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POLISH HOUSEHOLD DEFAULT RISK AND PHYSICAL RISK OF CLIMATE CHANGE[1]

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Abstract

This paper aims to assess the level of credit risk (from the perspective of default risk) among Polish households associated with the physical risks of climate change. In order to determine the potential impact of the physical risk of climate change on household credit risk, we conducted CAWI interviews with 1,006 borrowers residing in different Polish voivodeships (to account for heterogeneity of credit exposures to extreme weather events). According to these respondents, wildfires and storms in Poland are the greatest source of physical risk of climate change. In the event of a wildfire or storm, approximately 13% of borrowers would not be able to repay their loans while not being insured, which potentially increases banks' credit risk and exposes banks to losses. However, we find that households underestimate the credit risk that could arise from a drought.

JEL classification: G21, G28

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Introduction

Through its impact on the non-financial sector (firms and households), climate change puts pressure on the appropriate management of financial institutions. Unfortunately, many banks in Europe have still not implemented adequate procedures for identifying and managing climate risk (Bourtenbourg et al., 2019). The losses incurred due to the increasing frequency of extreme weather events (i.e. physical risk) and the costs associated with adapting the economy to more sustainable development (i.e. transition risk) are forcing financial institutions and supervisors to implement prudential mechanisms that increase banks' resilience to climate risk. The objective of climate-related prudential regulation is to ensure that the financial institution has sufficient resources to cover financial risks stemming from environmental risk (European Banking Authority, 2022). This requires different treatment of bank products or bank customers exposed to climate risk (e.g. carbon-intensive businesses or households in a flood risk area) compared to other categories of bank products or customers (e.g. 'green' businesses).

The aim of this paper is to examine, based on Poland's households, how those households assess their own ability to repay a loan as a result of an extreme weather event. There are two main channels of the climate risk impact on credit risk - i.e. through the impact on the probability of default (PD) and the impact on the value of collateral (i.e. LGD – loss given default). In our paper we focused on the impact of climate risk on the household's PD. Assessing the impact of climate risk on households' default risk would be an important milestone in the discussion on the appropriateness of prudential treatment of risks that arise due to climate change. The banking sector in Poland consists of mainly universal banks, with their core business being taking deposits from businesses and households and granting loans on this basis. Therefore, the situation of non-financial entities has significant implications for the financial standing and security of Polish banks.

In our study, we tested the scale of credit risk using a Computer-Assisted Web Interview (CAWI) survey. We addressed the survey to 1,006 borrowers residing in different areas of Poland. In addition to demographic characteristics, we asked respondents about their current debt situation and their ability to regulate their credit obligations in the case of a specific extreme weather event.

Our study is novel from several perspectives. First, it examines the relationship between default risk among households and climate risk. There are few studies in the literature that test climate risk in the banking sector arising due to households' financial situation. Studies of credit risk in the context of climate risk focus mainly on firms (e.g. Monnin, 2018; Capasso et al., 2020; Bauer & Hann, 2010); housing loans (Zancanella et al., 2018; Ouazad and Kahn, 2019) or bank lending policies (Al-Qudah et al., 2022; Weber et al., 2008). The perspective of climate risk among households is often overlooked. Our paper complements in this regard the study by Duprey et al. (2021) who examine the relationship between household financial vulnerabilities and physical risk. Secondly, our study is not based on bank level data, but on responses collected directly from borrowers exposed to varying degrees of physical risks. Finally, the results of our study are a valuable voice in the discussion on the consideration of environmental risks in prudential regulations in the banking sector. Therefore, our study fills the following gaps: (I) the theoretical gap relating to the relationship between default risk among households and climate risk, (II) an empirical gap relating to the discussion and considerations of environmental risks in prudential regulations.

The arguments presented in the rest of this paper are arranged as follows. The next section provides a literature review on the impact of physical risk on household wealth. In Section 3, country-specific conditions regarding climate change in Poland are briefly presented. Section 4 presents details on the CAWI survey and operationalization of responses. Section 5 provides detailed information on findings with policy discussion. Finally, the main conclusions are outlined.

Literature review

Due to rising global temperatures, physical risk is increasing over time (Amano et al., 2021). Castañeda et al. (2018) show that climate change particularly affects the welfare of households living on the margins of subsistence. As poor households' wealth is more exposed and vulnerable to physical risk than richer households' wealth, climate change and high physical risks may increase inequalities. Climate change can also have a significant impact on the flow of households escaping poverty. Since poverty reduction is mostly driven by wealth accumulation, the more reduced a household's income or the higher wealth losses due to extreme weather events, the more asset accumulation is slowed (Moser, 2008).

A difference in the exposure and the vulnerability between rich and poor may demonstrate the distinction between the impact of climate change on poverty and the impact on growth: there may be a minor impact of climate change on GDP, but a large impact on poverty, and the well-being of households living in or close to poverty (Hallegette et al., 2018). This view is supported by Barbier and Hochard (2018), who refer in their analysis to the concept of the elasticity of poverty reduction with respect to growth, according to which the majority of the poverty reduction around the world

with respect to growth, according to which the majority of the poverty reduction around the world has been achieved due to aggregate economic growth, rather than to redistribution of income within countries (Dollar & Kraay, 2002; Dollar et al., 2013). Barbier and Hochard (2018), show that less-favored areas (i.e. areas with poor biophysical conditions or poor market access) have a lower elasticity of poverty reduction with respect to growth, which means that more economic growth is needed to achieve the same level of poverty reduction. Where climate change leads to a higher concentration of households in less-favored areas, or an increase of the size of less-favored areas, poverty reduction might slow, even if the aggregate rate of per capita income growth remains unchanged. Therefore, this analysis demonstrates that differences in the exposure and the vulnerability of poor households to climate change and physical risks – compared with the rest of the population – are a critical determinant of the impact of climate change and physical risk on poverty (Barbier & Hochard, 2018).

Aaheim et al. (2012) show, however, that an increase in temperature at +2°C in Europe would positively impact GDP in some sub-regions and negatively affect Southern Europe, while an increase in temperature at +4°C would have a negative impact on GDP throughout Europe, with the most significant impact in Southern Europe. Furthermore, they find that climate change impacts differentiation in wages across Europe which might result in migrations from Southern Europe to northern parts. Ciscar et al. (2011) estimate that the annual loss of household wealth in the European Union resulting from climate change would range from 0.2% to 1% if the climate of the 2080s occurred today. Furthermore, they indicate that the results vary across the European Union. Southern Europe, Ireland, Northern and Central Europe seem to be the most sensitive to climate change, while Northern Europe appears to be the only region with benefits of climate change. Evaluating macroeconomic and distributional implications for Italian households, Campagnolo and De Cian (2022) show that climate change implications are regressive i.e. wealthy households limit expenditures on gas and fuels the most, while poor households living in or close to poverty increase electricity expenditures. Furthermore, the 2022 climate risk stress test of Eurosystem balance sheet shows that climate change has a material impact on the risk profile of banks, which also impacts households (European Central Bank, 2023).

Overall, physical risks can have a direct or indirect impact on households and enterprises. They are connected with the location of household's or enterprise's wealth and the resilience of this wealth to climate change. Direct impacts relate to damage to wealth, mostly to uninsured houses and factories, during extreme weather events, as well as to the wealth's write-off in high-risk areas. For instance, Belanger and Bourdeau-Biren (2018) show that a location within a flood zone significantly lowers property values in England. As a result, changes in asset valuations might affect the value of the capital, as well as the collateral underlying mortgages and corporate/consumer loans secured by the respective wealth and might, therefore, be the main factor driving credit risk (European Central Bank, 2022). Indirect impacts might have an adverse effect on enterprises' cashflow through various channels such as reduced revenues from decreased production capacity (e.g. due to supply chain interruptions and workforce absences), lower sales (e.g. due to demand shocks and transport difficulties), increased operating costs (e.g. due to the need to source inputs from alternative more expensive supplies) and increased capital costs (e.g. due to damage to facilities) (Monnin, 2018). Bilyk et al. (2020) show that the share of creditors who fell behind with their mortgage instalments increased significantly after the 2016 wildfires in Fort McMurray (Alberta). Winsemius et al. (2018) demonstrate that poor households are often disproportionally exposed to droughts and floods, particularly in urban areas, but this pattern is far from the rule. Based on the research conducted by Krishna (2006), a higher probability of drought results in a lower appetite of poorer households to invest, which makes it even more difficult for them to escape poverty (Elbers at al., 2007). As outlined by Kousky at al. (2020), flood insurance seems to be an important factor protecting households, particularly mortgage creditors, against credit risk arising from flood events caused by hurricanes. In the case of Hurricane Harvey, in households where flood insurance was not required, and as a result very few mortgage creditors had it, property damage increased significantly, and the likelihood of loans being 180 or more days in default increased substantially during the two years following the hurricane. Gallagher and Hartley (2017) show that greater flooding results in larger reductions in total debt. More precisely, lower debt levels are caused by property owners using flood insurance to repay their mortgages rather than to rebuild their houses. Moreover, private insurer exit from the highest -risk areas in Florida has been found to be due to a combination of state-level price controls limiting premium increases, and other capital market factors that restrict the availability of reinsurance (Oh et al., 2021). Some studies highlight that climate risk is more difficult to hedge than idiosyncratic household-specific income shocks (Cotter et al., 2015). In this context, some fintech companies designed their specific approaches to help insurers to integrate climate risk data (particularly flood risk data) into their underwriting processes (Fuster et al., 2019)

Country-specific factors

extreme weather events

Like any other country in Central and Eastern Europe or around the world, Poland is exposed to an increase in the frequency of extreme weather events due to climate change. Polish territory, administratively divided into voivodeships (provinces) further split into powiats (districts) and then divided into gminas (municipalities), is mainly exposed to four types of extreme weather events, which are drought, flooding, storms and wildfires.

The average temperature in Poland between 2011 and 2020 was as high as 9.1°C, as compared with 7.5°C in the period 1961-1990. Rising temperatures combined with an insignificant change in total precipitation make Poland increasingly vulnerable to the risk of extreme droughts (Somorowska, 2016; Kubiak-Wójcicka et al., 2021).

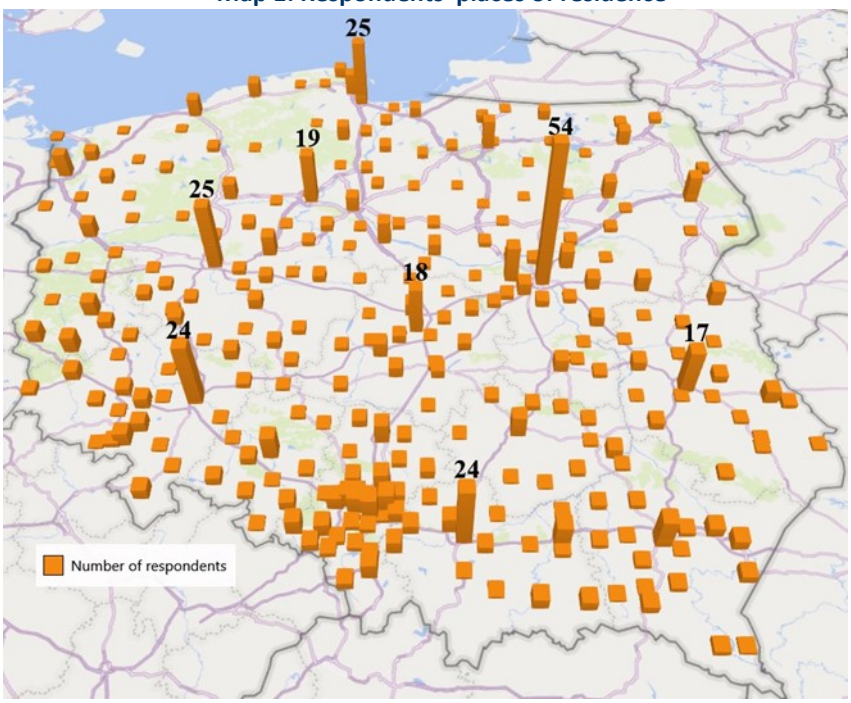
Precipitation characteristics have also changed over recent years. The trend shows a significant increase in the number of days with heavy daily precipitation exceeding 10 mm per day and an increase in rainless days (Pińskwar, 2019). With increasing temperatures combined with precipitation deficits, fire risk is increasing in Poland. In addition, Bielec-Bąkowska et al. (2021) have shown based on their measurements that Poland is increasingly experiencing conditions that favor the occurrence of intense convection leading to extreme storm events. As the average temperature continues to rise, the probability of intense precipitation will increase (Madakumbura et al., 2021). There has also been a marked extension of the storm season, the period during the year when storms are likely to occur. However, the probability of a tornado occurring in Poland has not changed over the last one hundred years.

The characteristics of floods in Poland are also changing. Although Poland used to have snowmelt-type floods during spring, nowadays, due to the lack or low level of snow cover, spring river levels are increasingly low. However, the short-lived and rapid precipitation often result in water flowing quickly over the surface into rivers and the Baltic Sea, causing numerous areas of flooding and flash floods (Pociask-Karteczka & Żychowski, 2014). An additional factor contributing to the increased intensity of flash floods is dry soil, which does not absorb rainwater quickly enough. Areas close to the Baltic Sea are also at risk of flooding. As a result of changes in the level of the Baltic Sea, the Polish coastline is receding at a rate of 1 mm to 2 mm per year (Graniczny et al., 2015)

Research methodology

Research on consumer behavior is mainly based on surveys, of which the dominant forms are selfdistributed questionnaires (Oke et al., 2021; Tikka et al., 2000), computer-assisted web interviews (CAWI, Damigos et al., 2020; Ščasný et al., 2017) or computer-assisted telephone interviewing (CATI e.g. McKercher, 2010; D'Souza et al., 2007). Our research was designed using 1,006 CAWI surveys from 11 to 19 May 2022 among randomly selected Polish borrowers, natural persons representing themselves. In estimating the necessary sample size, we took into account the adult population that repay credit in Poland (about 15 million people in 2022 or 47.4% of the adult population), a 95% confidence level, and margin of error close to 3%. In addition, our sample differentiated between places of residence to account for heterogeneity in the occurrence of extreme weather events across the country. The survey was conducted by a specialized external company. A link with the content of the survey was sent to respondents who had registered in the company's database. The company's database contains more than 135 366 respondents. The sample was randomized. The system sent surveys to specific respondents in order to obtain the assumed sample structure. The sample structure was continuously monitored in order to obtain the demographic characteristics of the respondents assumed at the beginning of the survey. The survey link ceased to be active when the assumed sample size and structure of respondents' demographic characteristics were received. Respondents were rewarded for completed surveys. In Appendix 1 we present the sample characteristics and on Map 1 places of residence of respondents.

Map 1: Respondents' places of residence



Note: The size of the bar illustrates the number of surveyed respondents from a given district. The number of completed surveys is indicated above the bars for the most numerous districts in our sample.

Source: Author's own work.

In our survey we asked respondents a number of specific questions to identify their exposure to physical risks. We have reflected the exact content of each question in Appendix 2. The questions were divided into two sections: (I) general questions and current debt situation (appendix 2), and (II) questions on physical risk (appendix 3).

For the general questions and current debt situation, we asked respondents to specify the type of loan they are repaying, the amount of the loan instalment, and their current debt situation (questions 1 to 3 in Appendix 2). Physical risk was identified by the respondent by indicating the extreme weather events their wealth is exposed to and whether they would have a problem repaying the loan if such a weather event occurred (among the events were drought, flooding, storms and wildfires). In the case of extreme weather events and debt situations, having insurance against the weather event is an important factor that may reduce probability of default. Therefore, we asked respondents whether they had this type of insurance (questions 1 to 3 in Appendix 3). In this approach to assessing physical risk, it was up to the respondent to determine the extent of the threat to their wealth from extreme weather events. However, not all respondents may have knowledge of the extreme weather events that may occur in their area of residence. Therefore, we presented a second approach to physical risk analysis. Namely, having information about the respondent's place of residence, we assigned to each respondent the type of extreme weather event to which they are exposed. In this case, we used maps made available by specialized institutions studying climate change in Poland. In Table 1, we present the assumptions that we made to identify the area at risk of an extreme weather event.

Table 1: Extreme weather event assumptions made in research

Event	Assumption regarding the area at risk of an extreme event	Research institution and source of information
Drought	Districts in Poland where a drought lasted more than five years within the last ten years (from 2007 until 2018)	Supreme Audit Office: Supreme Audit Office: Counteracting water shortages in agriculture (nik.gov.pl) (Accessed: 9.01.2023)
Flooding	Districts in Poland with high flooding risk (including all cities above 499 thousand inhabitants)	Polish Institute of Meteorology and Water Management IT System for the Protection of the Country against extraordinary dangers: Hydroportal (isok.gov.pl) (Accessed: 9.01.2023)

Event	Assumption regarding the area at risk of an extreme event	Research institution and source of information
Storms	Districts in Poland where the probability of storm occurance is higher than 8%	Polish Institute of Meteorology and Water Management IT System for the Protection of the Country against extraordinary dangers: The probability of occurrence of conditions conducive to the phenomenon of a hail storm in a year| IMGW (isok.gov.pl) (Accessed: 9.01.2023)
Wildfires	Municipalities in Poland where the number of wildfires is above the median number of wildfires in municipalities in Poland in 2021	State Fire Servcie: State Fire Service interventions: 2010-2021 reports - Headquarters of the State Fire Service (www.gov.pl) (Accessed: 9.01.2023)

Source: Author's own work.

Based on the data obtained, we assigned each respondent (and their credit) to one of several categories. Loan categories were created according to usefulness for credit risk management in financial institutions. Very similar loan categories in the context of climate risk were also used by Duprey et al. (2021). The rules for assigning specific credit to a category are shown in Table 2. In creating the categories, we considered country-specific conditions in terms of economic mechanisms and exposure to extreme weather events.

Table 2: Physical risk categories

Loan category	Definition
Currently defaulted	Percentage of respondents that currently are not able to repay debt
Not exposed	Percentage of respondents who stated that their wealth is not in danger due to any physical event
Exposed	Percentage of respondents who stated that their wealth is in danger due to a physical event, but debt repayment will be continued in the case of this event
Vulnerable, exposed and insured	Percentage of respondents who stated that their wealth is in danger due to a physical event and debt repayment will not be continued in the case of this event (they have insurance)
Vulnerable, exposed and uninsured	Percentage of respondents who stated that their wealth is in danger due to a physical event and debt repayment will not be continued in the case of this event (they have no insurance)

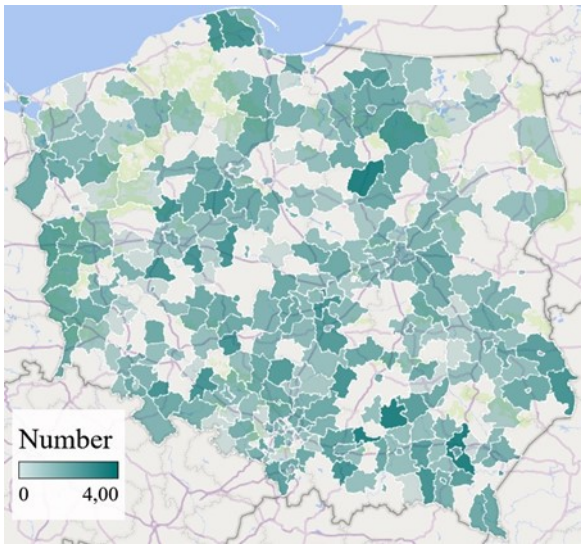
Source: Author's own work.

As indicated earlier, we present two versions of physical risk. The first is based on a respondent's identification of the risk of an extreme weather event (based on their answers in the questionnaire). In the second version, on the basis of the available maps of extreme weather events in Poland (see: Table 1), we assign to each respondent the fact that their wealth is exposed to an extreme weather event. This was done by asking each respondent to indicate their place of residence.

Results

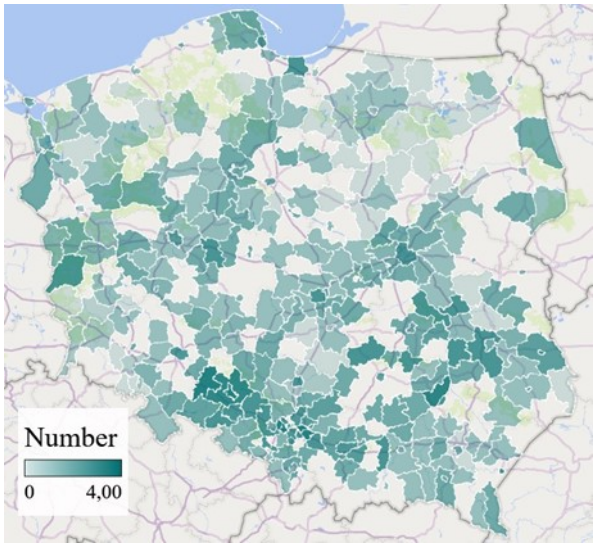
In line with the research method adopted, we present physical risk from two perspectives. The first one relates to the respondent's indication of the risk to their wealth from an extreme weather event. The second perspective is based on our own analyses and the assignment to each respondent (based on the given residential address) of exposure to extreme weather events (as assumed in Table 1). In the analysis and questions asked in the survey, we took into account the four most serious extreme weather events to which Poland is exposed, i.e. drought, flooding, storms and wildfires. At the beginning, we present the number of extreme weather events to which our respondents residing in a given area of Poland are exposed, broken down by the respondents' attribution of weather events (Map 2) and attribution of weather events according to our own analyses (Map 3).

Map 2: Average number of extreme weather events that the respondents are exposed to (respondents' answers)



Source: Author's own work.

Map 3: Average number of extreme weather events that the respondents are exposed to (own analysis based on respondents' addresses)

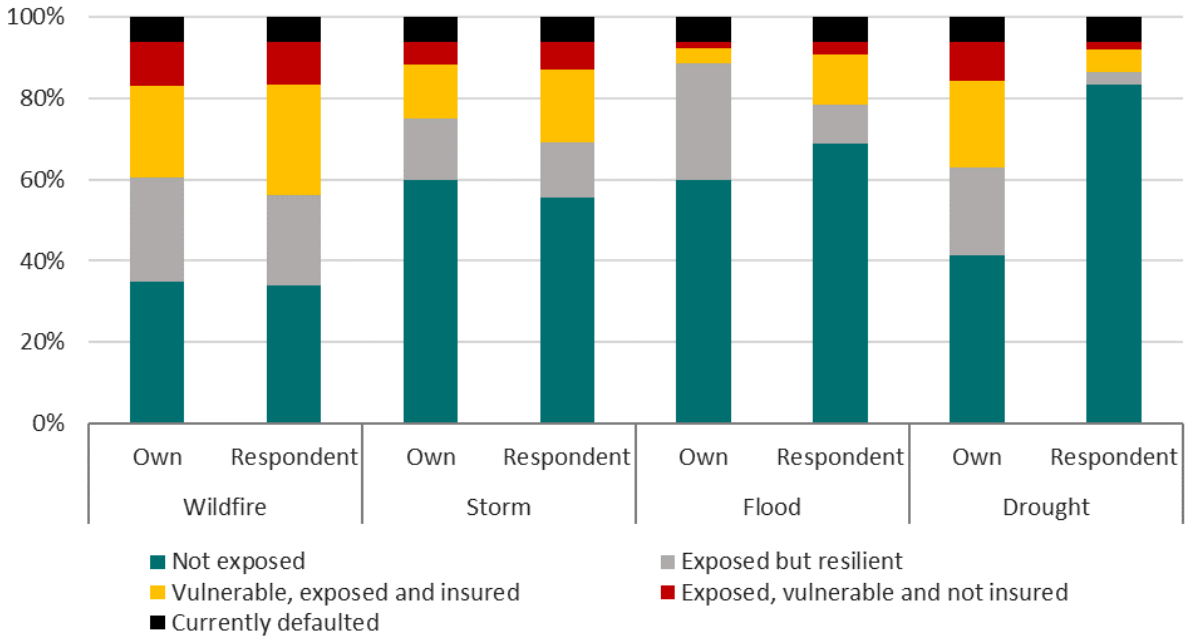


Source: Author's own work.

On average, respondents (borrowers) are exposed to 1.42 (according to respondents) and 1.9 (based on our own analyses) extreme weather events in Poland. The largest difference in the number of events to which respondents are exposed, based on their indications and our analyses, concerns the Opolskie and Śląskie voivodeships (southern and south-western parts of Poland). Respondents in these regions underestimate the risks associated with droughts and storms.

Both respondents and our own analysis indicated that wildfires are the event that most threatens households in Poland. In Chart 1, we indicated five categories to which each borrower was assigned. We have described the rules for assignment to a category in Table 2.

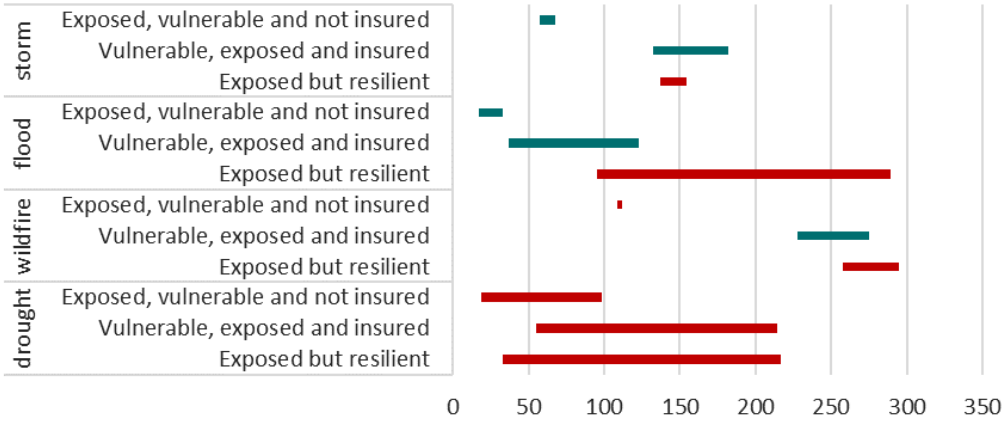
Chart 1: Impact of the physical risk on a household's default risk



Note: Respondent - extreme weather identified by respondent; Own - extreme weather identified by own analysis.
Source: Author's own work.

The group of borrowers assigned to the exposed, vulnerable and uninsured loan category represents the greatest credit risk in the banking business. This category includes borrowers who are exposed to an extreme weather event and at the same time indicate that debt repayment would not be continued in the case of this event (they have no insurance as well). For flooding, storms and wildfires, the magnitude of this category does not differ according to the approach to the analysis. Both the respondents' answers and our own analysis indicate that 10%, 7% and 3% of respondents are exposed, vulnerable and uninsured with regard to wildfires, storms and flooding respectively. Significant differences between the respondents' and our own assignment of extreme weather events were noted in the case of drought (see the category exposed, vulnerable and uninsured in the case of drought).

Chart 2: Differences in category range (i.e. number of respondents) depending on the approach to identifying extreme weather events (total sample – 1,006)



Note: The horizontal axis illustrates the number of respondents. R - extreme weather identified by respondent; O - extreme weather identified in our own analysis. The red bar indicates that the number of respondents in a given credit category is higher in our own analysis of extreme weather events compared to direct indications by respondents. The green bar indicates that the number of respondents in a given credit category is lower in our own analysis of extreme weather events compared to direct indications by respondents.
Source: Author's own work.

According to Chart 2, borrowers consider drought to be a minor threat to their wealth and thus to the repayment of their loan. Only 19 borrowers out of 1,006 interviewed would have problems repaying their loan in the event of a drought and at the same time are uninsured. According to our analyses, this percentage can be up to five times higher in the case of drought. In Chart 2 there is also a noticeable difference in the case of floods, however, this only applies to the exposed to default but resilient category. The other categories in the case of floods, more strongly related to default risk (i.e. vulnerable and uninsured) are rated by respondents more restrictively than our analysis of extreme events in the respondent's area of residence.

When analyzing the results, it is worth pointing out that there has been an increase in drought in Poland (particularly agricultural drought) and across Europe in recent years. Underestimation of this trend by households hampers health, financial, and behavioral responses. The erroneous interpretation of climate change consequences in the context of drought was also confirmed by Zappalà (2022). Households with an inadequate awareness of drought risk will not be able to manage their budgets appropriately, exposing themselves to default. This is particularly relevant in countries that still have a relatively high share of agriculture in generation of their GDP. However, a prolonged drought generates many other indirect consequences. As a result of the onset of drought, prices of agricultural products may increase significantly, which will have an impact on household spending. In addition, critically low water levels in rivers can halt the production of many businesses that use water for their production processes. According to our research, households are not aware of the impact of indirect mechanisms of drought on the economy.

In the next part of the analysis, we have presented the scale of default (for borrowers) and credit risk (for banks) depending on the type of loan. Table 3 shows the exposed, vulnerable and uninsured category of loans broken down into residential and consumer loans.

Table 3: Exposed, vulnerable and uninsured category - mortgage and consumer loans

	Mortgage loan (n = 392)		Consumer loan (n = 647)	
	Own	Respondent	Own	Respondent
Wildfires	6.89%	6.12%	12.21%	12.06%
Storms	3.57%	2.81%	5.41%	8.04%
Flooding	1.53%	3.06%	1.24%	3.25%
Drought	4.59%	1.53%	11.59%	1.70%

Note: Respondent - extreme weather identified by respondent; Own - extreme weather identified by own analysis. Consumer credit includes instalment loans, cash loans, car loans, overdrafts and credit card.

Source: Authors' assessment.

According to Table 3, the loan type that is more likely to be subject to credit risk as a result of an extreme weather event is a consumer loan. In the event of a wildfire, more than 12% of borrowers would have a problem repaying their consumer loan. Credit risk appears to be halved for mortgage loans. This conclusion is the result of differences in the restrictiveness of granting these two types of loans. Obtaining a mortgage in Poland is subject to a number of requirements (e.g. the need to make an initial payment or have an adequate level of income in relation to the monthly loan instalment), which limits the credit risk of this type of loan. Again, also in this case we confirm that households underestimate drought as a cause of default on their loans. Only 1.7% of borrowers indicate that they are exposed, vulnerable and uninsured in the event of a drought. However, our assessment of the drought risk attributed to each respondent based on their reported address indicates that the percentage of consumer loans at risk of repayment could increase to 11.59%.

Credit risk arising from physical risk seems to be manageable at this stage. The risk of not repaying the loan and at the same time not having insurance against an extreme weather event is declared by a maximum of 10% of respondents (for wildfires). This can be considered a significant risk for the bank if all borrowers experience an extreme weather event in a short period of time. However, such a situation is unlikely and the materialization of physical risk will be spread over time. Nevertheless, the level of physical risk should be monitored and reported by banks on an ongoing basis due to the increasing frequency of extreme weather events. In the case of physical risk, Caloia and Jansen (2021) came to similar conclusions. Using a stress testing framework, they show that Dutch banks are capitalized sufficiently to withstand floods in flood-prone areas. Banks can manage physical risk among other things by including climate change factors in their credit assessment or ICAAP (Internal Capital Adequacy Assessment Process) stress testing framework. For example, when granting a housing loan, banks can take into account

the location of the property (Sastry, 2021). Finally, we can conclude that physical risk for households in Poland, due to its long-term and staggered nature, can be successfully addressed in a bank's lending policy, risk appetite framework and business strategy.

Conclusions

Over time, climate risk will increasingly affect the conduct of banking business. This includes the impact of climate change on all banking risks - i.e. credit, market, operational and other risks (e.g. liquidity risk) (European Central Bank, 2020). The strongest impact of climate risk on banks is likely to be observed in the case of credit risk. Most banks' climate risk management processes are still at an early stage of development. For this reason, it is important to investigate how credit risk in the banking sector may increase as a result of climate risks.

The goal of this article is to examine how households assess their own ability to repay a loan as a result of an extreme weather event. To verify our goal, a CAWI survey was conducted among 1,006 borrowers residing in different districts of Poland in May 2022. Respondents were asked to answer questions about their debt situation, the exposure of their wealth to extreme weather events, and an assessment of whether they would be able to settle their loan obligation in certain cases. After collecting the responses, we assigned each loan held by the respondent to one of four categories - currently not repaid, not exposed to risk, exposed to risk, and exposed and vulnerable (similar to Duprey et al., 2021). In addition, based on address of residence provided by the respondent, we conducted our own analyses of the respondent exposure to extreme weather events.

The results highlight the importance of physical risk for credit risk. According to the respondents, the biggest risk to loan repayment is the wildfire risk. Approximately 10% of respondents would not be able to pay their loan after a wildfire without having adequate insurance. Comparing respondents' individual assessments to our analysis of exposure to extreme weather events, it appears that respondents underestimate the risk of drought. More than 80% of respondents consider that they are not exposed to drought, while our analysis shows that only 40% will not be exposed to this event, and almost 10% of them would have problems settling their loan obligations in the event of a significant drought. However, given the long-term horizon of physical risk materialization, banks can manage their credit exposures (e.g. through appropriate lending policies).

When interpreting the results of the study, it is important to remember the limitations of the paper. Further analysis, including the elasticity of the probability of default with respect to the intensity of the climate event, is needed to assess how borrowers' perceptions and specific situations affect the results. The second part of climate risk, i.e. transition risk, is worth considering in future research. Given the economic conditions in Poland (i.e. a high-carbon economy), the exposures of non-financial corporations and households to transition risk are likely to be significant and, together with physical risk exposures, may pose a systemic threat.

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Appendix

Appendix 1: Sample characteristics

Variable	Number of borrowers (n = 1,006)
Gender	
Male	442
Female	564
Age	
18-24	53
25-34	334
35-50	390
Age > 51	229
Education	
Primary	115
Secondary	437
Higher	454
Place of residence	
Village	191
Town up to 100,000 citizens	373
Town from 100,000 - 500,000 citizens	273
Town with more than 500,000 citizens	169

Source: Author's own work.

Appendix 2: Survey questions - general questions and current debt situation

No.	Question	Type of question	Possible answers
1.	What type of loan are you currently repaying?	Multiple choice	Mortgage
			Consumer (i.e. instalment, cash, car, overdraft, credit card)
			Other
2.	Are you currently having problems repaying your loan?	Single choice	Yes
			No
3.	What is the level of the instalment of the loan you currently repay?	Open question	PLN.....

Source: Author's own work.

Appendix 3: Survey questions - physical risk questions

No.	Question	Type of question	Possible answers
1.	Which extreme weather event among the following is your wealth exposed to?	Multiple choice	Drought
			Storms
			Wildfires
			Flooding
2.	Would you find it difficult to meet your loan obligations in the event of an extreme weather event (e.g. a major flood or severe storm) that would substantially damage your flat/house/car?	Single choice	Yes
			No
3.	Do you have property insurance (e.g. home) against an extreme weather event (e.g. flooding, wildfires)?	Single choice	Yes
			No

Source: Author's own work.