losses by firms and a downward revision of future income. The replacement of these assets by others that adopt more efficient, less polluting technologies will require high investments, as mentioned above, whose return may not materialise in the short term. An abrupt transition process may also have adverse effects on energy prices. In the short term, the lower production of fossil energy may not be offset by renewable sources, thereby leading to an increase in energy prices. In the medium term, energy prices may also be higher if renewable energy production costs exceed those of current fossil alternatives and are not subsidised. The possible increase in energy prices may have cross-cutting impacts on the whole economy, although relative prices of assets whose production process is less energy-intensive tend to decrease.

Households may also, in the short term, experience negative impacts on their disposable income, in particular by virtue of possible increases in energy prices or higher unemployment in sectors more adversely affected by the transition and whose absorption by other sectors may be subject to some friction. In this way, households may sustain a reduction in their debt servicing capacity. Household wealth may also be hampered by impacts on the real estate sector and the devaluation of financial claims on NFCs.

Accordingly, the financial system, in particular the banking sector, is exposed to the materialisation of credit risk and the devaluation of financial assets due to the exposure of economic agents to climate transition risks. The possible recognition of losses may deteriorate the solvency of financial institutions (Battiston *et al.* (2017), Vermeulen *et al.* (2018)), which may imply, in turn, a tightening in lending standards. The deterioration of financial conditions in the economy could lead to a contraction in investment and consumption, thereby exacerbating the economic impact of the energy transition. This scenario will be all the more likely the more abrupt the transition process is.

From a financial stability standpoint, it is important for institutions to incorporate climate risks into their risk management policies, analyses and processes. A risk assessment that considers the scale of structural changes that the economy will face will provide institutions with information to identify and manage such risks, assess their strategic resilience and prevent late and abrupt recognition of losses.

3. Methodology

This section presents a methodology to quantify the exposure of the Portuguese banking sector to the NFCs most sensitive to climate transition risks. This work cross-checks various sources of information, some of which are characterised by a high level of granularity. Starting from a database of the Portuguese banking system's firm-level exposures, the first part of this work classifies this portfolio into climate-policy-relevant sectors of activity. Next, GHG emissions from each sector

of activity are estimated, as well as emissions indirectly financed by the banking sector through exposure to NFCs.

3.1. Databases

Data on bank exposures to NFCs, as at 31 December 2019, were obtained from the Banco de Portugal's internal databases. For loan exposures, the Central Credit Register was used.[2] This database contains information on an individual basis of loans granted by the banking system. The information was aggregated at lender-borrower level (355,866 observations), and the total value of loans (net of impairments) amounted to around €59,704 million. With regard to bank exposures to NFCs in the form of debt and equity securities, the Securities Statistics Integrated System (Sistema Integrado de Estatísticas de Títulos – SIET)[3] was used to obtain the market value of securities held by financial institutions. Information, on an individual basis, was aggregated at investor-issuer level (2,580 observations), with the total value of debt securities amounting to around €16,914 million and that of equity to €1,278 million.

The characterisation of the NFCs to which the banking sector is exposed was mainly based on the annual report of the Simplified Corporate Information (Informação Empresarial Simplificada – IES), with reference to December 2019 (latest information available). The IES provides the sector of activity of firms resident in Portugal according to the Portuguese Classification of Economic Activities (CAE Rev. 3) (Instituto Nacional de Estatística (2007)), broken down by up to 5 digits (level 5), as well as accounting information used in data processing (Section 3.2), implementation of the methodology and calculation of indicators (Section 3.4). Although only accounting for around 3% of the banking sector's exposures to NFCs, exposures to non-resident NFCs were also considered in the analysis, characterised on the basis of Bureau van Dijk's private database Orbis. In this database, sectors of activity are classified according to the statistical classification of economic activities in the European Community (NACE Rev. 2), which is broken down by up to 4 digits (level 4). Note that CAE is harmonised with NACE, while providing only an additional level of detail.[4] However, the 5-digit

2. Instruction of the Banco de Portugal No 17/2018 - Regulates the reporting to the Banco de Portugal of the actual or potential liabilities arising from credit operations, in any form or type, so that it centralises and disseminates that information. It revokes Instruction of the Banco de Portugal No 21/2008, published in Official Bulletin No 1, 15 January 2009.

3. Instruction of the Banco de Portugal No 31/2005 - Regulates securities statistics: concept, entities covered, responsibility for information, data reporting and frequency, revisions, thresholds and simplified reporting regime, stakeholders, penalty framework.

4. The CAE and NACE designations or the level of detail of the sector of activity (number of digits of the activity code of the sector) shall be mentioned only where necessary for the sake of clarity. In CAE, "[the] numerical coding starts at Division level with two digits, down to the Group level (with three digits), then the Class level (four digits) and ends at the Sub-class level (with 5 digits)", available at (in Portuguese only): ine.pt.

detail provided by CAE made it possible to obtain more detailed information on the activity of some sectors (Section 3.3). Firms for which it was not possible to determine the sector of activity according to CAE/NACE were excluded.[5]

In addition to detailing the sectors of activity in which NFCs operate, the IES and Orbis also make it possible to replicate the composition of their economic groups. This information made it possible, by adopting certain assumptions, to distribute exposures to firms in the head offices and holding companies sectors, which generally do not produce goods nor provide services, among other sectors of activity (Section 3.2).

To estimate GHG emissions indirectly financed by the banking system, the Air Emission Accounts database provided by the Eurostat was used. GHG emissions are divided into three categories by the Kyoto Protocol (Greenhouse Gas Protocol Initiative (2015)): scope 1 emissions directly caused by the entity (direct emissions); scope 2 indirect emissions from the generation of electricity purchased by the entity; and scope 3 indirect emissions, corresponding to all other indirect emissions, generally attributable to the final consumption of goods and services produced (e.g. emissions generated by the use of cars).[6] The Eurostat database contains the direct emissions (scope 1) of all GHGs originating in each country each year by business activities, detailed by NACE Rev. 2[7], expressed in tonnes CO2 equivalent. GHG emissions originated in Portugal in 2019 were used.

However, this database does not present GHG emissions in the same detail for all sectors of activity, and some sectors are grouped at a higher level. For example, emissions from sectors of activity within Section D ('Electricity, gas, steam and air conditioning supply') or Sections C10 ('Manufacture of food products'), C11 ('Manufacture of beverages') and C12 ('Manufacture of tobacco products') are grouped together.

3.2. Adjustment of exposure to holding companies

Around 13% of the banking system's exposures to NFCs have as counterparties firms in the 'Activities of holding companies' (K64201 and K64202) and 'Activities of head offices' (M70100) sectors. Given that these firms mainly perform financial and operational management functions within a group of firms, the sector of activity in which they are included does not reflect the economic activities to which they are actually exposed. Thus, the exposure of banks to holding companies that are part of a given economic group was divided over the remaining sectors of activity

5. Firms without a sector of economic activity and with bank financing correspond to around 0.01% of the total exposure to NFCs.

6. For further information, see: ghgprotocol.org and ec.europa.eu.

7. The sectors of activity available in Eurostat are aggregated at different levels. See appendix D.

according to their representativeness in the total non-consolidated assets of the respective economic group.[8]

The economic groups of each holding company to which the banking sector is exposed were deduced on the basis of the reporting of group relationships in the IES. For each resident holding company, the parent company of the group was determined, and then all other resident companies with the same parent company were identified. Given that economic groups may contain non-resident firms, the information from the IES has been supplemented with that of Orbis. In the case of non-resident holding companies, the composition of their economic group was determined using Orbis data.

The assets of the NFCs making up each economic group (excluding other holding companies) were aggregated at sector of activity level (level-5 CAE)[9] and the respective group level, thus obtaining the weight of each sector in the total non-consolidated assets of the group. The exposure to each holding company was multiplied by each of these weights in order to obtain the value of the exposure to assign to each sector. As such, the exposure to each holding company h, part of group g, assigned to the sector of activity i ($\text{Exp}_{h,g,i}$) is given by:

$$\text{Exp}_{h,g,i} = \text{Exp}_{h,g} \times \frac{A_{g,i}}{A_g - A_{H,g}}, \sum_i \frac{A_{g,i}}{A_g - A_{H,g}} = 1 \tag{1}$$

The term $\text{Exp}_{h,g}$ corresponds to the banking system's exposure to holding company h of group g; $A_{g,i}$ refers to the aggregate assets of the NFCs in sector i within group g; A_g corresponds to the aggregate assets of the NFCs in group g; and $A_{H,g}$ refers to the aggregate assets of all holding companies (including holding company h) of group g.

3.3. Climate-policy-relevant sectors

The analysis of the banking system's exposures to transition risks through its exposures to firms requires the latter's breakdown into sectors of activity according to their relevance to climate policy. However, there is as yet no statistical

8. For further information about this adjustment, see appendix A.

9. As mentioned in Section 3.2, sectors of activity in Orbis are only broken down by up to 4 digits. As such, for non-resident firms, the code for the sector of activity had to be converted to 5 digits. In cases where there was a single sector with 5 digits (sub-class) within a sector with 4 digits (class), the conversion required only the allocation of the missing digit (e.g. sector A0112 becomes A01120). For sectors in which there is more than one sub-class in a given class, determining the correct sub-class would imply insight into the activity of each company. In these cases, the sub-class corresponding to the digit '1' was assigned (e.g. sector A0111 becomes A01111, although there is also sector A01112). The fifth digit of the sector of activity does not affect the matching of climate-policy-relevant sectors (CPRS), based on 4-digit coding (section 3.3). However, this affects the allocation to CPRS sub-sectors of a very limited number of sectors, corresponding to around 0.2% of the banking system's exposures to NFCs.

classification exclusively dedicated to the classification of economic activities on the basis of sensitivity to climate risks.[10]

Similarly to other studies on the financial system's exposure to transition risks, this article is based on the correspondence between sectors of activity (4 digits) and a set of climate-policy-relevant sectors (CPRS) suggested by Battiston *et al.* (2017).[11]

The CPRS have been identified taking into account the following factors (Battiston *et al.* (2020)): direct and indirect contribution to GHG emissions (e.g. production and distribution of fossil fuels or renewable energies); relevance to climate policy (e.g. sensitivity of the cost structure to regulatory or fiscal changes based on GHG emissions); and their role in the energy value chain (production, use, consumption). Accordingly, the following CPRS were identified: Agriculture, Fossil-fuel, Energy-intensive, Utilities, Buildings and Transportation. The sectors that were not included in any of these CPRS were assigned to a residual category (Other). The level of detail of the sectors of activity makes it possible to break down some of the CPRS, taking into account their line of business (appendix B).

The allocation of firms across CPRS and the residual category 'Other' was made only on the basis of their main sector of activity. Therefore, the 'Other' sector should also include firms that carry out activities in climate-policy-relevant sectors beyond their core activity. Similarly, some firms associated with a particular CPRS may also operate in other sectors of activity that are not relevant to climate policy.[12]

As will be explained in Section 4.2, the sectors included in CPRS 'Agriculture' have high carbon intensities (GHG emissions by sales). Charging additional costs on emissions from these sectors may have substantial economic impacts, in particular if there are no technologies available to reduce emissions (e.g. carbon capture and storage technologies).

CPRS 'Fossil-fuel' encompasses some of the sectors most directly impacted by the transition to a low-carbon economy due to its role in the energy value chain.

10. The European Commission has developed a classification system for environmentally sustainable economic activities, published in Regulation (EU) 2020/852 of 18 June 2020 (Taxonomy Regulation), available at eur-lex.europa.eu – a system that will be implemented with the publication of technical criteria for identifying these activities. However, for now, it is a system for classifying activities that are aligned with the EU's GHG emission reduction targets and does not classify activities that will be adversely affected by this transition process. As such, Taxonomy does not provide at this stage a classification of economic activities that is sufficiently comprehensive to quantify exposure to sectors sensitive to the transition to a carbon neutral economy. It should be noted, however, that under Article 26 of the Regulation, the European Commission will assess the possibility of extending the scope of the Regulation beyond environmentally sustainable economic activities in order to cover activities that significantly harm the environment.

11. Full correspondence between NACE Rev. 2 and the CPRS (and sub-sectors thereof) may be requested at finexus.uzh.ch.

12. For more information on how the core and secondary sectors of activity are determined, see the specifications of the Portuguese Classification of Economic Activities, available at (in Portuguese only): ine.pt.

In fact, these sectors are responsible for the production and distribution of fuels that produce high emissions of GHG in the course of their use, in particular in the production of electricity or fuels. Thus, the decline in carbon-intensive energy production will lead to the loss of value of assets allocated to the exploration and production of hydrocarbons (e.g. proven reserves, but which cannot be explored), which have a negative impact on the financial situation of firms.

Impacts on sectors associated with the production of fossil fuels will have downstream effects on firms in other sectors, such as electricity producers (included in CPRS 'Utilities', fossil-fuel-based and renewables-based) and sectors that require high energy consumption to carry out their activities (CPRS 'Energy-intensive'). The introduction of a carbon tax will have a direct impact on fossil fuel-based electricity companies (i.e. with high GHG emissions): the physical capital used in energy production will tend to reach the end of its useful life earlier, while renewable energy production will gain a competitive advantage. In CPRS 'Energy-intensive', an increase in energy prices caused by a carbon tax will tend to have adverse implications for firms. Furthermore, negative impacts will be the greater the more abrupt and significant the increase in the cost of GHG emissions.

A share of the structural changes that are the source of transition risks stems from the sectors of activity included in CPRS 'Transportation'. Transport companies will have to convert their fleet to include more vehicles with low GHG emissions, an investment that could be challenging for companies less able to obtain funding, in particular from the financial sector. In the case of sectors associated with land transport, since the penetration rate of electric cars is still very limited, it may be considered that their economic viability is currently dependent on activities producing high GHG emissions. Airlines are in a similar situation. Upstream, car and aircraft manufacturing companies may incur cost increases if the production of electric vehicles or vehicles powered by less polluting fuels is costlier. To the extent that these costs are passed on to retailers and consumers, a contraction in demand may occur, impacting the economic viability of some firms.

The relevance of the sectors included in CPRS 'Buildings', in the context of transition risks, relates to possible regulatory changes to increase energy efficiency in buildings, in order to reduce their energy consumption and thereby the GHG emissions generated in the production of this energy. The increase in energy efficiency of buildings could, on the one hand, lead to a surge in production costs in the construction sectors. On the other hand, firms in these sectors will be able to benefit from an expansion of their market due to the need for energy conversion of buildings already built. This process may involve large investments for firms in the housing sectors and may lead to the economic non-viability of some of them. In the case of real estate activities, the market segment with a lower energy certification label could become less liquid, leading to a decrease in prices, with consequent losses for owners and agents. Accordingly, climate transition risks related to exposures to these sectors could play a major role in the context of financial stability, in particular in the scenario of a more abrupt transition.

3.4. Greenhouse gas emissions by sector of activity

The direct GHG emissions available in Eurostat, i.e. by sectors of activity grouped at various levels (Section 3.1), can be combined with expenditure on electricity and fuels (energy costs) reported by resident firms to the IES in order to estimate GHG emissions by sector of activity at 5-digit level. This step makes it possible, at a later stage, to group emissions at CPRS level. Estimates of GHG emissions (scope 1) by sector of activity c (included in sector n based on Eurostat's aggregation) were calculated using data from all resident NFCs with the following formula[13]:

$$\text{Es1}_c = \text{Es1}_n \times \frac{G_c}{G_n} \tag{2}$$

The estimate of GHG emissions allocated to sector c (Es1_c) thus corresponds to the product of the GHG emissions of sector n (Eurostat aggregation), Es1_n, and the ratio of (i) the average energy costs, recorded between 2015 and 2019, of all NFCs in sector c (G_c) to (ii) the average energy costs in the same period of the firms in sector n which includes sector c (G_n). Note that these estimates have underlying assumptions. First, it is assumed that all firms within the same sector have the same efficiency in terms of GHG emissions in energy use, i.e. each euro spent by a firm on electricity and fuels results in the same amount of GHG emissions. Second, emissions associated with the consumption of purchased electricity are not included in Eurostat data (which only contains scope 1 emissions). As such, direct emissions from a number of more energy-intensive sectors could be overestimated. Third, the hypothesis of causality between energy costs (independent variable) and direct GHG emissions (dependent variable) is assumed. However, for most sectors of activity included in the CPRS, the correlation between energy costs and GHG emissions is positive.

Given that the GHG emissions available in Eurostat relate to all resident NFCs, scope 1 emissions from NFCs financed by the banking system were estimated. These estimates (Es1_c^{SB}) were obtained in proportion to the energy costs of the firms financed by the banking sector in each sector c, calculated as the product of the estimates obtained by equation (2) and the ratio of (i) the average energy costs, recorded between 2015 and 2019, of the NFCs in sector c financed by the banking system (G_c^{SB}) to (ii) the average energy costs in the same period of all NFCs in sector c (G_c):

$$\text{Es1}_c^{SB} = \text{Es1}_c \times P_c = \text{Es1}_c \times \frac{G_c^{SB}}{G_c} \tag{3}$$

Estimates of GHG emissions from NFCs financed by the banking system are used to calculate their carbon intensities at sector of activity level. The carbon

13. GHG emissions calculated for the holding companies sectors were subsequently broken down into the other sectors of activity (see appendix C). Emissions from these sectors are residual.

intensity of sector c (I_c) is defined as the ratio of these emission estimates(Es1_c^{SB}) to the sales of NFCs in sector c with bank financing (V_c):

$$I_c = \frac{\text{Es1}_c^{SB}}{V_c} \tag{4}$$

The carbon intensity of one sector, when compared to that of other sectors, can be used to illustrate the exposure to transition risks of sectors of activity with high GHG emissions. However, it should be noted that only direct emissions (scope 1) are used in this analysis, i.e. those derived from the production of goods and services, but not from their consumption.

Finally, estimates of indirect emissions of the banking system associated with exposures to NFCs, i.e. scope 3 or financed emissions, were calculated. This calculation was based on the method presented in PCAF (2020) for the calculation of financed emissions originated by business loans to non-listed NFCs.[14] Using this method at sectoral level, emissions from a given sector c financed by the banking system are given by:

$$\text{Es3}_{SB,c} = \text{Es1}_c^{SB} \times \frac{\text{Exp}_c}{A_c} \tag{5}$$

In equation (5), $\text{Es3}_{SB,c}$ corresponds to the estimation of the scope 3 emissions of the banking system derived from exposure to firms in sector c; Exp_c is the total exposure of the banking system to sector c and A_c corresponds to the total assets[15] of NFCs in sector c financed by the banking system.

4. Results

The results of the application of the methodology described above are presented in the following sections. Section 4.1 presents the quantification of the exposures of the Portuguese banking system to climate-policy-relevant sectors. Section 4.2 presents estimates for GHG emissions financed by the banking system, as well as the exposure of the banking system to NFCs according to their carbon intensity. Section 4.3 points out some of the limitations of the analysis.

14. The report presents several methods for calculating scope 3 indirect GHG emissions arising from financial institutions' investment portfolio, using information at counterparty level (financial exposures and GHG emissions). Since granular information about the GHG emissions from the NFCs financed by Portuguese banks is not available, sectoral data was used.

15. For the sake of simplicity, in the denominator of the attribution factor, the assets of the firms in the sector were used instead of the sum of debt and equity.

4.1. Exposure of the Portuguese banking sector to climate-policy-relevant sectors

The exposure of the banking system to NFCs considered in this publication amounted to around €77.9 billion as at December 2019. The CPRS account for around 61% of this value. By instrument, 80% of exposure to CPRS occurs in the form of loans, the remaining being in the form of debt securities (19%) and capital (1%).

The banking system is mostly exposed to CPRS in the sectors of activity (section or level-1 CAE) of manufacturing (Section C), real estate activities (Section L), construction (Section F), transportation and storage (Section H) and accommodation and food service activities (Section I) (Figure 1 – left-hand panel). This distribution by sector of activity is reflected in the importance of CPRS 'Buildings' (24% of total exposure to NFCs) and, to a lesser extent, CPRS 'Transportation' (14%) and 'Energy-intensive' (11%) (Figure 1 – right-hand panel).

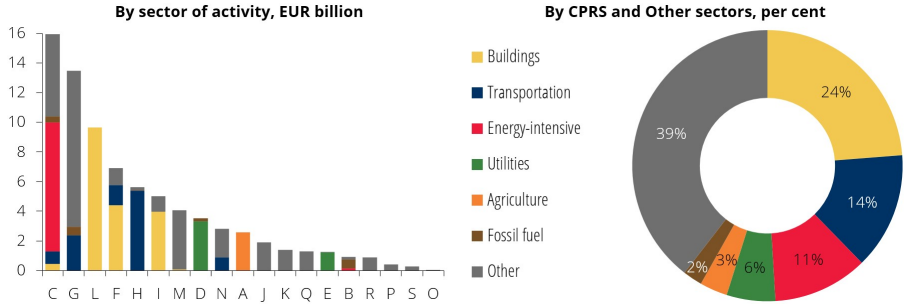

Figure 1: Exposure to NFCs, by sector of activity and by CPRS and Other sectors (2019)

Source: Banco de Portugal. | Notes: Left-hand panel: the letters on the horizontal axis correspond to the sections of CAE/NACE (level 1). The full name of the sections can be found in Figure D.2 of appendix D.

Around 58% of exposure to CPRS 'Transportation' is in sectors associated with road transport (e.g. construction of roads; manufacture and trade of motor vehicles; freight transport by road) (Figure 2). Together with the sectors related to air and water transport (directly or indirectly responsible for high GHG emissions), the exposure amounts to 69% of the total exposure to CPRS 'Transportation'.[16]

In CPRS 'Utilities' (6% of exposure to NFCs) the importance of renewables producing sectors, with 45% of the exposure to 'Utilities', is noteworthy, followed by fossil-based production, although with a significantly smaller importance (Figure

16. Some sectors included in the 'Other' sub-sector of CPRS 'Transportation' include ancillary activities related to various means of transport.

3). The distribution of the exposure of the banking system between renewable-based and fossil-based electricity production sectors reflects the country's energy mix.[17]

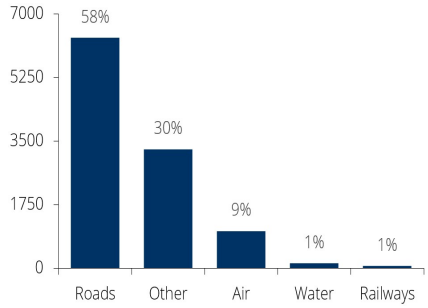

Figure 2: Exposure to CPRS 'Transportation' (2019) | EUR million, per cent

Source: Banco de Portugal.

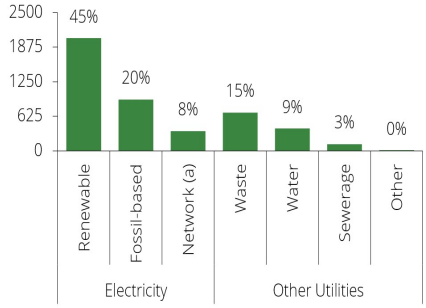

Figure 3: Exposure to CPRS 'Utilities' (2019) | EUR million, per cent

Source: Banco de Portugal. | Note: (a) Sectors related to the transmission, distribution and trade of electricity

Although combined into a single CPRS, the sectors considered in CPRS 'Energy-intensive' may exhibit differences as regards their energy intensity (Figure 4).[18] The sectors with the highest energy intensity (third and fourth quartiles) account for around 55% of the exposure to NFCs in CPRS 'Energy-intensive'. Note that the average energy intensity of the sectors in these quartiles is around four times higher than the sectors in the first and second quartiles. The fourth quartile, with 33% of exposure, has an average energy intensity eight times higher than that of the first quartile, which aggregates 19% of exposure.

Exposures to CPRS 'Agriculture' and 'Fossil-fuel' account for a relatively small share in the exposures of the banking system to NFCs, i.e. 3% and 2% of the total, respectively. In the case of CPRS 'Agriculture', 47% of the exposure relates to sectors associated with the growing of crops, followed by the sub-sector 'Other', which is mainly dominated by combined crop and animal production (Figure 5). In CPRS 'Fossil-fuel', 64% of exposure is in the sub-sector 'Oil', which includes the sectors related to the extraction of crude petroleum and the manufacture and trade of refined petroleum products (Figure 6). Next is the sub-sector 'Other', which includes the distribution and sale of fuels (excluding products derived from petroleum), with 25%.

17. For more information, see apren.pt.

18. Typically, energy intensity corresponds to the ratio of energy consumption in tonnes of oil equivalent to gross value added. Given that available information on energy consumption by sector

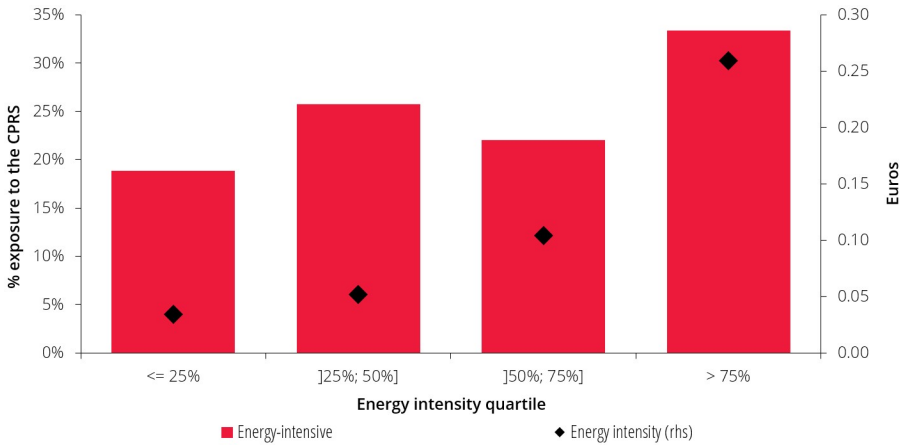

Figure 4: Exposure to CPRS 'Energy-intensive' (2019), by energy intensity quartile

Source: Banco de Portugal. | Notes: Resident NFCs. Energy intensity of NFCs financed by the banking system, measured as the ratio of electricity and fuel costs to GVA, calculated at sector of activity level. Quartiles calculated on the basis of aggregated information by sector of activity (level-5 CAE).

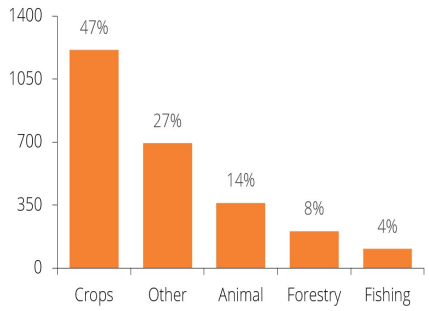

Figure 5: Exposure to CPRS 'Agriculture' (2019) | EUR million, per cent

Source: Banco de Portugal.

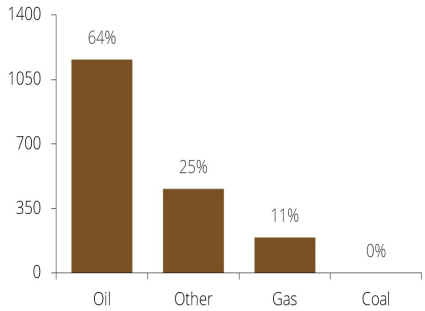

Figure 6: Exposure to CPRS 'Fossil-fuel' (2019) | EUR million, per cent

Source: Banco de Portugal.

CPRS sub-sectors can be regrouped into those that will be positively and negatively affected by the transition to a low-carbon economy, in particular by the introduction of a carbon tax. The former include sectors that produce or use

of activity is not as granular as that presented here, the electricity and fuel costs reported in the 2019 IES were used.

renewable energy or have low energy intensity. Firms in these sectors have a very small weight in the NFC portfolio of the Portuguese banking system, representing only around 3% of the total as at December 2019 (Figure 7). This figure stems mainly from the renewable energy producing sectors (Utilities – Renewable).

Negatively affected CPRS refer to sectors that produce or use fossil fuels or are more energy-intensive. These sectors have a weight of around 28% of exposures to NFCs, notably all sectors included in CPRS 'Energy-intensive' (40% of exposure to negatively affected CPRS) and CPRS 'Transportation' sectors related to road, air and water transport (34%).

In addition, for some sub-sectors the impact of transition is uncertain, either because these are sectors that are not directly affected by the introduction of a carbon tax (e.g. CPRS 'Buildings') or because they carry out ancillary activities, where impact will depend on how sectors that will directly be affected by the increase in carbon costs evolve. These sectors account for around 30% of total exposure to NFCs, most of which (24 p.p.) relating to CPRS 'Buildings'.

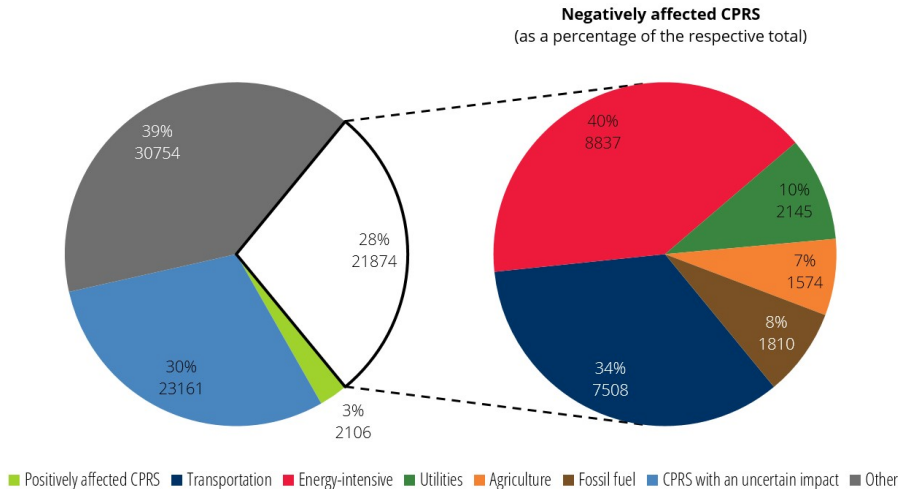

Figure 7: Exposure to NFCs by type of impact (2019) | Per cent, EUR million

Source: Banco de Portugal. | Note: The positively affected CPRS correspond to the 'Utilities' (renewable) and 'Transportation' (railways) sub-sectors; the negatively affected CPRS correspond to CPRS 'Fossil-fuel', 'Agriculture' (crops, animal and other), 'Energy-intensive', 'Transportation' (roads, air, water) and 'Utilities' (fossil-based, waste, water, and sewerage); the CPRS with an uncertain impact refer to CPRS 'Buildings' and the other CPRS sub-sectors not included in the previous categories.

4.2. Greenhouse gas emissions financed by the banking system

The calculation of GHG emissions from resident firms with bank financing, by sector of activity, using the methodology described in Section 3.4, is aimed at

computing the respective carbon intensities. Carbon intensities can be interpreted as an indicator of the level of transition risks to sectors with higher GHG emissions. Also, based on these estimates, indirect emissions (scope 3) of the banking system can be determined.

It is estimated that 79% of GHG emissions from resident NFCs are attributable to firms with bank financing. Total NFC emissions and emissions from firms financed by the banking system are similarly distributed among CPRS. The CPRS with the highest GHG emissions is 'Utilities', with around 31% of emissions from NFCs with bank financing (Figure 8). CPRS 'Energy-intensive' and 'Agriculture' account for 20% and 16% of emissions respectively. As a whole, the sectors included in the three CPRS account for approximately two-thirds of either total emissions or GHG emissions from resident NFCs financed by the banking system. However, these CPRS represent only 20% of total exposures of the banking system to NFCs (Section 4.1).

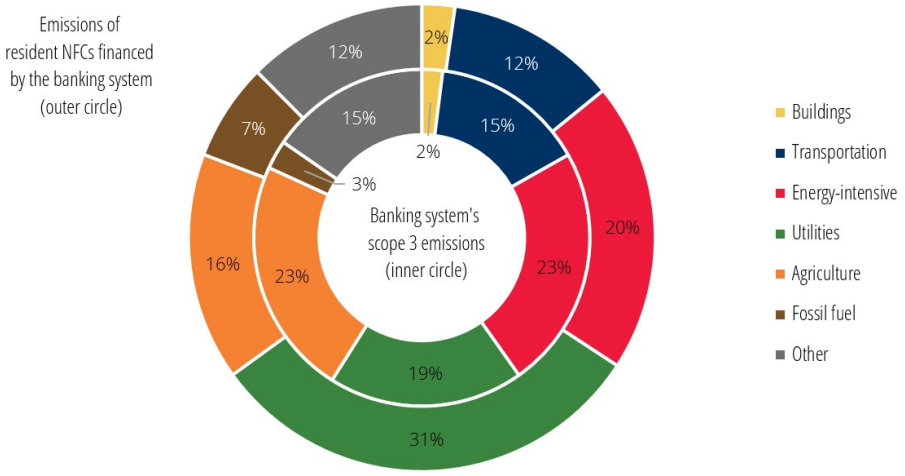

Figure 8: GHG emissions from NFCs financed by the banking system and emissions indirectly financed (scope 3) by the banking system (2019)

Sources: Eurostat and Banco de Portugal. | Note: Resident NFCs.

GHG emissions indirectly financed by the banking system (scope 3) account for around 16% of the total emissions allocated to resident NFCs with bank financing, with a different breakdown by CPRS (Figure 8). The weights of CPRS 'Utilities' and 'Fossil-fuel' are significantly lower than those in total emissions from NFCs financed by the banking system, reflecting the smaller weight of bank lending in the financing structure of firms in these sectors. The opposite is true for other CPRS, especially CPRS 'Agriculture', whose high direct GHG emissions make it responsible for 23% of estimated scope 3 indirect emissions from the banking system. However, the three most widely represented CPRS in scope 3 emissions are the same as those

observed in the distribution of total emissions, and have, as a whole, approximately the same weight (two-thirds of the emissions).

Estimates of direct GHG emissions from NFCs by CPRS can be broken down into the respective sub-sectors (Figure 9). As expected, CPRS 'Utilities' emissions are mainly generated in waste management (29%) and fossil fuel-based electricity companies (24%). These sectors account for 35% of exposure to CPRS 'Utilities' (Section 4.1). In CPRS 'Agriculture', emissions are mainly generated by the crop, animal and combined production sectors (the latter is included in the sub-sector 'Other'). In the case of CPRS 'Transportation', the sub-sector of land transport aggregates a higher volume of emissions.

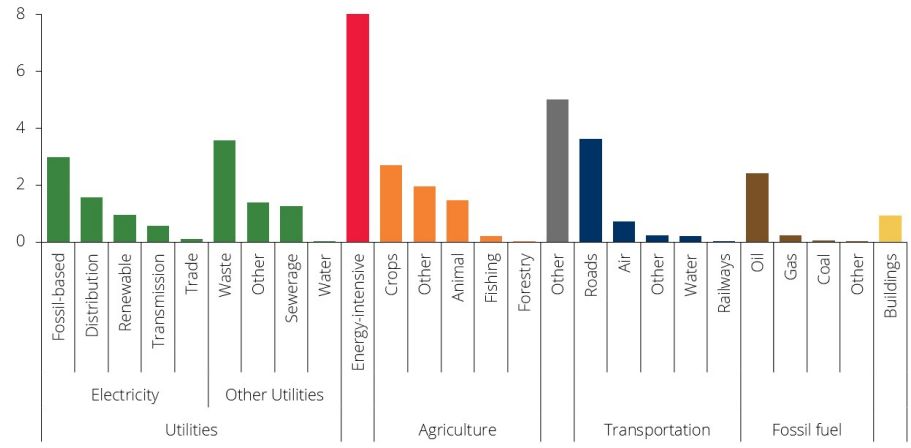

Figure 9: GHG emissions from NFCs financed by the banking system (2019), by CPRS sub-sector and 'Other' sectors | Million tonnes CO_2 equivalent

Sources: Eurostat and Banco de Portugal. | Note: Resident NFCs.

This exercise also makes it possible to calculate the carbon intensities of firms with bank financing, by sector of activity (level-5 CAE), measured by the ratios of their estimated direct GHG emissions to their sales.[19] As mentioned in Section 3.4, carbon intensity is an indicator of exposure to transition risks for sectors with high GHG emissions.

The banking system's exposures to NFCs are mostly in sectors of activity with lower carbon intensities, dominated by sectors in the CPRS 'Buildings' and 'Transportation' and the 'Other' category (Figure 10). Around 38% of exposures are concentrated in the first quartile of carbon intensity and approximately 61% in the first and second quartiles (sectors below the median carbon intensity). These sectors

19. Results do not differ significantly if, as an alternative to the GHG emissions per level-5 CAE estimated with the methodology presented here, carbon intensities are calculated for sectors of activity in the detail presented in Eurostat (appendix D).

should experience a smaller negative impact from the introduction of a carbon tax. The sectors in the third and fourth quartiles, i.e. sectors with GHG emissions per million euros in sales above the median, represent around 39% of exposure to NFCs (18% in the fourth quartile). In the fourth quartile, the predominance of sectors in CPRS 'Utilities', 'Agriculture' and 'Energy-intensive' is higher than the quartiles with lower carbon intensity.

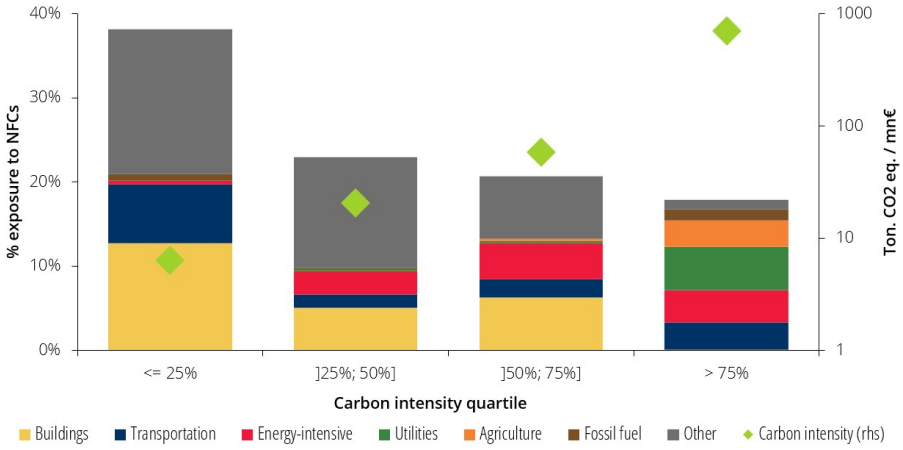

Figure 10: Exposure to resident NFCs, by CPRS and 'Other' sectors and carbon intensity quartile (2019)

Sources: Eurostat and Banco de Portugal. | Notes: Resident NFCs. Right-hand axis in logarithmic scale. Quartiles calculated on the basis of aggregated information by sector of activity (level-5 CAE).

4.3. Methodological limitations of the analysis

The analysis of exposures to climate-policy-relevant sectors is subject to some limitations. First, the NACE Rev. 2 sectors, to which the various CPRS are matched, do not constitute a taxonomy created for the purpose of classifying economic activities according to their relevance to climate policy. In fact, some CPRS sub-sectors require additional details of the activities carried out by firms. In this article, this obstacle was partly overcome by virtue of the additional detail provided by CAE Rev. 3, which also made it possible to make small adjustments to the allocation of sectors of activity among CPRS sub-sectors (appendix B). Second, the allocation of firms to each CPRS was based only on the main sector of activity, so it is possible that some firms not allocated to a CPRS carry out activities in climate-policy-relevant sectors. Third, the purpose of the financing obtained from the banking system was not considered, and the analysis therefore does not take into account, for example, any funding of investment aimed at increasing energy efficiency or decarbonising production processes. Fourth, the allocation of exposures among

CPRS also does not take into consideration differences between NFCs in the same sector of activity, such as energy efficiency, energy sources used, the origin of intermediate products or other measures to mitigate their climate impact. Thus, the development of a taxonomy of economic activities with negative climate impact would be relevant for a more precise mapping of the financial risks related to energy transition.

The estimation of GHG emissions by sector of activity according to its level-5 CAE is warranted by the attempt to match emission data (available at a highly aggregated sectoral level) with the CPRS, as well as by the interest in calculating carbon intensities with higher sectoral granularity. Underlying the methodology adopted are some strong assumptions. First, it is assumed that all firms within any given sector emit the same amount of GHGs for the same electricity and fuel costs. Second, the methodology is based on the hypothesis of causality between energy costs (independent variable) and direct GHG emissions (dependent variable). However, the energy consumption (or energy intensity) of a sector of activity results not in more direct emissions, but in a larger volume of scope 2 indirect emissions, i.e. GHG emissions generated by energy acquired and produced by third parties, which are not available at sectoral level. Thus, the methodology assigns a higher volume of direct GHG emissions to sectors of activity with higher energy consumption, and may penalise them for their unobserved scope 2 indirect emissions.

5. Conclusions

The analysis presented here is an approach to climate transition risks in terms of financial stability in Portugal. The results provide an initial quantification of the size of the Portuguese banking system's exposures to sectors of activity that may be affected by the transition to a low-carbon economy.

A substantial share of the banking system's exposures to NFCs (approximately 60%) is in climate-policy-relevant sectors. However, the varying natures of exposures to these sectors will dictate the expected impact of climate policy measures that will be adopted to meet the EU's GHG emission reduction targets. In fact, more carbon-intensive sectors (e. g. fossil-fuel-based energy production) or sectors indirectly responsible for a high volume of GHG emissions (e.g. energy-intensive industries and transport-related sectors) should be adversely affected by these measures. These sectors account for around 28% of the total exposure of the Portuguese banking sector to NFCs. Conversely, firms producing or using renewables should benefit from the transition process. Exposure of the banking system to firms in these sectors is low (3%). There are also a few sectors, representing around 30% of exposure to NFCs (of which 24 p.p. refers to real estate sectors), for which the impacts of the energy transition hinge on the ability of other sectors to adapt to this process (ancillary activities) or on measures to encourage the reduction of energy consumption (e.g. real estate sector). Thus, the exposure of the banking system to NFCs in climate-policy-relevant sectors carries different degrees of risk.

The exposure of the Portuguese banking system to the sectors that contribute most to direct GHG emissions from resident firms is relatively limited: only 20% of exposure corresponds to sectors that account for more than two-thirds of direct emissions from NFCs with bank financing ('Utilities', 'Energy-intensive' and 'Agriculture'). The share is similar for these CPRS as a whole when emissions are weighted by the ratio of bank financing to NFC assets (indirect, or scope 3, emissions from the banking system), although the weight of emissions from CPRS 'Agriculture' and 'Energy-intensive' is higher, as opposed to a smaller weight of CPRS 'Utilities'.

The exposures of the banking system to NFCs in sectors with carbon intensity below the median account for around 60% of the total. This in itself does not mean that the exposure to transition risks is low. Indeed, this analysis does not cover indirect GHG emissions from NFCs, such as those generated by the consumption of the goods and services they produce. However, the classification of sectors of activity into CPRS aims to include sectors which, while not large direct emitters, contribute with their activity to high GHG emissions upstream or downstream of the value chain.

In spite of the limitations identified in the previous sections, the results presented here make it possible to identify the sectors of activity where risks related to the transition to a low-carbon economy may be greater, as well as to quantify the exposures of the banking system to these sectors. In future analyses, taking into account exposures to households, such as credit for house purchase by energy certification label of immovable property pledged as collateral, or car loans, could increase the range of the banking system's exposures to climate transition risks.

A full assessment of climate transition risks, i.e. determining expected losses associated to these risks, requires that exposures identified above be subject to a shock under a default probability model that considers aspects such as the financial situation of firms and the existence of credit risk mitigating factors. These aspects are not one of the goals of this analysis, but are an item in the future research agenda on the importance of climate risks to financial stability.

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Appendix A: Impact of the adjustment of exposure to holding companies

Section 3.2 presents the methodology for allocating the exposure of holding companies (CAE K64201, K64202 and M70100), which account for around 13% of the exposure of the banking system to NFCs as at the end of 2019. This adjustment resulted in the allocation of half of this exposure, i.e. approximately 6.6% of total exposure to NFCs, to climate-policy-relevant sectors. The sectors of activity with the highest adjustment are included in the CPRS 'Buildings', 'Utilities', 'Fossil-fuel' and 'Transportation' (Figure A.1).

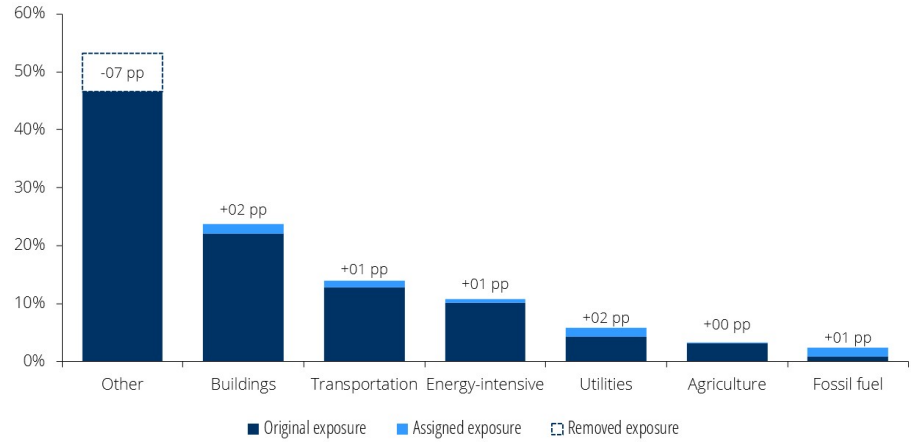

Figure A.1: Impact of the adjustment of holding companies' exposure (2019) | As a percentage and percentage points of total exposure

Sources: Eurostat and Banco de Portugal. | Note: The figures on top of the bars correspond to adjustments, in percentage points of the total exposure to NFCs.

Appendix B: Correspondence between sectors of activity and sub-sectors of CPRS

Correspondence between the sectors of activity (level-4 NACE/CAE) and the CPRS can be requested via the website of the University of Zurich. Figure B.1 below shows the CPRS and their sub-sectors, reflecting small adjustments to the original correspondence to sectors of economic activity. Overall, the adjustments in the CPRS sub-sectors reflect the level of detail provided by the fifth digit of the economic activity code, which exists in the Portuguese classification (CAE), but not in the European classification (NACE), on which the original correspondence between sectors of activity and CPRS was based. In some cases, breakdowns or aggregations of the original sub-sectors were applied.

Originally, CPRS 'Utilities' is broken down into four main sub-sectors: Electricity, Water and sewerage, Waste and Other. The sub-sector 'Electricity' is further divided into four categories: Production, Transmission, Distribution and Trade. In the case of sub-sector 'Electricity – Production', the CPRS classification assigns it a single activity code (level 4): D3511 'Production of electricity'. However, CAE breaks down this code into three sub-classes: D35111 'Production of hydroelectric energy'; D35112 'Production of thermal electricity'; and D35113 'Production of wind-generated, geothermal and solar electricity, and n.e.c. origin' (Table 1). As such, the sub-sector 'Electricity – Production' can be easily divided into 'Electricity – Renewable' and 'Electricity – Fossil-based', assigning the sectors D35111 and D35113 to the former and the sector D35112 to the latter.

CPRS 'Fossil-fuel' is broken down into sub-sectors 'Coal', 'Oil, 'Gas' and 'Other'. Sub-sector 'Other' included the activity code (level 4) G4671 'Wholesale of solid, liquid and gaseous fuels and related products'. By not specifying the type of fuel, this sector was originally assigned to the residual sub-sector 'Other'. However, in CAE, this sector is divided into the following sub-classes: G46711 'Wholesale of oil products' and G46712 'Wholesale of non-petroleum solid, liquid and gaseous fuels'. Accordingly, the first sector can be assigned to sub-sector 'Petroleum' in CPRS 'Fossil-fuel', while the second is included in sub-sector 'Other'.

The remaining adjustments refer to CPRS disaggregations that are possible with level-4 NACE, but which are not included in the original NACE-CPRS classification. These sectors present significant differences in their estimated GHG emissions volumes (Section 4.2) and were therefore allocated to different sub-sectors, as shown below.

In the original classification, CPRS 'Agriculture' contains a sub-sector that aggregates all activities other than forestry and fishing. However, NACE (and CAE) makes it possible to clearly distinguish the activities related to crop and animal production, as well as combined production activities and other activities related to the agricultural sector. Therefore, three sub-sectors were established: Crops (A011 'Non-perennial crops', A012 'Perennial crops' and A013 'Plant propagation'), Animal (A014 'Animal production') and Other (A015 'Mixed farming', A016 'Support activities to agriculture and animal production' and A017 'Hunting, trapping and related service activities').

In CPRS 'Utilities', the sub-sector 'Water supply and sewerage' was divided into two: Water (E3600 'Water collection, treatment and supply'), on the one hand, and Sewerage (E3700 'Wastewater collection, drainage and treatment', on the other.

A few, less relevant, adjustments were also made, which have no material impact on the analysis. In CPRS 'Transportation', the sub-sector 'Roads (Bicycles)', which corresponds to sector C3092 'Manufacture of bicycles and invalid carriages' was included in the sub-sector 'Other' within that CPRS, due to the residual value of the banking system's exposure to this sector. The original CPRS classification also includes a sub-sector related to space transport (the H5122 sector 'Space transport'), which was included in CPRS 'Transportation' and the sub-sector 'Air'. The original classification also includes two categories for research and development

as well as financial activities sectors. Given that these sectors are not directly exposed to climate and transition risks, they have been included in the residual category 'Other'.

CPRS	Sub-sectors	Comments	
Agriculture	Crops, Animal, Forestry, Fishing, Other	All sectors in Section A.	
Fossil-fuel	Coal, Oil, Gas, Other	Sectors related to mining and quarrying (Section B); manufacturing (Section C) and trade (Section G) of fossil fuels.	
Energy-intensive		Several sectors in mining and quarrying (Section B) and manufacturing (Section C).	
Utilities	Electricity	Fossil-based	Production of thermal electricity (D35112)
		Renewable	Production of hydroelectric energy (D35111) and Production of wind-generated, geothermal and solar electricity, and electricity of n.e.c. origin (D35113)
		Transmission, Distribution, Trade	Other sectors belonging to Section D (excluding sectors related to the manufacture, distribution and trade of gas).
	Water, Sewerage, Waste	Most sectors in Section E.	
Buildings		Several sectors in manufacturing (Section C), construction (Section F), accommodation and food service activities (Section I) and all real estate activities sectors (Section L).	
Transportation	Roads, Water, Air, Railways, Other	Sectors related to the manufacture of motor vehicles (Section C), construction of transport infrastructure (Section F), trade of motor vehicles (Section G), service activities incidental to transportation and support activities for transportation (Section H)	
Other		All other sectors	

Figure B.1: Climate-policy-relevant sectors (CPRS) and respective sub-sectors

Sources: Battiston *et al.* (2017); FINEXUS: Center for Financial Networks and Sustainability, University of Zurich.

Appendix C: Estimation of GHG emissions from holding companies

In Section 3.4, equation (2) sets out how to calculate the estimates of GHG emissions by sector of activity, including the holding companies sectors (CAE K64201, K64202 and M70100). In these cases, emissions were subsequently divided among the holding companies belonging to groups (around 90% of the assets of all holding companies) and the rest. For this adjustment, the estimated GHG emissions

were multiplied by the following proportions, resulting, respectively, in the emissions from holding companies belonging to groups and stand-alone companies:

$$S_c^s = \frac{A_c^s}{A^s},$$

$$S_s = 1 - \sum_c S_c^s,$$

$$s \in \{K64201, K64202, M70100\}.$$

The term S_c^s refers to the ratio of the assets of holding companies in sector s allocated to sector c, A_c^s, (calculated with the same allocation key as described in Section 3.2) to the total assets of holding companies in sector s (whether or not belonging to groups); and S_s is the proportion of emissions in sector s that will not be distributed across other sectors, i.e. it corresponds to the fraction of emissions attributable to stand-alone holding companies.

Emissions from each sector c (all sectors of activity, except those related to holding companies) and each sector s (holding companies), after the adjustment above, are given respectively by:

$$\begin{aligned}
&\mathsf{Es1}_c^* = \mathsf{Es1}_c + \left(\sum_s S_c^s \times \mathsf{Es1}_s\right), \\
&\mathsf{Es1}_s^* = S_s \times \mathsf{Es1}_s, \\
&\mathsf{Es1}_c^{*,SB} = \mathsf{Es1}_c^{SB} + \left(\sum_s S_c^s \times \mathsf{Es1}_s\right), \\
&\mathsf{Es1}_s^{*,SB} = S_s \times \mathsf{Es1}_c^{SB}.
\end{aligned}$$

Note that this adjustment has no material impact on the estimates presented in Section 4.2, since the emissions from NFCs in the holding companies sectors account for only 0.01% of the total.

Appendix D: Carbon intensities calculated with original emissions

Section 4.2 presents carbon intensity distributed by quartiles and the distribution of the banking system's exposure by carbon intensity quartile and CPRS. Carbon intensities were calculated by estimating GHG emissions for each sector of activity with the highest possible level of granularity (level-5 CAE). These estimates result from the application of the methodology described in Section 3.4.

In order to verify the impact of this methodology, carbon intensities were calculated for each sector of activity available in Eurostat (Figure D.2). The distribution of the banking system's exposure by carbon intensity quartiles and, within each quartile, by CPRS is similar to that shown in Chart 10 of Section 4.2

(Figure D.1). In general, the exposure of the banking system to sectors in the fourth carbon-intensity quartile is 3.5 pp lower than that observed in Section 4.2. CPRS 'Fossil-fuel', 'Utilities' and 'Energy-intensive' experience a smaller exposure in this quartile, as opposed to greater exposure in the first quartile. CPRS 'Transportation' presents a smaller exposure in the first quartile, particularly as opposed to the second.

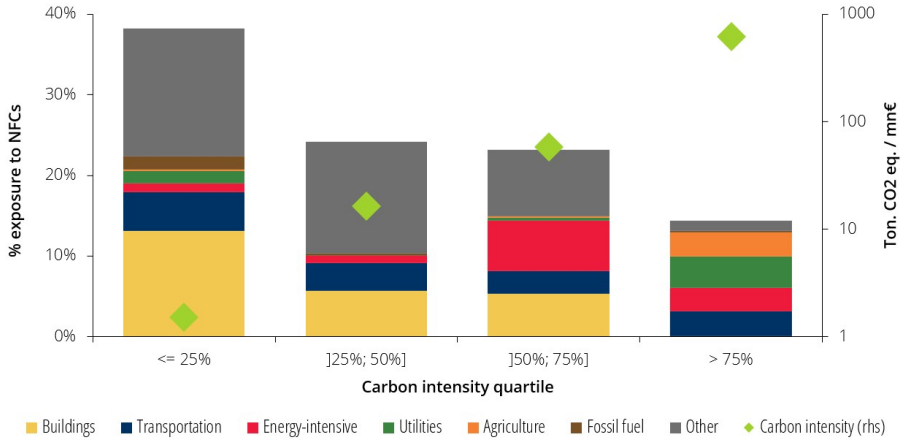

Figure D.1: Exposure to resident NFCs, by CPRS and 'Other' sectors and carbon intensity quartile (Eurostat sectors) (2019)

Sources: Eurostat and Banco de Portugal. | Notes: Resident NFCs. Right-hand axis in logarithmic scale. Quartiles calculated on the basis of aggregated information according to the sectors of activity available in Eurostat.

Section	Name	Eurostat detail[(a)]
A	Agriculture, forestry and fishing	A01, A02, A03
B	Mining and quarrying	B
C	Manufacturing	C10-C12, C13-C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31-C32, C33
D	Electricity, gas, steam and air conditioning supply	D
E	Water supply; sewerage, waste management and remediation activities	E36, E37-E39
F	Construction	F
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	G45, G46, G47
H	Transportation and storage	H49, H50, H51, H52, H53
I	Accommodation and food service activities	I
J	Information and communication	J58, J59-J60, J61, J62-J63
K	Financial and insurance activities	K64, K65, K66
L	Real estate activities	L
M	Professional, scientific and technical activities	M69-M70, M71, M72, M73, M74-M75
N	Administrative and support service activities	N77, N78, N79, N80-N82
O	Public administration and defence; compulsory social security	O
P	Education	P
Q	Human health and social work activities	Q86, Q87-Q88
R	Arts, entertainment and recreation	R90-R92, R93
S	Other service activities	S94, S95, S96
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	T
U	Activities of extraterritorial organisations and bodies	U

Figure D.2: Detail of the sectors of activity in the Air Emissions Accounts (Eurostat)

Source: Statistics Portugal. | Note: Available at ine.pt; (a) more granular detail available.

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