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Climate risks assessment of Ireland's economy and the policy implications for the Republic of Korea

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ABSTRACT

This paper compares Ireland's physical and transition climate risk costs by estimating potential losses to properties through flood disaster damages in a scenario in which global greenhouse gas emissions continue to rise (RCP 8.5 scenario), as well as potential near-term financial losses to greenhouse gas emission intensive sectors in a disorderly short-term green transition scenario. The potential costs of physical climate risk in Ireland are calculated based on future flood risk estimates by region data obtained from the JBA Risk Management flood model, which estimates future flood risk to properties via geocoding in a RCP 8.5 scenario by region, combined with mortgage and property value data from banks operating in the Irish market. Estimates of Ireland's transition risk costs are made with data from the European Central Bank's 2022 climate risk stress test and loans based on sector data from bank financial statements. This study finds that Ireland faces significant physical and transition risks related to climate change. The near-term economic losses from a rapid green transition are estimated to be smaller than losses from climate change-induced physical risk related to increased flooding, thus providing support for the necessity of an orderly near-term green transition to mitigate the long-term threat of physical impacts from climate change. This study concludes by discussing policy implications for the Republic of Korea as the country shares various similarities with Ireland and also faces significant physical and transition risk costs.

Key words: Transition risks, Financial stability, Physical risks, Flood disasters, Ireland

1. Introduction

The European Union (EU) has pledged to achieve carbon neutrality by 2050 and achieve at least a 55% reduction in greenhouse gas (GHG) emissions by 2030 relative to 1990 levels. The Republic of Ireland, hereafter referred to as Ireland, has pledged to reduce its GHG emissions by 51% by 2030 relative to 2018 levels (Government of Ireland, 2023). As an EU member state, Ireland's GHG emission reduction targets are established under EU Effort Sharing Regulation and are legally binding (European Commission, 2023), and Ireland could have to pay multibillion fines if the emission reduction targets are not met (Irish Times, 2019). However, Ireland's Environment Protection Agency (EPA) predicts that on its current policy trajectory Ireland will reach 29% reduction of GHG emissions by 2030 compared to its 2018 levels, well below the government stated 51% reduction target (EPA, 2023).

As shown in (Fig. 1), Ireland's agricultural sector and transport sector together emit 55.7% of Ireland's total GHG emissions. Ireland's agriculture emissions are hugely disproportionate to its overall economic importance, with the agriculture sector contributing only around 1.02% to the GDP of Ireland in 2021 (Central Statistics Office, 2023). In terms of emission reductions

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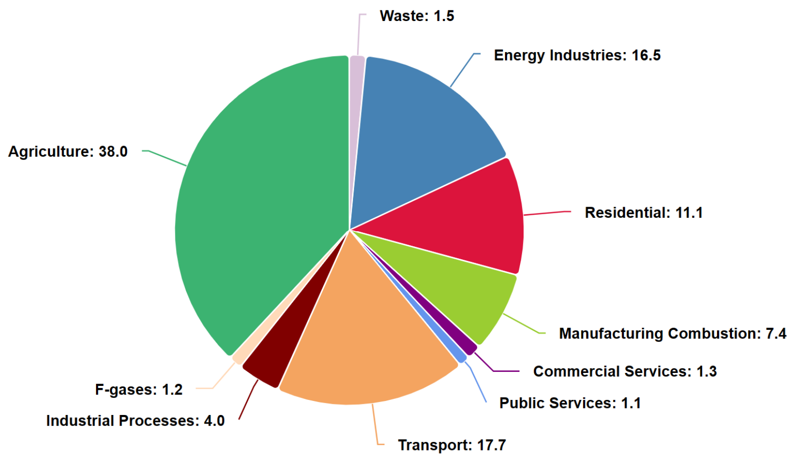

Fig. 1. Ireland GHG emission by sector, 2021

Source: Ireland EPA

by sector, only Ireland's energy sector is achieving significant progress with 36.4% of electricity being from renewable energy sources in 2021 (SEAI, 2022).

Ireland's GHG emissions per capita were the second highest in the EU in 2021 at 12.34 metric tons of CO2 equivalent (MTCO2e), behind Luxembourg at 14.67 MTCO2e (EEA, 2022). In 2022, Ireland's GDP per capita was sixth in the world at $104,038 current USD (World Bank, 2023), therefore has much more economic capacity to greatly reduce its GHG emissions compared to most other countries, particularly developing countries.

Ireland is vulnerable to climate change through both physical and transition risks. Physical risks are direct costs of climate change through the increased frequency of extreme weather events, such as heatwaves and storms, and the long-term changes in countries' climates, such as average higher temperatures and alternations of rain patterns. Transition risks are the economic costs of transitioning to a carbon neutral economy, which may occur through various channels such rising carbon prices and other GHG mitigation polices, changes in investor and societal preferences, and the continuing decrease in the levelized cost of electricity (LCOE) from renewable energy and other technological innovations (Bolton et al., 2020). The physical impacts of climate change, particularly flooding, have the potential to inflict immense damage to housing, commercial property and critical infrastructure in Ireland, resulting in major economic costs and threats to human health (Scott et al., 2022). Policies to reduce GHG emissions incur major economic costs (Kim, Moon, et al., 2023) and Ireland also faces major transition risks with GHG mitigation policies and technology potentially inducing major asset value declines (Central Bank of Ireland, 2022). Understanding, quantifying, and comparing both physical and transition risks is vital for long-term stability of Ireland's financial system and economy.

There are significant knowledge gaps regarding the potential costs that the physical and transition risks of climate change pose to Ireland's financial system and wider economy. Conducting comparisons between physical risk and transition risk costs is extremely difficult due to the differing time horizons of the risks and their associated damages. Despite this difficult it is necessary and urgent to develop methodologies to compare these risks to empower policy makers and stakeholders to make informed decision about potential costs and benefits of alternative policy pathways. This issue is currently one of the major challenges faced by climate change researchers. Methodologies for achieving this are still under development, with integrated assessment models (IAMs) being one of the most common means of attempting to such complex, long-term, interdisciplinary analysis (Hickmann et al., 2022). Transition risk is a far more near-term risk, thus it the methodologies for assessing it reflect this. Common methods include the application of dynamic stochastic general equilibrium (DSGE) models Bartocci et al., (2022), with economic damages calculations ranging from a few years (Carlin et al., 2022) to 2030 (Coenen et al., 2023). Methods of quantifying and comparing physical climate risk and transition risks are still in the early stages, and this research aims to contribute to the development of such methodologies. This research seeks to contribute to addressing the knowledge gap regarding the relative costs of physical and transition risks in Ireland by assessing Ireland's climate risks by estimating potential losses to properties through flood disaster damages in a RCP 8.5 scenario and potential near-term financial losses to GHG emission intensive sectors in a disorderly short-term green transition scenario.

The representative concentration pathways (RCPs) are specific emission scenarios which include data on land use and land cover developed from peer-reviewed literature (Moss et al., 2010). The RCP8.5 scenario is a scenario in which emissions continue to rise rapidly and was developed through the MESSAGE IAM (Rao and Riahi, 2006; Riahi et al., 2007). The RCP8.5 is often compared with the RCP2.6 scenario which entails global warming likely being kept below 2°C above pre-industrial temperatures, and the two medium stabilisation pathways of the RCP 4.5 and the RCP 6.0 scenarios which are simulated through the GCAM and AIM IAMs (Fujino et al., 2016; Thomson et al., 2011).

The paper begins by providing background regarding the nature of Ireland's climate risks, proceeds to outline the data and methodology utilized and their subsequent findings, and concludes by discussing the policy implications of the findings for the Republic of Korea, the importance of a long-term perspective when considering the costs and benefits of climate action, and concludes by discussing the limitations of the study.

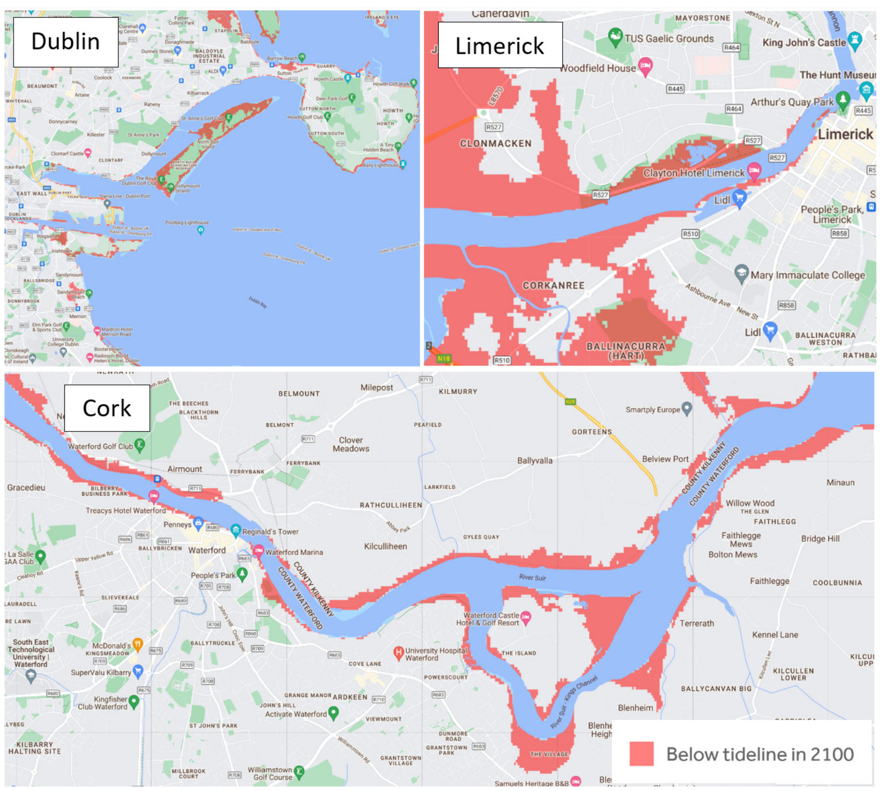

Fig. 2. Area in Ireland's three cities projected to be below tideline in 2100 in RCP 8.5 scenario

Source: Climate Central (2023)

2. Ireland's climate risks

If global GHG emissions continue to rise and the aims of the Paris Agreement of keeping global warming under 2° are not met, Ireland would be severely impacted by the physical impacts of climate change (Nolan and Flanagan, 2020). Climate change would cause higher market volatility (Noh and Park, 2023) and global warming induced changes in in streamflow patterns would reduce hydropower electricity generation capacity (Dallison and Patil, 2023). Agricultural productivity would be detrimentally impacted (White et al., 2021), and Ireland's biodiversity is also undermined as fauna struggle to adjust to the rapidly changing climate (Furness and Robinson, 2019). As Ireland has historically not faced regular heat waves, its indoor cooling infrastructure is extremely limited meaning increased frequency of periods of high temperatures pose particular danger to vulnerable groups (Paterson and Godsmark, 2020).

One of most significant dangers facing Ireland if climate change remains unmitigated and worsens is flooding disasters (Basu et al., 2022). Various features of Ireland's topography such as its large coastlines relative to total landmass ratio and urbanization in flood risk regions increase Ireland's exposure to flooding and the country is highly vulnerable to increased flooding if global temperature continue to rise as due to sea levels rising and the greater frequency of extreme storm events (Paranunzio et al., 2022). Areas susceptible to flooding in Ireland would greatly rise under a RCP 8.5 scenario, posing major challenges to water management and water quality (Murphy et al., 2023; O'Loughlin and Mozafari, 2023). Critical transport, information and Communications Technology (ICT), and energy infrastructure would also face major damages from greater flooding (Hawchar et al., 2020). (Fig 2.) shows how rises in sea levels in a RCP 8.5 scenario would affect Ireland's three largest cities; Dublin, Cork, and Limerick.

To achieve 2050 carbon neutrality, Ireland would need to enact green transition consistent investment decisions over the next 5 years yet such as a development pathway would entail near-term GDP losses relative to business as usual pathway (Glynn et al., 2019). Rising carbon prices would put pressure on both Irish business and households (Kelly et al., 2020). Ireland is also susceptible to transition risks the country a small open economy it is vulnerable to sudden capital flow shocks with analysis from Ireland's Central Bank finding concluding that transition risks from abroad will likely be particularly prominent in the country (Central Bank of Ireland, 2022). Ireland has experienced devastating impacts of banking and financial sector crises. The banking stabilisation measures in response to the 2007/2008 financial crisis incurring a net cost €40-42.4 billion to the Irish government (C&AG, 2018). Ireland's financial sector is growing particularly post-Brexit as many British financial companies have moved their operations to Ireland in order to continue to operate within the EU regulatory framework. Many of Europe's largest fund management companies are located in Ireland, with total assets overseen by management companies in Ireland reaching €1.3 trillion in 2018 (Financial Times, 2019). These management companies serve as operating planforms for Undertakings for the Collective Investment in Transferable Securities (UCITS) and Alternative Investment Funds (AIFs). UCITS are predominantly designed for retail investors and perceived as safe due to the strict regulations regarding what type of assets can be included in an UCITS, and AIFs are any fund other than a UCITS, and can include risker assets such as property and derivatives (European Securities and Markets Authority, 2023). Ireland may be exposed to transition risk through these management companies as sudden changes in Ireland's regulatory structure could prompt their relocation.

The Central Bank of Ireland releases its own climate-related financial disclosures yearly which includes a weighted average carbon intensity (WACI) unit to quantify portfolios exposure to carbon-intensive issuers, which is expressed in tCO2e per million Euro revenue or GDP, as well a total carbon emissions (TCE) metric which measures the total emissions in tCO2e associated with a portfolio (Central Bank of Ireland, 2023). However, are still significant knowledge gaps regarding

Ireland's potential physical and transition risks, as such measures do not focus on bank level loan portfolios and thus are unable to be utilized to create climate risk stress tests.

3. Methodology

3.1. Physical risk assessment

To create an estimate of Ireland's physical risk from climate change, this study focuses on future flood risk to properties. Data of property mortgages were accessed and compiled from reports and balance sheet statements from each of the five banks which provide mortgages in the Irish market: Bank of Ireland, Allied Irish Banks (AIB) Group, permanent TSB, KBC Bank Ireland, and Ulster Bank, as well as the three non-bank lenders of ICS/Dilosk, Finance Ireland and Avant Money. Ireland mortgage market is dominated by its two largest banks, the Bank of Ireland and the AIB Group, which hold 51% and 40% of total mortgages outstanding. Using share of mortgage lending volume by county data from the Banking & Payments Federation Ireland (BPFI), the total volume of mortgages outstanding in each county was calculated (BPFI, 2023). As previously stated, this study only includes the Republic of Ireland, thus the six counties of Northern Ireland are not included. As shown in Fig. 3, mortgage lending value is primary focused in the capital, Dublin, and surrounding counties.

The estimates of future flood risk according to regions is from JBA Risk Management, which estimated future flood risk to properties locations via geocoding in a flood model based on RCP 8.5 Pathway in which GHG emissions continue to increase (JBA Risk Management, 2023). Flood risk from this model has been utilized in the Bank of Ireland's assessment of their mortgage portfolio risk in the United Kingdom and the Republic of Ireland (Bank of Ireland, 2022). County level mortgages were compiled according to the regions of the JBA flood model and using the percentage of regional lending at risk data, total potential losses through flooding in the

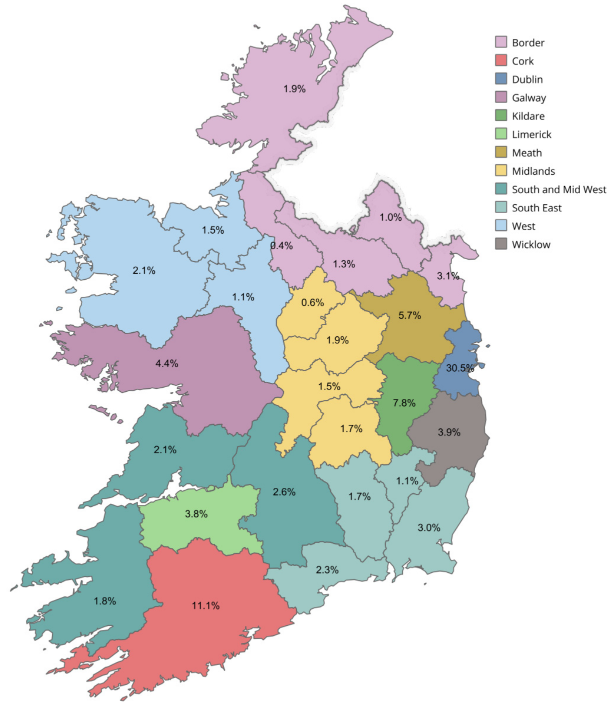

Fig. 3. Share of Ireland mortgage lending value by county, 2022

Source: BPFI (2023)

RCP 8.5 scenario could be estimated according to the following equation:

$$Banks\ total\ mortage\ volume\ at\ risk = \sum_{i=1}^{k} M_i R_i \qquad (1)$$

where i is the region, k is the number of regions, M is the volume of outstanding mortgages, and is R the percentage of lending at risk from JBA flood model.

Next, this study seeks to create an estimate of potential flood damage to the national housing stock. The rationale behind the study also including 'Property value at risk' from flooding is that from a long-term total society welfare perspective relevant physical risk costs are not just limited to private sector bank loan losses but would also include national level costs including property losses by individual households. In order to do this, total housing stock by county data from the Ireland's 2022 Census (Central Statistics Office, 2022), with is multiplied by the average house price data (Real Estate Alliance, 2023), to estimate the total property value by each county. To address the fact that vacant properties usually remain unsold in the housing market and may be worth substantially less than occupied properties, vacant properties are excluded by deducing the percentage of vacant properties from the county level housing stock prior to multiplication. The county level total property values are then merged into the regions of the JBA flood risk model and using the regional lending at risk parameter the total potential property losses in the RCP 8.5 scenario are calculated.

$$Region\ total\ property\ value = \sum_{c=1}^{j} H_c O_c P_c \quad (2)$$

where c is the county, j is the number of counties in the region, H is the housing stock, O is the percentage of properties occupied, and P is the average house price.

$$National\ property\ value\ at\ risk = \sum_{i=1}^{k} V_i N_i \quad (3)$$

where i is the region, k is the number of regions, V is the total property value, and N is the percentage of lending at risk parameter based on JBA flood risk model.

3.2. Transition risk assessment

To estimate Ireland's transition risk potential loan losses through defaults of banks outstanding loans for each sector in disorderly transition scenario are calculated. Only the Bank of Ireland and AIB Group are analysed as the total holdings in climate risk vulnerable sectors are negligible in the other six financial institutions. Each sector faces a different degree of transition risk; thus, the probability of default differs by sector. Emission intensities are particularly high from the agricultural, energy, transport, and manufacturing sectors (KBC, 2022), and these are the four highest risk sectors AIB recognises in its own analysis (AIB Group plc, 2022). Probability of default by sector estimates are accessed from the European Central Bank's 2022 Climate Risk Stress Test (ECB, 2022) and are applied to the current loan holdings by sector of Bank of Ireland and the AIB Group. [Fig. 4] shows the sectoral impact in terms of cumulative loan losses as a share of total sector loans in basis point units in the ECB's short-term disorderly scenario compared to the baseline scenario from 2022 to 2024.

The loans losses as a percentage of total loans by sector are applied as parameters to the assets by sector of the Bank of Ireland and the AIB Group to assess Irish banks near-term losses from transition risk in the following formula:

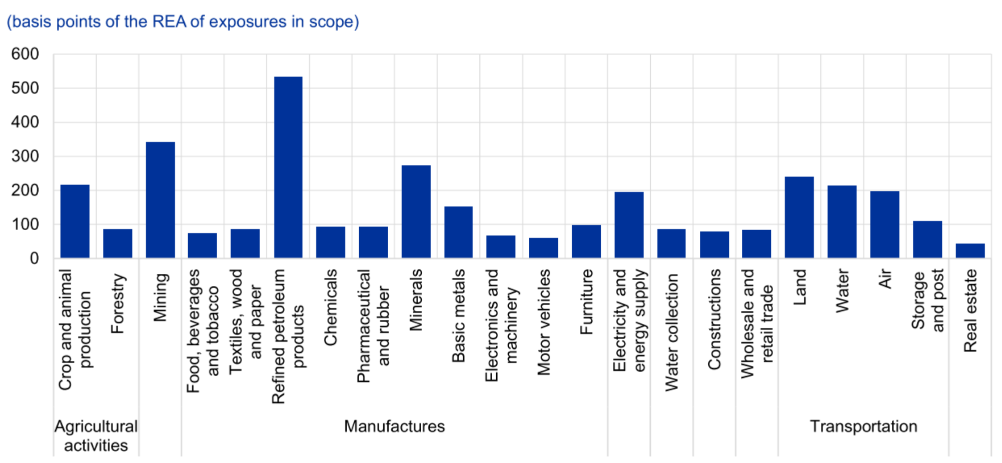

Fig. 4. Cumulative loan losses in the short-term disorderly vs baseline scenario

Source: ECB (2022)

Table 1. Bank's sector loans as percentage of total outstanding loans

Sector	Bank of Ireland, sector % of total outstanding loans	AIB group, sector % of total outstanding loans
Mining	0.1%	-
Agriculture	2.4%	2.8%
Energy	0.6%	4.6%
Transport	1.1%	4.2%
Manufacturing	6.6%	4.7%
Motor lending	3.5%	-
Total	14.3%	16.3%

$$Loan\ loss\ value\ in\ rapid\ green\ transition = \sum_{s=1}^{t} A_s L_s \tag{4}$$

where s is the sector, t is the number of transition risk exposed sectors, A is the total assets of each sector held by the bank, and L is the cumulative percentage asset value at risk parameter from the ECB 2022 stress test.

Table 1 shows loan by sector holdings of the Bank of Ireland and AIB group as percentages of their total loan holdings. Climate vulnerable sectors account for about 15% of total loans outstanding for each of the two banks.

Cumulative loan losses percentage from the ECB climate stress test (ECB, 2022) are applied to each sector as parameters. For the manufacturing sector it is necessary to further delineate between different manufacturing sub sectors as their GHG emissive intensities greatly differ. As the financial statements of the banks do not provide such detailed information, the loan volume by manufacturing sub-sectors is calculated from the assumption that the banks' loans volumes to each sub-sector is proportionally to the sub-sector size as percentage of the total manufacturing sector. This data was accessed from Ireland's Central Statistics Office (CSO), net selling value by sub-sector 2021 (CSO, 2023). As the mining sector is already included as a separate sector in the banks' financial statements, the mining sector is removed from the manufacturing sub-sector calculations to avoid double counting.

4. Results

In a RCP 8.5 scenario, Ireland faces major physical risk from flooding disasters due to climate change. About 1.6% of total mortgage lending would be at risk, resulting in substantial asset write offs on the financial institutions balance sheets. Table 2 shows cumulative loan losses of the Bank of Ireland and the AIB group due to flood losses until 2100 in a RCP 8.5 scenario. As shown in Table 2, the capital region Dublin consists of nearly half of total lending value at risk as mortgage lending is most concentrated in this region and the area faces large scale flooding due to unmitigated climate change.

Beyond the scope financial sector, the larger impacts of flooding disasters on Ireland's property stock would likely be substantial. Table 3 shows an estimation of national property value losses until 2100 in a RCP 8.5 scenario. The total estimated losses reach over €10 billion in a RCP 8.5 scenario, with the majority of losses being focused in the Dublin area due to the high average value of properties in the region, the housing stock density, and the regions high flood risk.

Under the assumption that Ireland's sectors would follow the same cumulative loan loss portions as the EU wide sector, under short-term disorderly transition scenario, Ireland's banks would face €301.7 million of loan values losses in the years following a disorderly green transition. (Fig. 5) shows near-term bank loan losses by sector in disorderly transition. As shown in (Fig. 5), losses from the transport, agriculture, manufacturing, and energy sectors would be largest.

Table 2. Loan losses due to flooding by region in a RCP 8.5 scenario

Region	Lending at risk value from flooding by region, million Euro	Region's lending value at risk from flooding as % of national total
Dublin	€550.6m	45.9%
South West (Cork, Kerry)	€174.6m	14.5%
Mid East (Kildare, Louth, Meath, Wicklow)	€154.2m	12.8%
Mid West (Clare, Limerick, Tipperary)	€134.3m	11.2%
South East (Carlow, Kilkenny, Waterford, Wexford)	€115.1m	9.6%
Border (Leitrim, Sligo, Cavan, Donegal, Monaghan)	€50.5m	4.2%
West (Galway, Mayo, Roscommon)	€17.1m	1.4%
Midlands (Laois, Longford, Offaly, Westmeath)	€4.3m	0.4%
Total	€1,200.6m	100%

Table 3. National property value at risk due to flooding by region in a RCP 8.5 scenario

Region	Lending at risk value from flooding by region, million Euro	Region's lending value at risk from flooding as % of national total
Dublin	€5,603.6m	55.6%
South West (Cork, Kerry)	€1,462.9m	14.5%
Mid East (Kildare, Louth, Meath, Wicklow)	€935.6m	9.3%
Mid West (Clare, Limerick, Tipperary)	€832.8m	8.3%
South East (Carlow, Kilkenny, Waterford, Wexford)	€763.2m	7.6%
Border (Leitrim, Sligo, Cavan, Donegal, Monaghan)	€317.5m	3.2%
West (Galway, Mayo, Roscommon)	€131.9m	1.3%
Midlands (Laois, Longford, Offaly, Westmeath)	€24.8m	0.2%
Total	€10,072.3m	100%

The pharmaceutical sector plays an important role in Ireland's economy, with a sectoral €58.1 billion net selling value in 2021. As shown in Table 4, due to size it would also face the largest amount of loan losses in short-term disorderly transition scenario accounting for 45.3% of total manufacturing sectors losses. The 'Food products' and 'Chemicals & Chemical Products' sectors would also consist of significant portions of total manufacturing sector losses at 16.5% and 11.7% respectively.

Comparisons of economic losses of a RCP 8.5 scenario versus a short-term disorderly transition scenario included in this study find that even though a green transition would likely entail significant costs, compared to the long-term physical risk of climate change these costs would be relatively small.

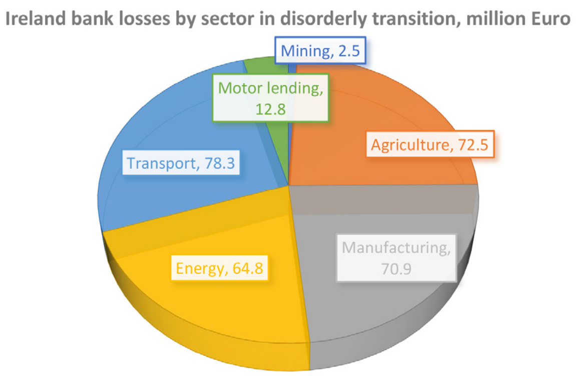

Fig. 5. Ireland bank losses by sector in disorderly transition, million Euro

5. Discussion and conclusions

This research finds evidence that Ireland faces significant physical and transition risks from climate change. The economic losses from a rapid green transition included in this study are estimated to be smaller than losses from the climate change induced physical risk of increased flooding, thus provide support for the necessity of a timely green transition. Ireland has received criticism for its relatively slow implementation of EU environmental and climate change legislation (Torney and O'Gorman, 2019) and Ireland's own Environment Protection Agency states that the policy response to

Table 4. Potential bank loan losses by manufacturing sub-sector in a disorderly transition

Sub-sector	Sub-sector bank loan losses, million Euro	Sub-sector bank loan losses, % of total manufacturing sector
Basic Pharmaceutical Products & Preparations	€32.1m	45.3%
Food Products	€11.7m	16.5%
Chemicals & Chemical Products	€8.3m	11.7%
Other	€6.3m	8.8%
Basic Metals & Fabricated Metal Products, Machinery & Equipment	€4.5m	6.4%
Computer, Electronic, Optical & Electrical Equipment	€3.1m	4.3%
Wood & Wood Products, Other Non-Metallic Mineral Products, Furniture	€2.2m	3.1%
Beverages	€1m	1.4%
Rubber & Plastic Products	€0.9m	1.2%
Paper & Paper Products	€0.5m	0.7%
Transport Equipment	€0.2m	0.2%
Textiles, Wearing Apparel, Leather & Related Products	€0.2m	0.2%
Total manufacturing sector	€70.9m	100%

climate change has not delivered sufficient progress (Dekker and Torney, 2021). Ireland strengthening its climate change mitigation policies would not only be honouring its legal requirements as an EU member but also be in its long-term self-interest. To effectively mitigate Ireland's climate risks, a holistic governance framework which ensures for social, environmental, and economic development is required (Maskrey et al., 2023). Effective carbon pricing through policies such as carbon taxes and emission trading schemes can provide an effective pathway for mitigating climate change (Dominioni, 2022), but Ireland must prepare for the adverse economic and social effects of implementing GHG mitigation measures as well. Ensuring the correct range of structures and incentives exists in the financial sector for a transition to carbon neutrality is also vital for to enabling climate action across the private sector (Deignan et al., 2022).

The results of this paper have policy implications for the Republic of Korea as the country also faces significant physical climate risks and transition risks. Ireland and the Republic of Korea both surrounded by the sea on their West, South and East sides, with many large urban areas located around rivers and in coastal areas. The high concentration of population, buildings, and infrastructure near rivers make the Republic of Korea particularly vulnerable to climate related flood risks (Yu, 2022). In a RCP8.5 scenario flooding would significantly increase in the five major river basins of the Republic of Korea (Kim et al., 2023), resulting in losses of both human life and property (Park et al., 2023). Climate change would induce increased flooding severity as heavy rains and sea level rises cause significant damages to urban and coastal areas (Song and Lee, 2022). In terms of transition risks, the Republic of Korea's decarbonization pathway to achieve its enhanced NDC of reducing GHG emission by 40% by 2030, compared to 2018 levels, entails major economic costs (Jeong et al., 2022). The aggregate emission intensity of the Republic of Korea's exports make the country vulnerable to domestic and international requirements to reduce its GHG emissions (Kim and Tromp, 2023). Even though energy efficiency has improved in the country's energy and manufacturing sectors (Kim and Bae, 2022), they still are very carbon intensive, and similarly to Ireland attempts to rapidly reduce GHG emissions from these sectors would entail large costs which may decrease international competitiveness. Both Ireland and the Republic of Korea are relatively open economies with exports being a key driver of their economic growth, therefore any reduced international competitiveness due to raising carbon prices could pose transition risk. The approach utilized in this study could be applied to the Republic of Korea by assessing the physical risk costs the country would face in a RCP 8.5 scenario, through flooding and other physical climate risks such as heat waves, and comparing these costs to transition risk costs such as bank and industrial sector losses in a rapid green transition scenario.

This paper assessed physical risks from climate change through a limited scope of focusing solely on flood disaster risks, but Ireland's exposure to the detrimental effects of climate change expands far beyond this issue. Climate change would also negatively impact a diverse range of sectors including tourism (Hsu and Sharma, 2023), renewable energy generation capacity (Dallison and Patil, 2023), agriculture (Tzemi and Breen, 2019) and biodiversity (Donnelly, 2018). Other important limitations of this study are underlying assumptions, such as flood damages losses by region parameter and loan loss by sector through a disorderly transition. As this study primarily focused on potential losses from climate change through flooding disasters, the methodology it employs for assessing transition risk is greatly simplified. Ireland's banks and financial institutions provide detailed information to the central bank of Ireland regarding their climate risk measures, however such detailed information, for example regarding sector loan breakdown by climate risk, is not currently released. More detailed public disclosures of Irish banks' loan exposures by sector would enable researchers to carry out further studies employing such data to conduct more detailed and complex assessment of Ireland's physical and transition risks.

This study finds that from a long-term perspective climate action entails the optimal economic growth and prosperity maximising development pathway in the context of Ireland. This result has policy relevance for the Republic of Korea, as it finds that the long-term physical risk costs of climate change are larger than near term transition risk costs, which is consistent with the results of various integrated assessment models (NGFS, 2022). Near-term potential economic losses are a major obstacle to countries taking stronger climate action in Asia as well as in other regions. The Republic of Korea's current policy trajectory and NDC has been appraised as incompatible with the goals of the Paris Agreement (Climate Transparency, 2022). A green transition would like entail economic costs for the Republic of Korea (Kim, Gwon, et al., 2023) and other countries in Asia, which is a likely a prevalent factor in the countries not taking more stringent action to reduce its GHG emissions. However, if policy makers in Ireland, the Republic of Korea, and worldwide adopted a more long-term horizon perspective the overall benefit of strong, near-term climate action would be more clearly understood, and a Paris Agreement consistent growth and development pathway could be implemented.

A major limitation of this study is the divergent time periods of the physical risk assessment and the transition risk assessment. This is a highly complex issue to overcome given how transition risk is inherently a more near-term risk while physical risk is inherently a long-term risk. The methodology applied in this study for assessing climate risks is not entirely comprehensive due to data limitations and the fact methodologies for conducting such analysis are still in their early stages, which is currently a major challenge for climate change researchers and the IPCC assessment cycle. Attempts to develop comprehensive cost-benefit analysis will require transdisciplinary approaches to cover as many potential costs and benefits as possible (Sharma et al., 2020). Other relevant factors not included in the scope of this article is how effective adaptation measures could reduce physical risk damages. While recognising the limitation of scope of the applied approach, this research aims to contribute to the development of methodologies for conducting climate risk analysis which are still in early stages of development. Further exploration and refinement of methodologies for long-term climate risks assessment would be an important and fruitful research area for future studies.

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