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FINANCIAL SECTOR ASSESSMENT PROGRAM

February 2025

TECHNICAL NOTE ON CLIMATE RISK ASSESSMENT

This Technical Note on Climate Risk Assessment for the Indonesia FSAP was prepared by a staff team of the International Monetary Fund and the World Bank as background documentation for the periodic consultation with the member country. It is based on the information available at the time it was completed on February 5, 2025.

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TECHNICAL NOTE

CLIMATE RISK ASSESSMENT

Prepared By
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This Technical Note was prepared by IMF and World Bank staff in the context of the Financial Sector Assessment Program. It contains technical analysis and detailed information underpinning the FSAP's findings and recommendations. Further information on the FSAP program can be found at http://www.imf.org/external/np/fsap/fssa.aspx, and www.worldbank.org/fsap.

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Glossary

AFOLU	Agriculture, Forestry, and Other Land Use
CA	Current Assets
CAR	Capital Adequacy Ratio
CBAM	Carbon Border Adjustment Mechanism
CCE	Cash and Cash Equivalents
CCDR	Country Climate and Development Report
CES	Constant Elasticity of Substitution
CET1	Common Equity Tier 1
CGE	Computable General Equilibrium
CL	Current Liabilities
COGS	Costs of Goods Sold
CR	Current Ratio
EBIT	Earnings Before Interest and Taxes
EC	Emissions Costs
EIA	US Energy Information Administration
EMDE	Emerging Market and Developing Economy
FE	Financial Expense
FI	Financial Income
FSAP	Financial Sector Assessment Program
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GVA	Gross Value Added
ICR	Interest Coverage Ratio
IMF	International Monetary Fund
LCR	Liquidity Coverage Ratio
LGD	Loss Given Default
LR	Leverage Ratio
MANAGE-WB	Mitigation, Adaptation and New Technologies Applied General Equilibrium at the World Bank (MANAGE-WB)
NDC	Nationally Determined Contribution
NGFS	Network for Greening the Financial System
OC	Operating Costs
REV	Sales Revenue
SAM	Social Accounting Matrix
TA	Total Assets
TAX	Corporate Tax Expense
TD	Total Debt

EXECUTIVE SUMMARY[1]

Indonesia is exposed to both climate change transition risks and physical risks. With primary energy supply heavily dominated by fossil fuels, like many other countries, and as a major exporter of coal and liquefied natural gas, Indonesia is exposed to risks from the transition toward a carbon-neutral economy. Moreover, Indonesia is vulnerable to natural hazards, such as floods, droughts, and wildfires. With global temperatures rising, the frequency and severity of such events is expected to rise as well.

The FSAP assessed both transition and acute physical risks posed by climate change. The transition risk analysis followed an integrated micro-macro approach where transition scenarios for various economic sectors are structurally linked to corporate vulnerability indicators and then translated into corporate credit risk paths and eventually banks' credit exposures. For physical risks, scenarios simulating the macroeconomic impact of severe flooding events—under current and future climate conditions, and compounded by a severe earthquake—are adopted and translated into bank losses.

The analysis and results should be regarded as exploratory and interpreted with caution given the uncertainty associated with the scenarios and modeling approach. Both the transition and physical risk analyses are subject to various assumptions, data, and model limitations. Further analysis and better data are needed to explore the sensitivity of the results. While the analysis relied on standard stress testing methodologies, it is not a standard stress test and is not focused on quantifying capital needs of the financial sector given the various challenges and the exploratory nature of the exercise.

The climate risk analysis highlights potential vulnerabilities from climate-related physical and transition risks. To better monitor these risks, the authorities should further develop internal capacity and models for climate risk analysis, improve data collection, offer more detailed methodological guidance to financial institutions, and enhance the collaboration among government agencies on climate risk analyses.

[1] This Technical Note has been prepared Michaela Dolk (World Bank), Ou Nie (World Bank) and Felix Suntheim (IMF), under the guidance of Ranjit Singh (mission chief) and Mindaugas Leika (deputy mission chief). Research assistance was provided by Lu Zhang (IMF). The macro modeling for the physical risk analysis was carried out by Zoltan Jakab (IMF) and Ruy Lama (IMF) and the stress testing modules were provided by Xiaodan Ding (IMF). The macro modeling for transition risk analysis was carried out by Martin Aaroee Christensen (World Bank). Nicholas Pondard (World Bank) supported the development of the scenarios for the physical risk analysis. The team is grateful to BI and OJK for their excellent collaboration in this exercise.

Table 1. Indonesia: 2024 FSAP Recommendations on Climate Risk Analysis

Recommendations	Authorities	Time[1]
Improve data collection to enable comprehensive and granular analyses of transition and physical risk.	BI, OJK	MT
Further develop internal capacity and models for climate risk analysis, assess and further develop methodological guidance to financial institutions on climate risk assessment.	BI, OJK	MT
Improve collaboration on climate risk analyses among government agencies, including between BI and OJK, research institutions, and the private sector.	BI, OJK	MT
Consider the outcome of climate risk analysis in prudential policies, using a risk-based approach, to ensure that the banking sector implement adequate risk management of climate-related financial risks.	BI, OJK	ST

[1] Immediate (less than one year), ST: short term (1–2 years), MT: medium term (3–5 years).

INTRODUCTION

1. **Indonesia is exposed to climate change physical and transition risks.**[2] Indonesia is vulnerable to natural disasters, such as floods, droughts, and wildfires, having experienced almost 300 climate-related natural disasters over the past 3 decades—affecting more than 16 million people (World Bank, 2023). With global temperatures rising, the frequency and severity of such events is expected to rise as well. Indonesia, like many other countries, is also exposed to risks from the transition toward a carbon-neutral economy. Nevertheless, Indonesia is home to the third-largest tropical rainforest globally, covering 94.1 million hectares. It also boasts the largest tropical peatlands, spanning 14.9 million hectares, and mangrove forests of 3.36 million hectares. These natural resources are vital for storing vast amounts of carbon, which helps mitigate the effects of climate change. As in many other ASEAN countries , Indonesia's primary energy supply is heavily dominated by fossil fuels with coal alone fueling more than 50 percent of electricity generation. Indonesia is also a major exporter of fossil fuels—according to the US Energy Information Administration (EIA) it was the world's largest exporter of coal and the seventh-largest exporter of liquefied natural gas in 2020.[3]

2. **Physical and transition risks could affect Indonesia's financial sector via credit and market losses.** Acute climate-related shocks can affect the real economy by disrupting businesses and damaging assets, spilling over to the financial sector via higher credit and market losses. Similarly, sudden changes to climate policies could pose risks to the financial sector. For example, more ambitious than expected decarbonization policies—either domestically or internationally—could lead to a fall in output which in turn could affect Indonesia's banking system which is heavily exposed to carbon intensive firms.

3. **The analysis of climate-related risks is an increasing priority of FSAPs (Adrian and others, 2022).** For example, the FSAPs of Chile (International Monetary Fund, 2021), Colombia (Sever and Perez-Archila, 2021), Mexico (International Monetary Fund and World Bank, 2022a ; Dolk et al., 2023; Laliotis and Lamichhane 2023), Norway (Grippa and Mann, 2020), Kazakhstan (International Monetary Fund, 2024) and the United Kingdom (International Monetary Fund, 2022b) assessed transition risks posed by climate change mitigation and implications for the financial sector. The FSAPs of Mexico (International Monetary Fund and World Bank, 2022a) and the Philippines (International Monetary Fund and World Bank, 2022) assessed physical risks. Several central banks and international financial institutions, including Bank Indonesia, have started to undertake climate risk assessments to evaluate the financial system's exposure to climate transition.[4]

[2] Climate-related risks can be broadly categorized into transition risks and physical risks. Transition risks are those related to the process of adjusting towards a low-carbon economy, which can impact the value of financial assets and liabilities. Physical risks include acute risks from the impacts of increasing frequency and severity of hydrometeorological disasters due to climate change (e.g., wildfires or floods), and chronic risks associated with gradual changes induced by climate change (e.g., lower productivity due to higher temperatures).

[3] https://www.eia.gov/international/overview/country/IDN.

[4] See for instance ECB 2021, 2023 and Reinders and others 2021, Nie and others (2024).

Bank Indonesia also ranked 9th based on the Green Central Banking Scorecard, which scores and ranks the full range of green policies and initiatives adopted by G20 central banks.[5]

4. The FSAP analyzed climate-related physical and transition risks to the Indonesian financial system. The analysis of transition risks uses a micro-macro approach where sectoral outputs under different climate policy scenarios are mapped to corporate credit risk which is then translated into the impact on aggregate sectoral bank credit exposures. Physical risks are analyzed using a "macro-approach" which involves designing macrofinancial scenarios due to shocks to physical capital and quantifying the impact on aggregate banks' credit risk.[6]

5. The analysis of the financial stability implications of transition risk and physical risk should be considered exploratory, and results treated with caution. Both the transition and physical risk analyses are subject to substantial scenario and model uncertainties. They are also subject to various simplifying assumptions given data and model limitations, e.g., a lack of granular geographic exposure data. The analysis is not a standard stress test and is not focused on quantifying capital needs of the financial sector given the various challenges and the exploratory nature of the exercise. Its objective is to raise awareness of the risks and to encourage the development of analytical tools and the collection of data to enable banks and supervisory bodies to better assess these risks.

TRANSITION RISK

A. Overview: Transition Risks in Indonesia

6. Indonesia's economic growth is highly dependent on greenhouse gas (GHG) emissions.[7] In 2020, Indonesia's total greenhouse gas (GHG) emissions reached 1.48Gt, or the fifth in the world—only behind China, the United States, Russia, and India, even though the emission per capita of Indonesia is ranked 129th in the world and far below the G20 countries average. The agriculture, forestry, and other land use (AFOLU), and energy sectors being the main drivers. Land use emissions are largely result from the expansion of farming and commodity production which can entail deforestation, fires, and peat drainage. Electricity and transport sectors also contributed significantly to emissions unrelated to the AFOLU sector since much of Indonesia's electricity production is based on fossil-fuels (predominantly coal). Indonesia also has a substantial mining and quarrying sector with the oil, gas, and coal related sectors making up 12.2 percent of total 2022 GDP.

[5] The analysis is based on a literature review, expert consultations, and bilateral interactions with central bankers and supervisors.

[6] Several other FSAPs, have applied macro scenario stress testing methodologies to analyze the impact of physical risk on the economy and bank capital, including those in Chile, Ireland, Mexico, the Philippines, and South Africa.

[7] Per capita emissions in Indonesia in recent years have been in line with those of other large developing economies, and lower than those of large, developed economies (World Bank 2023).

7. Risks from the transition to a carbon neutral economy could arise in several ways. Limiting global warming requires a significant transformation of the energy system and will result in substantial impacts on the economy. Abrupt introduction to GHG emission reduction policies could lead to significant adjustment costs for companies and households. Disruptive technological changes as well as changing consumer and market preferences toward greener goods and services could result in structural economic shifts. Transition risks may also arise at the international level. For example, foreign financial flows could transition away from polluting firms as international investors start to increasingly value green alternatives or international climate regulations, such as carbon border adjustments that pose a tariff on carbon-intensive products, could affect export and import flows.

8. International climate actions could impact Indonesia's economy and international trade. Indonesia became the world's largest coal exporter in 2021, with coal exports representing around 10 percent of total exports. Climate actions such as individual countries' implementation of their NDC targets or the European Union's Carbon Border Adjustment Mechanism (CBAM) may lead to a reduction in demand for Indonesia's coal exports. Further, the palm oil industry, whose exports contribute to over 70 percent of global supply, faces challenges as the low-carbon transition restricts supply of new land and increase costs of fuel and fertilizer.

9. Transition risks in the real economy could affect Indonesia's financial sector. Almost three-quarters of the Indonesian banking system's lending portfolio comprises sectors that are potentially exposed to climate transition risks (Figure 1). The processing industry comprises 24 percent of Indonesian banks' loan portfolio, while agriculture (including palm oil) comprises 11 percent, followed by construction (10 percent), transportation (8 percent), and real estate (7 percent). Shocks to these sectors, for example from rapid and unanticipated decarbonization coupled with lack of industry preparedness, could thus spill over to the financial sector via loan losses. Moreover, stock markets in Indonesia are also exposed to climate transition risk with 75 percent of listed firms belonging to transition-sensitive sectors.

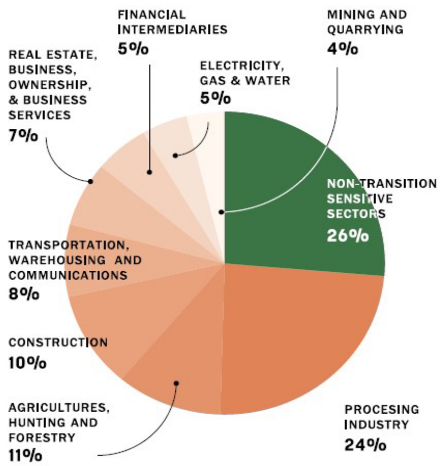
B. Methodological Approach

10. The modeling framework for transition risk analysis follows an integrated micro-macro approach (Figure 2). First, transition scenarios and carbon price trajectories for each scenario are developed. These transition scenarios directly inform the macroeconomic modeling of overall and sector-specific trajectories of production, the paths of which are then structurally linked to firm level corporate vulnerability indicators. Finally, the impact on these indicators is translated into corporate credit risk paths which are then eventually translated into impact on banks' credit exposures to various sectors.

Figure 1. Indonesia: Financial Sector Exposure to Transition-Sensitive Sectors

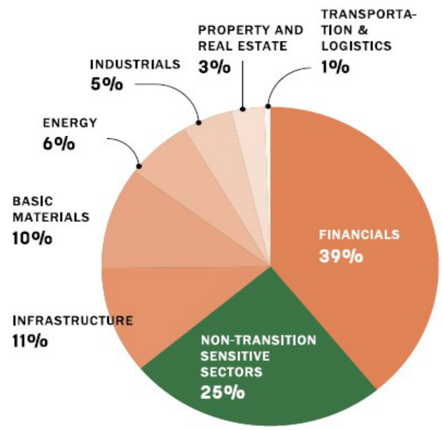
Lending Exposure of Indonesian Banks to transition-sensitive sectors are high.

Distribution of Non-transition and Transition Sensitive Loans



Indonesia's stock markets are weighed toward emission-exposed sectors.

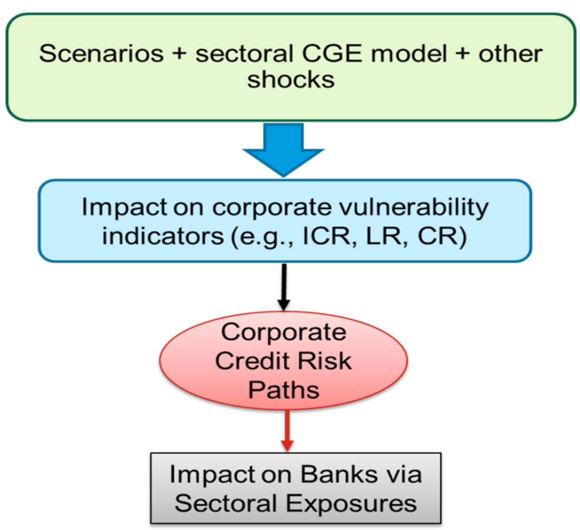
Distribution of Transition Sensitive Equities



Source: IMF Climate Change Dashboard (2021) and World Bank (2023).
Note: In panel 1, some sectors may be incorrectly classified due to aggregation. Indirect impacts such as supply chains are not captured. Transition sensitive sectors are those with either high emission intensity, high exposure to emission intensive sectors, or are expected to be directly affected by climate policies.

Figure 2. Indonesia: Methodological Approach

The modeling framework for transition risk analysis follows an integrated micro-macro approach



Source: IMF.
Note: CGE = Computable General Equilibrium; ICR = Interest coverage ratio; LR = Leverage ratio; CR=Current ratio.

Transition Scenarios

11. The FSAP considered three main transition scenarios for Indonesia. We closely follow the scenario design of the Network for Greening the Financial System (NGFS) database and the World Bank's Country Climate and Development Report (CCDR) by considering the following scenarios:[8]

- **Redirection of electricity & fuel subsidies (Redirection).** Elimination of electricity and fuel subsidies, with no additional energy and land policies. Government consumption is assumed constant. Two alternative uses of the savings from elimination of subsidies are considered. Firstly, the savings are used to compensate the households at the bottom 40 percent of the income distribution. Secondly, the savings are used to finance a rise in public investments.

- **Nationally Determined Contribution (NDC).** This scenario includes all pledged policies, even if they have not been implemented yet. This includes, the elimination of electricity and fuel subsidies, energy policies, land policies and a carbon tax that reaches US$40.00/tCO2eq by 2040. Energy policies includes the Green RUPTL (Electricity Supply Business Plan). Land policies include forest and peatland restoration measures that have potential benefits in terms of reduced losses due to fires and improved health impacts. The carbon tax is applied to all sectors and greenhouse gas emissions except for agriculture. The tax is gradually phased in. Revenues from the carbon tax are used for investment–including in low-carbon equipment. It is assumed that replacing stranded fossil fuel assets accounts for 25 percent of the new investment.

- **Nationally Determined Contribution Plus (NDC+).** This scenario includes all the actions from the NDC scenario, but with a much higher carbon tax rate, reaching US$200/tCO2 by 2040. This is a more ambitious scenario that would involve higher net costs for Indonesia. To help compensate for the costs, a sensitivity analysis is added to this scenario with an increase in foreign investment that is equivalent to 1 percent of GDP throughout the projection period.

12. The carbon price in the NGFS scenarios varies based on the level of ambition and timing of climate policy. Stringent policies result in higher carbon prices, while assumptions regarding the availability and cost-effectiveness of green technologies influence the carbon price (lower prices for cheaper green technologies). Furthermore, disorderly policy introductions lead to quicker and steeper required increases in carbon prices to achieve climate targets. Transition trajectories are interpolated to align with the yearly time intervals of the CGE model used later in the analysis.

13. The carbon price trajectories within the various climate policy scenarios play a crucial role in determining the required trajectory for the power sector. Carbon prices lead to a reduction in the share of non-renewable energy sources such as coal and an increase in the share of renewable sources such as solar photovoltaic (solar PV). We use estimates by the Indonesia CCDR using the PLEXOS power sector model for the sensitivity of power-generating sectors to one-unit

[8] Each scenario is examined relative to a business-as-usual scenario.

changes in carbon price.[9] Investment costs related to the various technologies/power sector trajectories are inputs to this simulation. However, the scenarios presented in this study are more ambitious than those in the CCDR, requiring an extrapolation of sensitivities with the more ambitious carbon price scenarios while incorporating certain limits on the maximum speed of technological change. The result is a projected change in fuel mix within the power sector under the different carbon price trajectories within the climate policy scenarios. Those fuel mixes are used as inputs for the MANAGE model, as the model has a production structure that allows for an endogenous energy intensity of production that fluctuates with carbon pricing policies (see later Section for details). The model then determines the macroeconomic and sectoral impacts from those climate policies.

14. **The choice of transition scenarios was motivated by balancing cross-country comparability with country context and quantitative importance.** Other transition scenarios were considered, including a scenario modeling CBAM adjustment. However, the scenario was not included because the majority of Indonesia's coal export goes to EMDE Asia so that any impact of global climate actions would probably be limited.

Macroeconomic Model

15. **Transition risk scenarios are modelled using a computable general equilibrium (CGE) model.** CGE models are a class of macroeconomic models which are widely used to study the long-term effects of policy changes (e.g., tax changes, new trade policies) and external shocks (e.g., climate, natural disasters) on economic activities, households, and production factors. They are economy-wide models designed to capture the interactions between economic agents (e.g., households, firms, governments, and the external sector) in a simplified way, based on detailed economic data reconciled in a Social Accounting Matrix (SAM) which provide a snapshot of the flows between economic agents in a given (base) year by combining: the Input-Output table, government finances, balance of payments, trade, and micro data such as household, labor, agriculture, industrial, and surveys.[10]

[9] PLEXOS is a power system planning software platform and was used to understand the implications of different levels of emissions reductions on the capacity and generation mix given assumptions about demand growth and available technologies. The results should not be interpreted as forecasts, but as projections of the scale and speed of necessary interventions. See https://www.energyexemplar.com/plexos for details.

[10] A SAM is usually constructed by building a macro-SAM using the National Accounts and various other sources, and then disaggregating macro-SAM to the desired degree of detail. A variety of data sources are needed to construct a SAM, including (i) National Accounts (aggregated and by institutional sectors); (ii) full Input-output tables; (iii) household surveys including information on consumption and expenditure patterns of households and the source of household income; (iv) labor force surveys, i.e., statistics on the labor market and its composition, especially regarding skilling, employment, wages, sectors, etc.; (v) specific surveys on certain sectors and on specific socioeconomic aspects, such as population census, agricultural census, surveys of manufacturing and services; (vi) accounts of the public administrations, i.e., tax data and statistics; and (vii) debt statistics, and trade data, i.e., imports and exports.

16. The FSAP for Indonesia employed the Mitigation, Adaptation and New Technologies Applied General Equilibrium at the World Bank (MANAGE-WB) model developed at the World Bank. Features of the model are outlined in the MANAGE model documentation (2017) and Hallegatte and others (2023) and briefly summarized here:

- Most features of the MANAGE model match the standard CGE approach based on neoclassical theory—i.e., labor force growth is exogenous and capital accumulation derives from savings/investment decisions. Savings and investments are endogenously determined such that the interest rate on government debt and returns on private investment clears supply and demand of loanable funds.

- The model follows a savings-driven closure where aggregate investment and capital accumulation reacts to the available volume of savings. Foreign savings are exogenous and fixed as a share of GDP, while government savings are endogenous and adjust to public revenue and expenditures. Household and enterprise savings reacts to changes in returns to capital. The interest rate on government debt and returns on private investment clears supply and demand of loanable funds. Hence, the model reflects a crowding-out effect, whereby government investment displaces private investment.

- Firms are profit maximizers under technologies with constant returns to scale. All markets in the model are perfectly competitive, implying that prices are equal to marginal costs in equilibrium.

- A nested production function with constant elasticity of substitution (CES) technology describes how the economic system transforms inputs into outputs and added values. The supplies of labor and land are sensitive to average real wages and land prices, respectively.

- The government collects taxes and receives transfers from the rest of the world and domestic agents, then spends them on government consumption, investment, transfers, and savings. The government can borrow from domestic institutions or from the rest of the world. The volumes of the government's current and investment spending are assumed a constant share of GDP, implying that government savings are endogenous and adjust to clear the government balance.

- Exports and imports are determined according to Constant Elasticity of Transformation and Armington specifications, respectively. Both these specifications assume that domestic commodities are not perfect substitutes for traded commodities. World market prices are considered exogenous in line with the small open economy assumption.

- Annual projections until 2040 on real GDP, population growth, energy consumption and the power mix are used to generate a dynamic baseline which is used as a reference business-as-usual (BAU) scenario in the model simulations.

17. MANAGE-WB allows the modeling of energy use. Electricity production accounts for five types of electricity generation activities: Coal, Gas, Hydro, Solar and Others. The electricity generation mix is endogenously determined, based on the relative cost of each generation activity, which fluctuates with carbon pricing policies. Alternatively, the model allows the targeting of a specific energy generation mix by adjusting the investment in each type of electricity generation activity (e.g., increasing investment in renewables). The model also allows for different productivity assumptions such as autonomous improvements in energy efficiency that can differ across agents and energy carriers, and it features levers to integrate results from sectoral models (e.g., energy, transport, or biophysical models). The model also incorporates an on-demand vintage structure for capital that allows for sluggish mobility of installed capital.

18. **For Indonesia the model is calibrated to a Social Accounting matrix with the base year 2018.**[11] The model contains 40 production sectors producing 36 commodities. Production factors are land, capital, and labor, with labor divided into skilled/unskilled and by gender. Representative households are considered by income quintile and earn income from factor payments and transfers, and spend their income on taxes, savings, and consumption. The aggregated commodities groups are food, manufacturing, electricity, other energy, services, and transport. The distribution of consumption across commodities is determined by a two-level utility function. At the first level, a Constant Difference in Elasticities (CDE) utility function determines the consumption of aggregated commodities. The use of CDE enables a better representation of income effects on household demand, by allowing consumption shares to change as income and prices change. The aggregated commodities groups are food, manufacturing, electricity, other energy, services, and transport. Effectively, the first-level utility function distributes household consumption spending across the broader categories. Then, a second level CES nest distributes spending on each aggregate consumption group among commodities in that group.

Firm-Level Modeling Framework

19. **The results from the model simulations are used as the input to firm-level simulation, which are then aggregated to the sector- and bank-level.** The analysis relies on balance sheet and profit and loss (P&L) data from 448 large Indonesian corporates. The data sample was sourced from S&P Capital IQ over a sample period from 2008 to 2022. Depending on the sector, sample firms' outstanding debt corresponds to 5–60 percent of banks' loan portfolios (Figure 3).[12]

20. **Sectoral gross value added (GVA) is linked to firm-level P&Ls and balance sheets through various structural and econometric components (Table 2).** EBIT of firm i at time t under each scenario s ($EBIT_{i,t,s}$), is estimated based on firms' revenue and cost, which change across scenarios.

$$EBIT_{i,t,s} = REV_{i,t,s} - COGS_{i,t,s} - OC_i - EC_{i,t,s}$$

[11] The SAM used in this analysis is based on modeling work completed during the World Bank's 2023 CCDR for Indonesia and WB staff calculations.

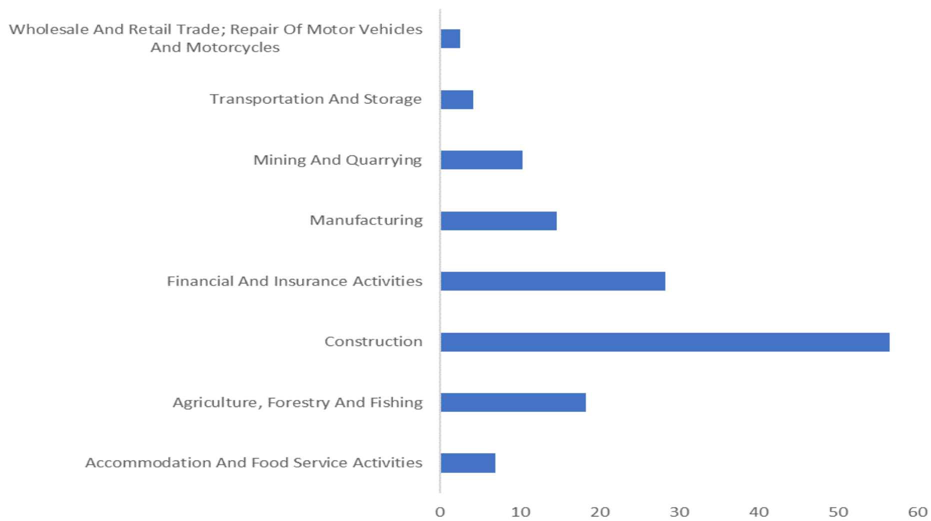
[12] Due to data limitations firms' outstanding debt cannot be directly mapped to banks' loan portfolios. Figure 3 should therefore be interpreted with caution as firms' debt could also be held by other institutions.

Firm's revenue ($REV_{i,t,s}$) changes with sectoral output and is thus directly affected by climate policies. There are three components of firm's cost: cost of goods sold ($COGS_{i,t,s}$), operating cost (OC_i), and emissions cost ($EC_{i,t,s}$). Each firm's cost of goods sold and emissions cost change over time and across scenarios, while operating cost is held constant.

Figure 3. Indonesia: Sample Coverage

Sample firms' outstanding debt correspond to 5–60 percent of banks' loan portfolios

Portfolio Firms' Total Debt Relative to Banks' Lending Portfolio by Sector (Percent)



Source: Capital IQ and IMF staff calculations.

Table 2. Indonesia: Firm P&L Modeling

P&L Component	Modeling Approach
Sales revenue (REV)	Aligned with sectoral gross value added (GVA) projections from WB macro model.
Costs of goods sold (COGS)	Linked to sales revenues.
Operating costs (OC)	Constant.
Emissions costs (EC)	Estimated based on projected firm-level GHG emissions.
Financial income (FI)	Changes proportionally with sales revenues.
Financial expense (FE)	Constant interest/debt ratio.
Corporate tax expense (TAX)	Based on 22 percent Indonesian corporate tax rate.

Source: IMF staff calculations.

21. Firm-level P&Ls are linked to sectoral GVA projections from MANAGE through sales revenues and emissions cost. Sales-to-GVA elasticities are estimated based on log level firm-fixed effects panel regression by sector, using historical firm-level data (448 firms) with annual frequency (2008–2022).[13]

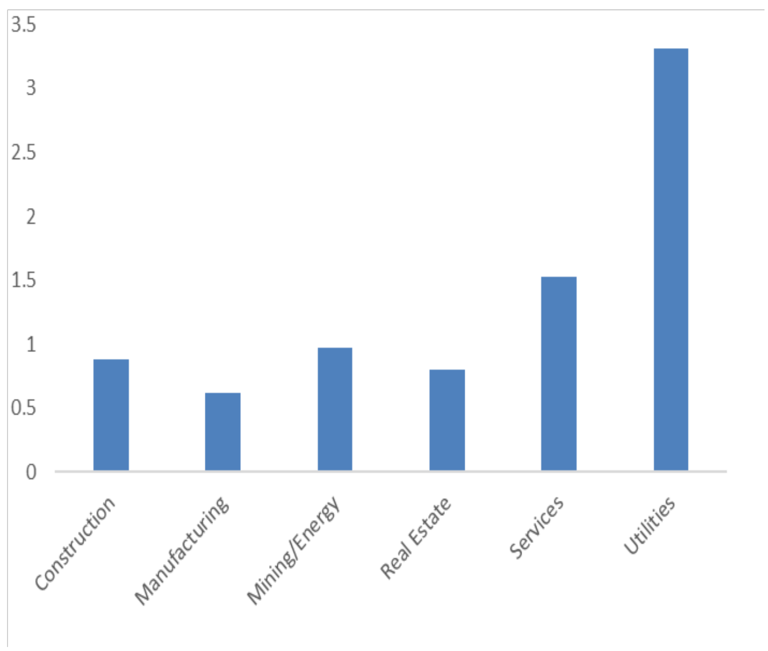
$$\log(REV_{i,t}) = \alpha_i + \beta^{sector} \log(GVA_{s,t}) + \epsilon_{i,t}$$

where β^{sector} is the sales-to-GVA elasticity and estimated separatel by business sector (Figure 4).

Figure 4. Indonesia: Sales-to-GVA Elasticities

Firm-level P&Ls are linked to sectoral GVA projections through sales revenues

Sales-to-GVA Elasticity by Sector



Source: IMF staff calculations.

22. Firms' cost of goods sold (GOGS) are linked to sales revenue and changes with scenarios. COGS-to-sales elasticities are estimated using log level pooled fixed effect regressions.

$$\log(COGS_{i,t}) = \alpha_i + \beta \log(REV_{i,t}) + \epsilon_{i,t},$$

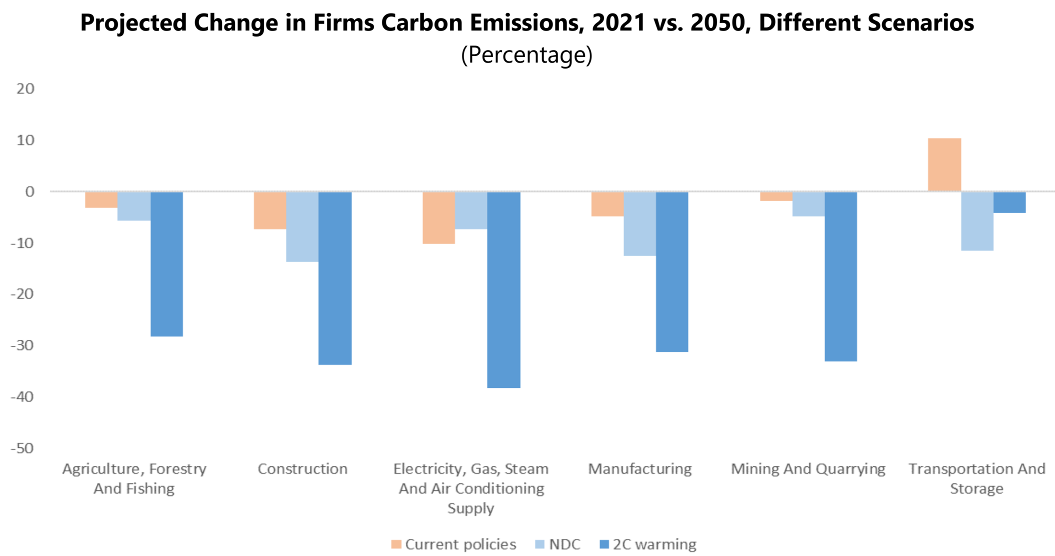
where β refers to the COGS-to-Sales elasticity. The estimated β is 0.99.

[13] Appendix I. Table 1. details the mapping of sectors in MANAGE to NACE.

23. Firms' emissions costs are projected based on the scenario dependent carbon price path and firm-level emission projections. Emission projections are obtained from ICE CTF Emissions Data for 2022-2040 under different climate scenarios (Figure 5). Scope 1 emissions and Scope 2 emissions (indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling) are considered based on scenarios comparable to the NDC and NDC+ scenarios.[14]

Figure 5. Indonesia: Emission Projections

Emission projections vary by sector and scenario



Source: ICE and CTF; Capital IQ; and IMF staff calculations.
Note: Scope 1 emissions and Scope 2 emissions (indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling).

24. Firm's periodic profit $P_{i,t,s}$ is estimated accounting for all income and expenses.

$$P_{i,t,s} = EBIT_{i,t,s} + FI_{i,t,s} - FE_{i,t,s} - TAX_{i,t,s},$$

where $FI_{i,t}$ is firm's financial income which changes proportionally with sales revenue; $FE_{i,t}$ is financial expense, calculated based on constant interest/debt ratio; $TAX_{i,t}$ is corporate tax expense, calculated based on a 22 percent Indonesian corporate tax rate.

25. Firms' balance sheet dynamics are driven by their net cash flows. Total assets and current assets (CA) of a firm change by the net profit at an annual frequency. In the case that the firm's cash stock would turn negative during the simulation debt is increased. There is no repayment of principal debt considered, i.e., outstanding debt is rolled over continuously (see Table 3 for details on firms' balance sheet modeling).

[14] The two scenarios are "emissions under the nationally determined contributions" and "emissions under a less than 2°C warming scenario."

Table 3. Indonesia: Firm Balance Sheet Module

P&L component	Modeling Approach
Cash and Cash Equivalents (CCE)	$CCE_{i,t+1} = max\ (0,\ CCE_{i,t} + P_{i,t+1})$
Total Assets (TA)	$TA_{i,t+1} = max\ (0,\ TA_{i,t} + P_{i,t+1})$
Total Debt (TD)	$TD_{i,t+1} = TD_{i,t} - min\ (0,\ CCE_{i,t} + P_{i,t+1})$
Current Assets (CA)	$CA_{i,t+1} = max\ (0,\ CA_{i,t} + P_{i,t+1})$
Current Liabilities (CL)	$CL_{i,t+1} = CL_{i,t} - \min\ (0,\ CCE_{i,t} + P_{i,t+1})x0.5$

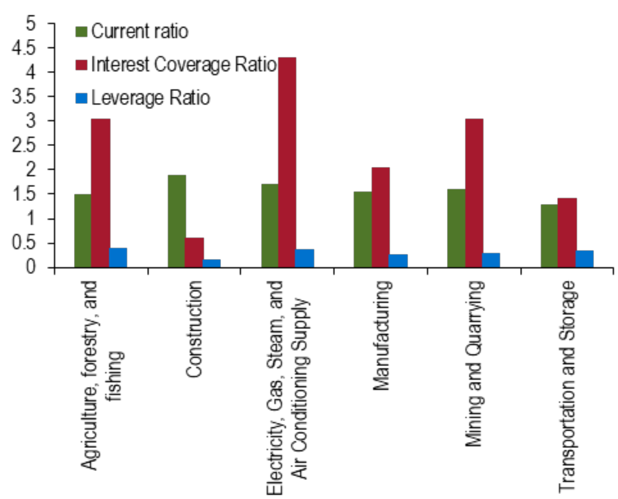
Source: IMF staff calculations.

26. Macro effects are structurally linked to firms' PDs through the projected firm-level balance sheets. Three solvency and liquidity metrics are calculated based on projected firm-level balance sheets: (i) Interest coverage ratio ($ICR_{i,t} = \frac{EBIT_{i,t}}{FE_{i,t}}$); (ii) leverage ratio ($LR_{i,t} = \frac{TD_{i,t}}{TA_{i,t}}$), and iii) current ratio ($CR_{i,t} = \frac{CA_{i,t}}{CL_{i,t}}$). Figure 6 shows the heterogeneous risk characteristics of various corporate sectors.

Figure 6. Indonesia: Solvency and Liquidity Metrics

Heterogeneous risk characteristics of various corporate sectors

Median Solvency and Liquidity Metrics, 2021



Source: Capital IQ and IMF staff calculations.
Note: Interest coverage ratio is defined as $ICR_{i,t} = \frac{EBIT_{i,t}}{FE_{i,t}}$, leverage ratio is defined as $LR_{i,t} = \frac{TD_{i,t}}{TA_{i,t}}$, and current ratio is defined as $CR_{i,t} = \frac{CA_{i,t}}{CL_{i,t}}$.

27. A structural link between the corporate vulnerability indicators and default risks is used to project firm level probabilities of default. Firm fixed-effect panel regressions are used to link the solvency and liquidity metrics to PDs:

$$\text{logit}(PD_{i,t}) = \alpha_i + \beta_1 ICR_{i,t} + \beta_2 LR_{i,t} + \beta_3 CR_{i,t} + \epsilon_{i,t},$$

The left-hand side PD data are obtained from Moody's KMV over the period 2014-2022. The right-hand side variables are the corporate vulnerability indicators that capture firms' financial health. The right-hand side does not contain any macro-financial variables because the firm-level solvency and liquidity metrics are already driven by the CGE sectoral outputs and carbon prices. The results are shown in Table 4.

Table 4. Indonesia: Fixed Effects Panel Regression Estimation in the PD Model

Coefficient	Logit(PD)
ICR	-0.0011***
CR	-0.0532***
LR	3.6124***
Observations	3,056
Firm fixed-effects	Yes

Source: IMF staff calculations.

28. Using the PD model, scenario specific PD paths for individual firms are then aggregated to weighted average sectoral PD paths and mapped to banks' sectoral credit exposure. For each bank, the difference in PDs relative to the baseline, weighted by their sectoral exposures, are then estimated for each scenario, with the assumption that sectoral credit exposures of each bank remain constant over time and across scenarios. Projected sectoral PDs are translated into bank credit losses, using incurred loss approach and the same LGD parameters used in the solvency stress test, aggregated at the sectoral level.[15] Due to data limitations, the exposure of banks cannot be mapped to individual firms and only aggregated credit exposures by economic sectors is available. Therefore, exposure-weighted sectoral PDs are estimated for each scenario.

C. Results: Transition Risk Impact on the Banking System

29. Results from the CGE model simulations suggest a substantial reduction of GHG emissions under the NDC and NDC+ scenarios (Figure 7). The Redirection scenario is expected to reduce emissions by 3–4 percent but the effects are limited once redirection is completed. Land use policies and carbon prices are projected to have a more substantial impact, with continued emissions reduction as carbon prices increase. Under the NDC scenario GHG emissions are projected to be 30 percent lower than BAU by 2030 which would help meet Indonesia's conditional NDC

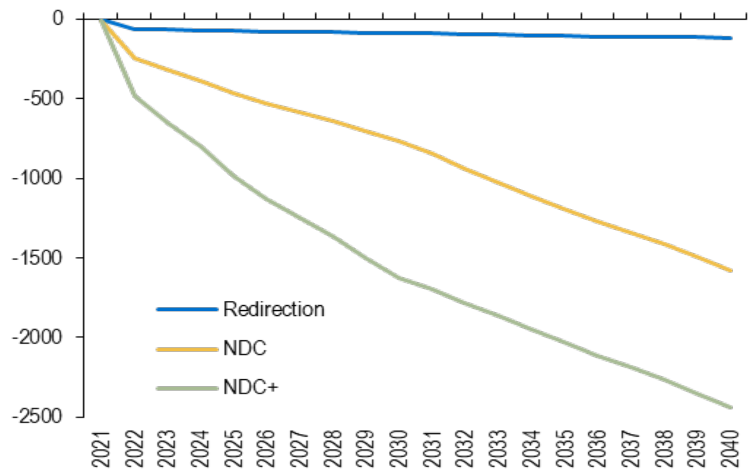
[15] For a more detailed description of the methodology and the sample of banks see IMF (2024b).

target. Under the NDC+ scenario, GHG emissions are 65 percent below BAU by 2030. The power sector, manufacturing and transport all show substantial emission reductions.

Figure 7. Indonesia: GHG Emissions

The ENGAGE model simulations suggest a substantial reduction of GHG emissions under the NDC and NDC+ scenarios.

Total GHG Emissions, Difference from BAU, MtCO2eq



Source: WB-MANAGE model.
Note: Redirection is the redirection of electricity and fuel subsidies scenarios with (i) savings used to compensate households; and (ii) savings used to finance a rise in public investments. NDC is the Nationally Determined Contribution scenario. NDC+ are the Nationally Determined Contribution Plus scenarios with and without an increase in foreign investment.

30. The impact of climate actions on long-term GDP depends, in part, on how carbon taxes and savings from reduced subsidies are recycled (Figure 8).

- The Redirection scenario leads to a rise in GDP relative to BAU due to the removal of the distortionary effects from the subsidies, and potential additional indirect air quality effects on labor supply. Recycling of savings from lower subsidies through transfers, results in a lower long run rise in GDP than recycling of savings through investments.

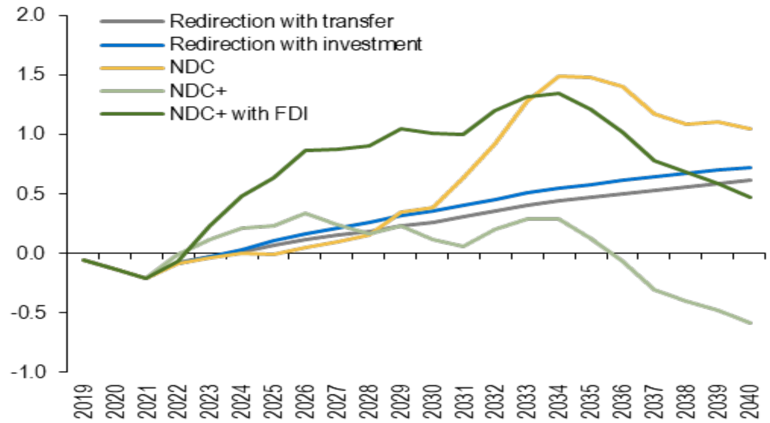
- Under the NDC scenario the recycling of carbon tax receipts to investment results in a strong long-term rise in GDP relative to BAU. This result is driven by the removal of economic distortions from energy subsidies, higher investments financed out of carbon tax receipts, an increase in agricultural productivity from land reforms, and enhanced labor productivity through improved air quality. The air quality effect grows in line with the phase-out of coal.

- Under the more ambitious NDC+ scenario the distortionary effects of the carbon tax outweighs the positive effects. The higher carbon tax reduces the use of fossil fuels more quickly than the economy can offset through the adoption of new technologies (thereby reducing growth). Increased availability of external financing drive up domestic investments which plays an important role in determining the long-term economic growth path.

Figure 8. Indonesia: The Impact of Climate Actions on GDP

The impact of climate actions on long-term GDP depends, in part, on how carbon taxes and savings from reduced subsidies are recycled.

Changes in Real GDP, Percent Deviation Relative to BAU



Source: WB-MANAGE model.
Note: Redirection is the redirection of electricity and fuel subsidies scenarios with (i) savings used to compensate households; and (ii) savings used to finance a rise in public investments. NDC is the Nationally Determined Contribution scenario. NDC+ are the Nationally Determined Contribution Plus scenarios with and without an increase in foreign investment.

31. Aggregate results mask differences at the sectoral level as there are clear winners and losers from the low-carbon transition.[16] Sectors that are heavily exposed to transition risks are expected to suffer large output losses while sectors that are crucial for the clean energy transition are expected to benefit. Sectors that are likely to be most directly affected by carbon pricing and other emissions reduction measures include energy, electricity production based on fossil fuel, transport, waste, and energy intensive industries. These sectors experience the sharpest drops in output and gross value added (Figure 9). The primary energy sector will be negatively impacted by domestic decarbonization and global reduction in demand over the long term. Model results also show a reduction in output for fossil fuel producers across all scenarios. Other sectors, including construction, electricity production based on renewables, retail trade, manufacturing, and services, are projected to expand.

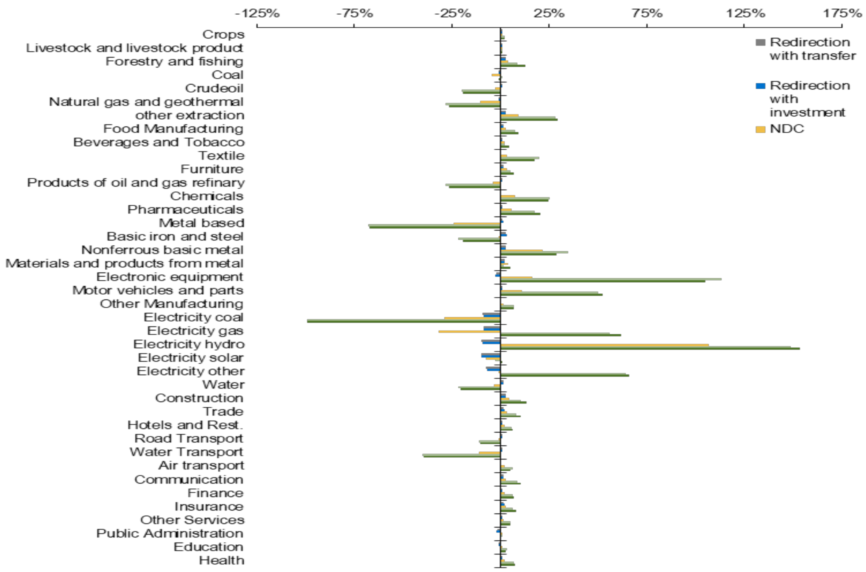
32. Climate related transition policies could have implications for the financial sector. The analysis suggests that default risks of firms in transition sensitive sectors increase substantially only in the NDC+ scenario with a very ambitious carbon tax (US$200/tCO2 by 2040). In this scenario probabilities of default in some carbon intensive sectors increase by up to 700 basis points by 2030 (Figure 10). In the other, less severe scenarios, the impacts appear to be small.

[16] Carbon pricing and other emission reduction measures also lead to a shift in employment across sectors. Employment changes are mainly driven by a shift away from energy, transport and energy intensive industry towards forestry, manufacturing, construction, and retail. The subsidy removal scenarios also lead to a shift in sectoral employment with a move from gas and power sectors towards construction and retail.

Figure 9. Indonesia: The Impact of Climate Actions by Sector

Aggregate results mask differences at the sectoral level as there are clear winners and losers from the low-carbon transition.

Changes in Gross Value Added, Percent Deviation Relative to BAU



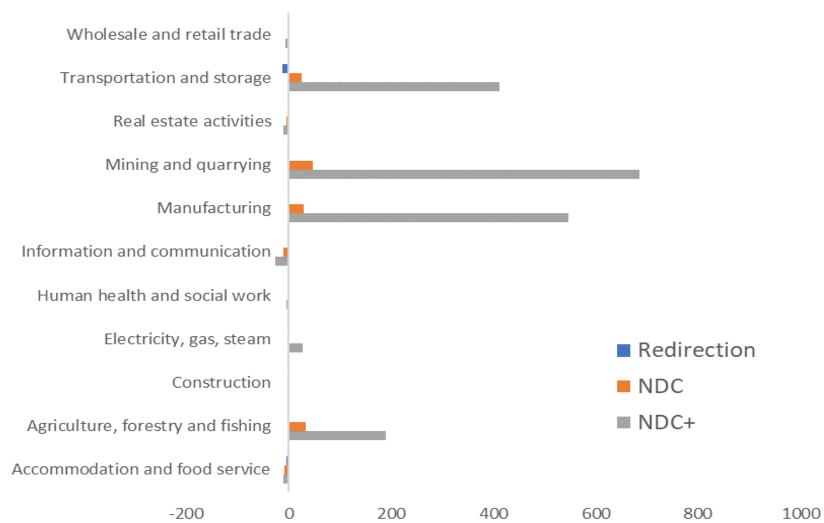
Source: WB-MANAGE model.

Note: Redirection is the redirection of electricity and fuel subsidies scenarios with (i) savings used to compensate households; and (ii) savings used to finance a rise in public investments. NDC is the Nationally Determined Contribution scenario. NDC+ are the Nationally Determined Contribution Plus scenarios with and without an increase in foreign investment.

Figure 10. Indonesia: Firms' Projected Probabilities of Default

Average Projected PDs in 2030 by Scenario, Difference from Baseline, Select Sectors

(Basis points)



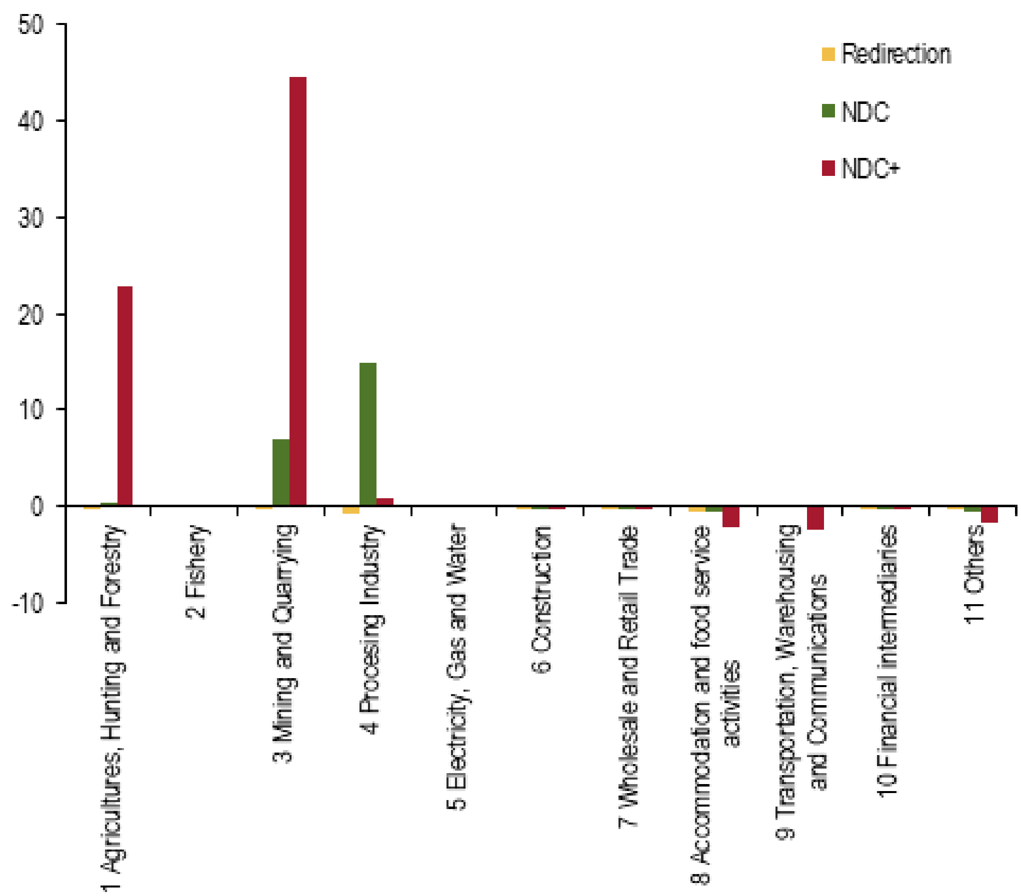
Source: World Bank and IMF staff calculations.

Notes: Redirection is the redirection of electricity and fuel subsidies scenarios with (i) savings used to compensate households; and (ii) savings used to finance a rise in public investments. NDC is the Nationally Determined Contribution scenario. NDC+ are the Nationally Determined Contribution Plus scenarios with and without an increase in foreign investment.

33. Banks' credit losses in excess of those under the baseline scenario vary across scenarios. Under the NDC+ scenarios the rapid increase in carbon prices would result in a substantial increase in bank credit losses in the affected sectors while the impacts are more muted under the NDC scenario and negligible under the Redirection scenario (Figure 11).

Figure 11. Indonesia: Banks' Credit Losses

Bank Credit Losses by Sector, Cumulative by 2040, Share of Loans in Each Category, Relative to BaU
(Percent)



Source: World Bank and IMF staff calculations.
Notes: Redirection is the redirection of electricity and fuel subsidies scenarios with (i) savings used to compensate households; and (ii) savings used to finance a rise in public investments. NDC is the Nationally Determined Contribution scenario. NDC+ are the Nationally Determined Contribution Plus scenarios with and without an increase in foreign investment.

34. The analysis of transition risk is subject to a number of important caveats. First, due to data limitations, it was not possible to map banks' loan portfolio directly to sectoral, sub-sectoral, or firm-level credit risk projections such that the analysis may mask vulnerabilities at banks with a particularly high exposure to transition sensitive sectors. Similarly, a lack of data on the balance sheets and carbon emissions of smaller firms limits the representativeness of the analysis. Second, the analysis relies on a range of model assumptions that could affect the results. For example, in the medium to long run, firms and banks may adjust their balance sheet structure beyond what can be modelled in this FSAP to reflect changing risks due to transition policies. Third, there are large model uncertainties associated with the macroeconomic scenarios, including from the development and deployment of new technologies.

PHYSICAL RISK

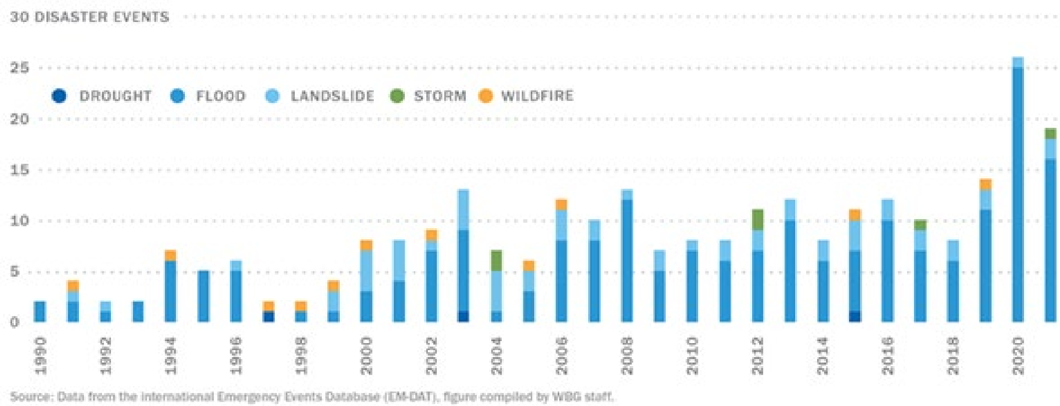
A. Overview: Physical Risks in Indonesia

35. The analysis of physical climate risks in this FSAP focuses primarily on acute risks. Acute climate physical risks are associated with changes in the frequency and severity of extreme events (e.g., floods, storms, fires). Chronic climate physical risks arise from shifts in longer-term climate patterns (e.g., sea level rise, sustained temperature increases, and shifts in rainfall patterns). While both types of risks may be substantial for Indonesia, and may compound with one another, the analysis in this FSAP focuses primarily on acute risks. The chronic risk of sea level rise is however considered in the analysis of flood risk. The analysis of other chronic risks (e.g., risks to agricultural production; World Bank, 2023) could be relevant for inclusion in future analysis, particularly given potential impacts of increasing temperatures and shifting rainfall patterns. Recognizing the importance of seismic hazards in the Indonesian context, and given their potential to compound with climate-related disasters (potentially also non-linearly increasing the impacts of climate-related shocks), earthquakes are also considered as part of the FSAP analysis.

36. Indonesia is exposed to a range of hydrometeorological hazards associated with acute physical climate risks, including floods, wildfires, and droughts. Over the past three decades, Indonesia has been impacted by more than 300 disaster events associated with natural hazards (Figure 12). Approximately 70 percent of these were climate-related, including more than 200 flooding events affecting more than 11 million people. Climate change is expected to exacerbate the frequency and severity of climate disasters in Indonesia. For example, more extreme heavy rainfall events are likely to exacerbate flood and landslide risks, whilst more frequent extreme El Niño events may increase drought and fire risks (Cai and others, 2014).

37. Climate-related disasters can have major economic, financial, and fiscal consequences, particularly if regions with large concentrations of economic and financial exposures overlap with areas with high hazard. As such, understanding the geographic distribution of economic activity and credit exposures relative to the geographic distribution of hazards is important for analyzing potential impacts of disasters on the economy and banking sector, particularly for hazards that may be localized (e.g., floods). It is also relevant to consider the sectoral distribution of economic activity and credit exposures in the case of climate-related perils that may disproportionately affect particular sectors (e.g., droughts impacting agricultural production).

Figure 12. Indonesia: Meteorological, Hydrological, and Climatological Disaster Incidence in Indonesia, 1990–2020



Source: World Bank 2023.

38. In Indonesia, the lending distribution is concentrated geographically, reflecting the distribution of economic activity.[17] In 2022, four provinces contributed collectively to more than 50 percent of the national GDP: DKI Jakarta (16.6 percent), Jawa Timur (14.3 percent), Jawa Barat (12.7 percent), and Jawa Tengah (8.2 percent) (BPS, 2023). Credit exposure in Indonesia is also heavily concentrated in the same few provinces: 48.7 percent (3,100,632 billion IDR, as of April 2023) of total commercial credit (6,464,551 billion IDR, as of April 2023) is recorded in DKI Jakarta (Figure 13; OJK, 2023). Other provinces that account for a relatively high reported credit exposure are Jawa Barat, Jawa Timur, and Jawa Tengah which contribute respectively 8.5 percent, 8.1 percent, and 5.5 percent of total commercial credit. The remaining provinces account for only 29.1 percent of total commercial credit exposure.[18] The geographic distribution of physical exposures for residential, commercial, and industrial assets (in terms of replacement cost) is also consistent with the geographic distribution of GDP and credit, and concentrated in the same four provinces (GEM, 2023).

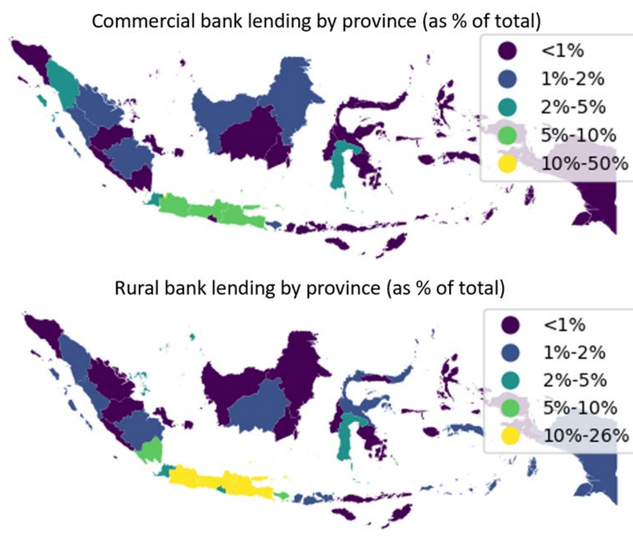
39. The island regions of Java and Sumatra have historically experienced the highest number of flood events in Indonesia. Jakarta, located on the island of Jawa, is a "hotspot" where frequent floods occur (e.g., in 2003, 2007, 2013, and 2019), resulting in significant economic losses and casualties. According to EM-DAT (CRED, 2023), the total (unadjusted) damage and losses associated with the 2007, 2013 and 2019 events corresponded to 1.0 billion USD, 3.0 billion USD and 1.2 billion USD respectively (corresponding approximately to 16,000 billion IDR, 47,500 billion IDR, and 19,000 billion IDR respectively, as of 1 February 2024). The geographical location of Jakarta is a key factor for flood risk, because the city lies on a deltaic floodplain, with 13 rivers flowing into the

[17] Bank lending is also concentrated at the sectoral level (Figure 1).

[18] However, it should be noted that credit may be recorded at the domicile of a firm's headquarters (often in Jakarta), even though the operations financed by the credit may be located elsewhere in the country.

metropolitan area. The island of Jawa also has a high concentration of physical capital stock, economic activity, and credit exposures, as discussed above. This concentration of exposure, combined with high hazard levels, contributes to the high flood risks on Jawa. While the impact of climate change on flood risk in Indonesia is associated with large uncertainties, most studies suggest that climate change has the potential to worsen the frequency and severity of floods in the region, primarily due to impacts on extreme precipitation, with sea level rise, subsidence, and ongoing urbanization also contributing to increased risk (Bennett and others, 2023; Priyambodoho and others, 2022; Januriyadi and others, 2018; Budiyono and others, 2016; Muis and others, 2015).

Figure 13. Indonesia: Commercial Lending (Upper Panel) and Rural Bank Lending (Lower Panel), by Province, as Percent of Total



Source: WB staff calculation using commercial credit data from OJK (April 2023).

40. Indonesia is also exposed to drought and fire (typically associated with El Niño conditions), with historical events impacting large swaths of the country. While fire and drought are associated with relatively small direct damages compared to other hazards like floods and earthquakes (e.g., physical damage to buildings), they have a large indirect economic impact (e.g., loss of agricultural production; World Bank, 2023). Droughts are among the most complex climate-related hazards, with wide-ranging and cascading impacts across ecosystems and the economy. Agriculture (and associated supply chains) losses are a key impact. Land and forest fires are worse during drought years and these fires damage ecosystems, pollute watersheds, and reduce air quality with serious health effects. Significant drought and fire events in Indonesia over the past decades include the 1997–1998, 2015, and 2019 events. Although the cause of these fires was manmade, their severity was amplified due to the drought conditions. Agricultural, forestry, transportation, trade, and industry sectors tend to record the highest economic losses from fires. Climate change is projected to worsen the severity of droughts, including through a decrease of 15 percent rainfall by 2080 for all Indonesian islands south of the Equator (World Bank, 2023). This, combined with increasing temperatures, is also likely to exacerbate fire risk.

41. Due to the relationships between droughts and fires in Indonesia, their impacts are often difficult to separate. The total (unadjusted) damage and losses associated with the historical fires and droughts of 1997–1998, 2015, and 2019, corresponded to 9.3 billion USD (CRED, 2023), 16.1 billion USD (Glauber and others, 2016), and 5.2 billion USD (World Bank, 2019) respectively. Direct damage to assets contributed generally to a very small fraction of the total fire and drought losses, while the indirect economic losses contributed to most of the total losses (e.g., in 2019, the direct damage to assets corresponded to 0.2 billion USD, and indirect economic losses corresponded to 5.0 billion USD, for a total loss of 5.2 billion USD; World Bank, 2019).

42. While the FSAP analysis focuses primarily on physical climate risks, it also recognizes that Indonesia is highly exposed to seismic risks, and should such risks manifest in close succession, the impacts of disasters may be compounded. Indonesia is located on the "Ring of Fire" and is one of the most seismically active countries in the world. Also, the country has the largest number of active volcanos in the world (more than 130). Therefore, Indonesia is highly exposed to major earthquakes and volcanic eruptions. Over the past century, these events caused among the largest casualties and economic losses in Indonesia, including the magnitude 9.2 Sumatra earthquake in 2004 (more than 200,000 fatalities, 7 billion USD in losses; CRED, 2023), and the more recent magnitude 7.5 Sulawesi earthquake near Palu in 2018. Earthquakes have the potential to result in changes in flood risk, for example through the impacts of ground subsidence and uplift, sediment from earthquake-associated landslides blocking river channels, and damage to flood infrastructure. As such, compounding of these disasters may be of relevance for the analysis of climate-related risks in Indonesia, particularly given the high risk from both earthquakes and floods in the country.

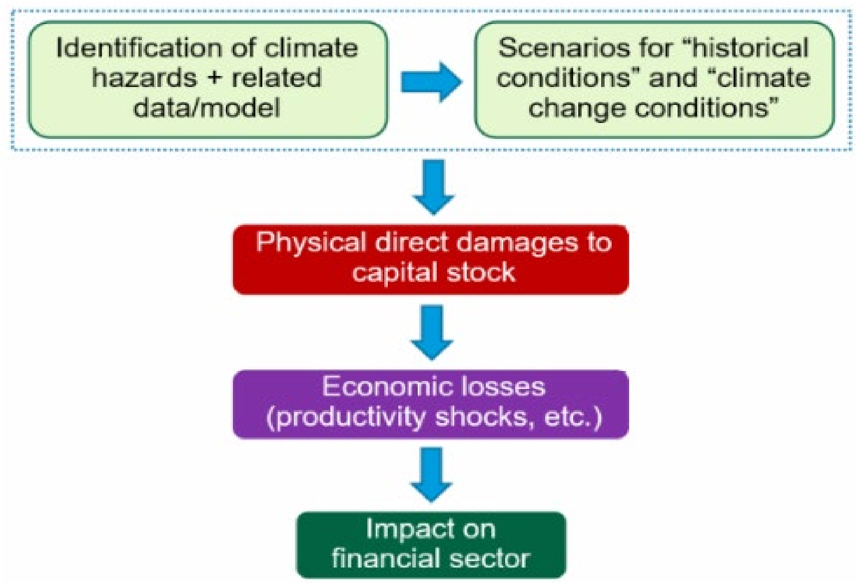
43. Physical risks cause physical damage (direct impacts) as well as broader disruption to economic activity (indirect impacts). For example, floods can result in damages and losses of assets, including production facilities, infrastructure, and commercial and residential properties. Such destruction of capital can reduce asset values and disrupt production activities and supply chains, affecting economic activity in the region directly impacted, as well as other regions via contagion effects. Similarly, droughts and fires can have direct and indirect impacts on a range of sectors (e.g., agriculture, forestry, and water-dependent sectors), as well as sectors connected via supply chains, and the broader economy (e.g., via impacts on food prices). Such impacts can affect firms' profitability and raise credit risk to lenders.

B. Methodological Approach

44. The FSAP followed a macro-approach to analyzing the impact of physical risks on the financial system (IMF, 2022, Figure 14). First climate scenarios under current and hypothetical future climate scenarios are defined. Catastrophe risk models are then used to estimate direct damages to capital stock. The macro-financial impact of physical hazards is subsequently modelled using a standard global macro-financial model. The GFM model allows for generating general equilibrium paths of macro-financial variables given various shocks, including those arising from the destruction of physical capital stock, a decline in productivity, or a drop in house prices.[19]

Figure 14. Indonesia: Methodological Approach

The modeling framework for physical risk analysis follows a macro approach



Source: IMF.
Note: CGE = Computable General Equilibrium; ICR = Interest coverage ratio; LR = Leverage ratio; CR=Current ratio.

Physical Risk Scenarios

45. The FSAP considered the potential impacts of a flood scenario (Scenario FL) and a compound earthquake and flood scenario (Scenario EQ-FL). Additional combined scenarios for drought and fire were also considered, however their macroeconomic and financial sector impacts could not be adequately modelled for the FSAP analysis.

46. Scenario FL represents a series of floods with direct damages equivalent to a 1-in-50-year aggregate annual damages from flooding. This scenario is based on the JBA flood risk profile for Indonesia (2021). These floods could be envisaged as serious flooding in Jakarta and surrounding provinces. As discussed above, Jakarta has high flood risk, and has historically experienced several severe events, primarily caused by heavy rainfall. Climate change has the potential to worsen the frequency and severity of floods in the region, primarily due to impacts on extreme precipitation, with sea level rise, subsidence, and ongoing urbanization also contributing to increased risk.

[19] GFM is a stochastic dynamic general equilibrium model set up for forty countries, featuring several nominal and real rigidities, a financial sector and interlinkages. Details of the model are provided in Vitek (2018).

47. Scenario EQ-FL represents a compound shock consisting of a 1-in-100-year earthquake event followed by 1-in-50-year flooding. The earthquake and flooding are assumed to occur within the same year. The earthquake component of the scenario is based on the GEM earthquake risk profile for Indonesia (2023). According to GEM (2023), the physical loss associated with a 1-in-100-year earthquake in Indonesia would be significantly larger than the loss associated with the 2004 Sumatra and 2018 Sulawesi earthquakes. This is because the 2004 and 2018 events occurred in regions of relatively low capital stock and economic activity, compared to other regions. Therefore, it was considered relevant to use a more severe event as part of this FSAP, should a future earthquake occur in a region with higher capital stock and economic activity (e.g., in Jawa). Scenario EQ-FL was included to analyze the potential for substantial economic and financial impacts if Indonesia is impacted by a series of independent events in close succession. Given that both the modelled earthquake and flooding events are already "tail" events, the compound shock would be a very extreme event (low probability of the earthquake and flood occurring in the same year) but is nonetheless considered plausible. Series of extreme events have occurred historically in Indonesia, as illustrated by an analysis of EM-DAT event data (CRED, 2023). A recent example is the magnitude 7.5 Sulawesi earthquake in September 2018, followed several months later by the May 2019 Sumatra and then the December 2019 Jawa floods.

48. The succession of earthquakes and floods could potentially result in compounding of damages through a range of mechanisms. For example, earthquakes can trigger landslides mobilizing sediment and debris that can block river channels and worsen flooding (Tang and others, 2011). In addition, ground subsidence and uplift (affecting rivers, other channels, and the floodplain) and damage to flood protection infrastructure (e.g., levees and urban drainage infrastructure) can result in increased flood hazards (Cavalieri and others, 2023). Such effects are difficult to foresee and quantify—for the FSAP analysis a simple assumption of the compounding of direct damages has been used (discussed below). Indirect economic impacts may also be nonlinearly amplified through compounding effects arising from various feedbacks (NGFS, 2023), though these dynamics are not captured in the macro modeling used in this FSAP analysis.

49. To analyze potential future impacts of climate change on the severity of flood risks to the financial sector, two versions of each scenario have been defined. The first version is based on the estimated distribution of extreme events under current climate conditions (FL-current and EQ-FL-current). The second version is defined based on literature reviews of the estimated distribution of extreme events under future climate change conditions by the middle of the century (FL-cc2050, EQ-FL-cc2050). These future climate change scenarios consider potential future increases in flood hazard severity (e.g., due to changes in precipitation, subsidence, and sea level rise) but assume constant vulnerability and exposure, and no change in earthquake risk.

Damage Estimates

50. The methodology for estimation of the financial sector impacts for each of the scenarios uses a "modeling chain" approach. Catastrophe risk models are used to estimate direct damages, which are then used as input to the economic and financial sector impact modeling. The direct damages are modelled as the percentage of physical capital stock that is damaged due to the extreme event(s) defined for each scenario. Catastrophe risk models are used to estimate direct damages using a bottom-up modeling approach that combines information on hazard (e.g., the flood depths or earthquake-induced ground shaking at different locations for events of different frequencies and severities), exposure (e.g., the spatial distribution of residential, commercial, and industrial assets and their characteristics), and vulnerability (estimating the damage expected for a given flood depth and/or ground-shaking for the exposure at risk). The earthquake model estimates were provided by GEM (2023),[20] and the flood model estimates by JBA (2021).[21]

51. Direct damages estimates under future climate change conditions are based on estimates from available literature, but are associated with very high uncertainty. Several research studies focused on flood risk in Jakarta were reviewed for the analysis. Whilst several quantify changes in flood hazard,[22] only a subset estimate changes in the expected damages due to changes in precipitation, land subsidence, sea level rise, and other dynamics.[23] Januriyadi and others (2018) simulated future flood risk in Jakarta, based on combination of urbanization and climate change. Climate change alone is expected to increase the expected annual damage costs for flood by 54–100 percent by 2050 and 72–127 percent by 2100. Land subsidence is expected to increase expected annual damage costs by 95 percent. However, these estimates are associated with large uncertainties as the results of the study are aggregated across multiple representative concentration pathways (RCPs), making it difficult to disentangle estimates of changes in flood risk under a particular pathway. Estimates by Budiyono and others (2016) and Muis and others (2015) also show very high ranges of uncertainty. Budiyono and others (2016) found that precipitation changes could result in changes in flood risk ranging from a decrease of 94 percent to an increase of 104 percent, while sea level rise could increase risk by 7–20 percent, depending on the RCP and climate model used. Muis and others (2015) estimated that between 2000 and 2030, sea level rise could contribute a 19–37 percent increase in flood risk by 2030. Model results from Aqueduct Floods indicates a potential doubling of the percentage annual expected urban damage risk for an RCP 8.5 scenario by 2050, and a tripling by 2100. Based on the range of estimates in the literature, a highly simplified

[20] GEM's earthquake risk profile for Indonesia (GEM, 2023) was produced using the Global Earthquake Model (GEM). GEM is an open global earthquake risk model developed by the GEM Foundation. The model consists of several key modules: a repository of probabilistic seismic hazard models; a global exposure dataset with information on residential, commercial, and industrial buildings; and a set of fragility and vulnerability functions. For further details of the GEM methodology, see Silva et al. (2020). The GEM modelled damages (as a percentage of total exposure) were used to derive the estimate the percentage of capital stock damaged, which were subsequently used to estimate TFP and house price impacts, used as input to the macro model.

[21] JBA's flood risk profile for Indonesia (JBA, 2021) was produced using JBA's Global Flood Model. JBA's Global Flood Model is a probabilistic flood model, which can model losses to buildings, contents and business interruption from fluvial and pluvial flooding. It uses a Global Flood Event Set, which contains a catalogue of more than 15 million plausible flood events worldwide. The data in this event set characterizes the extent and intensity of flooding geographically. To produce the flood risk profile for Indonesia, JBA ran the Global Flood Model using exposure data from the Ged4All exposure database, including data on estimated number of buildings, construction type, occupancy code and respective replacement values. The JBA modelled damages (as a percentage of total exposure) were used to derive the estimate the percentage of capital stock damaged, which were subsequently used to estimate TFP and house price impacts, used as input to the macro model.

[22] E.g., Bennett and others (2023) and Priyambodoho and others (2022).

[23] E.g., Januriyadi and others (2018), Budiyono and others (2016) and Muis and others (2015).

assumption was taken for the FSAP analysis to illustrate plausible climate change and land subsidence impacts on flood risk: relative to FL-current, direct damages are assumed to increase by 145 percent for the FL-cc2050 scenario for an intermediate climate pathway.[24] This assumption is illustrative only, and should be further refined in future work.

52. To model the compound shock Scenario EQ-FL, the modelled earthquake damages were summed with the flood damages (for current climate and future climate change versions), with an amplification factor applied to the flood damages to capture potential compounding effects. The compounding effects from the earthquake are assumed to result in a 30 percent increase in flood damages. However, as discussed above, the processes and dynamics that could cause compounding of direct damages are highly uncertain and difficult to model. Hence the assumption of a 30 percent amplification used for this analysis should be interpreted as illustrative only. It was nonetheless considered relevant to include an estimate of a possible compounding effect in the analysis to highlight the potential for such effects to exacerbate the impacts of climate-related physical shocks.

53. The results of the estimation of the direct damages highlight the potential for high direct damages from climate-related shocks. For the historical/current climate conditions, Scenario FL and Scenario EQ-FL are estimated to result in direct damages of 1.21 percent and 2.81 percent of capital stock, respectively (Table 5). By mid-century, due to the effects of climate change and land subsidence, the direct damages for the analyzed scenarios are estimated at 2.97 percent and 5.09 percent for Scenario FL and Scenario EQ-FL, respectively.

54. Direct effects of physical hazards are also generally accompanied by indirect effects that could amplify the initial direct effects. The FSAP considered two additional channels and amplifiers to account for impact that is not captured by immediate direct damages. First, shocks to total factor productivity (TFP) arising from the direct damages to the capital stock. Disasters reduce the productivity since it may not be possible to rebuild the capital quickly enough for the output to recover. Damage to infrastructure could also result in non-infrastructure becoming less productive, which can magnify the impact of the disaster (Hallegatte and others, 2023). Empirical studies confirm that disasters reduce both the stock of capital and TFP (Bakkensen and Barrage 2018), with roughly one-third of the impact on GDP stemming from capital destruction, and the other two-thirds are due to the accompanying TFP shock. The shock to TFP was thus calibrated to be twice as much as the capital stock damage rate and assumed to be highly persistent, consistent with previous FSAPs (Philippines, 2022; Mexico, 2022). Second, a decline in house prices equivalent to the destruction of the housing stock[25] under the different scenarios was assumed.[26]

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[24] The scenarios are estimated to be representative of a pathway between RCP 4.5 and RCP 8.5.

[25] The damages to housing stock were estimated based on the estimated damages to residential exposures reported by GEM (2023) and JBA (2021). A decline in house prices equivalent to the destruction of the housing stock is an extreme scenario and likely an upper bound to the actual decline in house prices.

[26] There could be other indirect channels, for example adverse effects on employment and stock markets. However, the impact of these channels within the macro model considered in this analysis are likely going to be small.

Table 5. Indonesia: Physical Risk Scenarios

Scenario	Shock to Capital Stock (Percent)	Shock to House Prices (Percent)	Shock to TFP (Percent)
Flood under current climate conditions	1.21	1.64	2.42
Flood under mid-century climate conditions	2.97	4.02	5.94
Earthquake and flood under current climate conditions	2.81	3.35	5.62
Earthquake and flood under mid-century climate conditions	5.09	6.44	10.18

Source: World Bank staff calculations.

55. The estimated direct damages are sensitive to the design of the scenarios, including the selection of return periods and the size of the TFP shock. The scenarios considered in the analysis focus on a 1-in-100-year earthquake, and 1-in-50-year flooding. These return periods were considered relevant for the analysis to capture severe but plausible shocks. However, the results are sensitive to this selection of return period. For example, if a 100-year return period is used instead, the direct damages are estimated to be 16 percent higher for flooding (JBA, 2021). The direct damages for the 1-in-100-year earthquake used in this analysis are 75 percent higher than the estimate for a 1-in-50-year earthquake (GEM, 2023). There are also large uncertainties related to the likely impact of a disaster on TFP, especially on a geographically large country like Indonesia. As a robustness test, a milder version of the compound scenarios have been considered as well, with a 1-in-50-year earthquake scenario and a TFP shock based on Dieppe, Çelik and Okou (2021).

56. There are large uncertainties and limitations associated with the direct damage estimates used in this FSAP analysis. The modelled direct damage estimates rely on outputs from two global catastrophe risk models (JBA and GEM). These models themselves are subject to uncertainties and dependent on underlying assumptions. Different models could potentially produce different estimates of direct damages for similar scenarios.[27] A comparison of model results could be considered for future work on quantifying climate and disaster risks in Indonesia. As discussed above, there are also large uncertainties in the potential impacts of climate change on future flood risk. These are associated with uncertainties in climate pathways, as well as estimates of the changes in risk associated with different climate pathways. For this FSAP, an effort was made to use literature focused on Jakarta and Indonesia, however, even amongst the available literature for this region there are a wide range of estimates of potential future changes in risk. Further, there are considerable uncertainties stemming from the estimation of potential compounding effects for

[27] While several other catastrophe models are available for Indonesia (e.g., Inasafe, Maipark, RMS), the FSAP team did not have access to these models for this analysis.

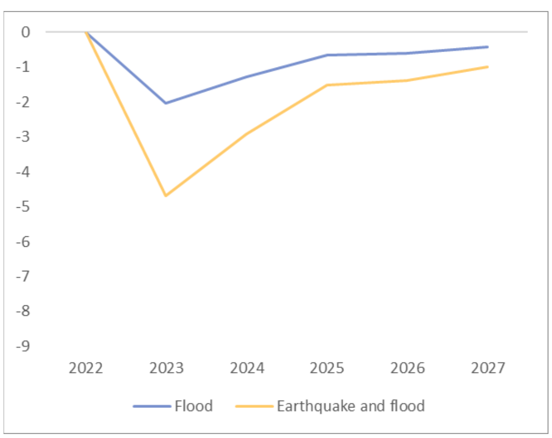
Scenario EQ-FL, as highlighted above. There are also several dynamics that are not captured in the scenario direct damage estimates. For example, the scenarios do not consider urbanization (which can affect the concentration of exposures and also alter flood hazard due to impacts on hydrology). In addition, risk reduction measures (e.g., potential future investments in flood protection infrastructure) and other adaptation measures that could reduce the direct damages are not modelled. Together, these factors mean that there is large uncertainty in the direct damage estimates, hence they should be interpreted as illustrative plausible scenarios rather than precise estimates.

C. Macro-Financial Impact

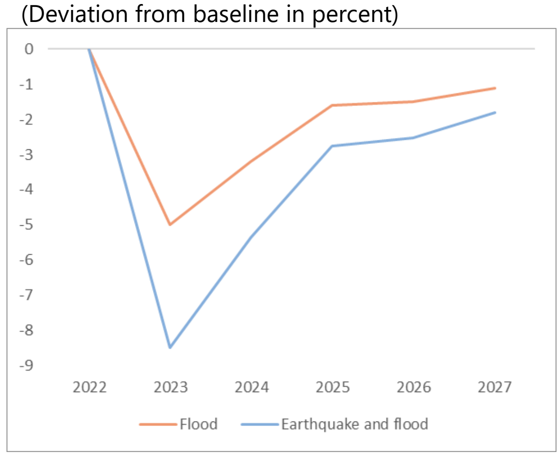
57. The macroeconomic impacts of floods and compound flood and earthquake scenarios can be substantial, especially under hypothetical future climate conditions (Figure 15). Damages to physical capital were modelled as negative investment specific shocks such that not just the production possibilities are damaged but that there is an immediate drop in aggregate output. The drop in potential output is then partly offset by the demand effect and monetary loosening. After the event demand for capital and investments increases. The drop in total factor productivity is modelled as a negative supply shock lowering potential output and the demand for labor and capital. In the absence of a significant drop in demand, prices increase, and monetary policy tightens. The devaluation of the housing stock leads to a wealth effect and lower housing investments. Overall, macro financial impacts result in lower output and somewhat higher inflation after the shock. As the shock fades away the economy returns back to the counterfactual in the medium run.

Figure 15. Indonesia: Preliminary Results for Climate Change Physical Risk Analysis

Simulated Output Paths, Current Climate Conditions
(Deviation from baseline in percent)



Simulated Output Paths, Mid-century Climate Conditions
(Deviation from baseline in percent)

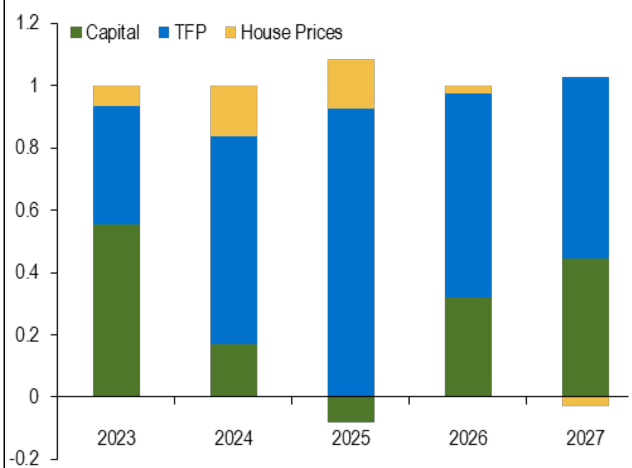


Source: IMF staff calculations.

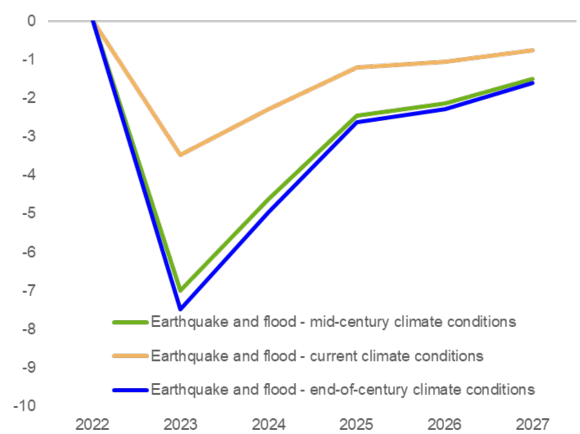
58. Shocks to TFP and to capital stock have the largest impact on output growth (Figure 16, panel 1). While the shock to capital stock has the largest immediate impact the decline in productivity is the main driver of lower output growth in the medium term. Alternative scenarios with a more modest shock to capital stock (considering a 1-in-50 year earthquake scenario) and TFP (based on Dieppe, Çelik and Okou, 2021) show a slightly less pronounced drop in output (Figure 16, panel 2).

Figure 16. Indonesia: Drivers of Output Deviation and Alternative Scenarios

Contribution of Capital Shock, TFP Shock, and House Price Shock to Output Deviation
(Percent)



Simulated Output Paths, Alternative TFP Shock, and 1-in-50 Years Earthquake Shock
(Deviation from baseline in percent)



Source: IMF staff calculations.
Note: In panel 2 a scenario with a 1-in-50-year earthquake scenario and TFP shock based on Dieppe, Çelik and Okou (2021) is considered.

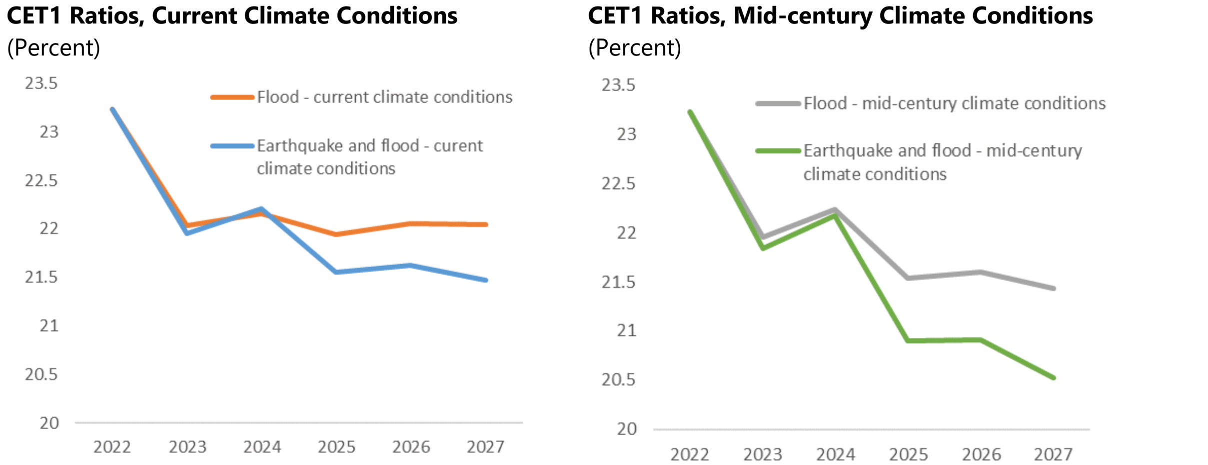
59. The climate risk analysis follows the same methodology as the scenario-based bank stress test.[28] The macro scenarios are translated into the evolution of PDs, LGDs and interest rates using a set of satellite models, and indirectly affect the growth of balance sheet items, pre-provision net income and other components. Shocked risk parameters drive Risk-Weighted Assets and provisions, market valuation and net interest income changes to obtain CET1, Tier 1 and total capital and leverage ratios over the stress testing horizon. The baseline scenario draws on projections from the IMF October 2023 WEO.

60. Under current climate conditions, the financial stability implications from physical risk appear modest. In the case of Indonesia, the main drivers of capital losses of banks due to physical risk shocks are a decline in growth and asset prices following the shock, and to a lesser extent the reaction of interest rates. While the economic damages across scenarios can be severe, the impacts on the banking system are generally modest, with capital ratios declining by a maximum of about 2

[28] See IMF (2024b) for a detailed description of the methodology.

percent in the most severe compound earthquake and flood scenarios (Figure 17, panel 1). Under hypothetical future climate conditions the impacts on the banking system could be more substantial, especially for compound scenarios (Figure 17, panel 2).

Figure 17. Indonesia: CET1 Ratios under Different Climate Scenarios



Source: IMF staff calculations.

61. **It is important to interpret the results with caution given a range of scenario and model limitations.** The aggregated national-scale macro model used to arrive at impact on GDP and other macro relevant variables, the regional variations, do not capture the interconnected dynamics across different parts of the country in a sufficiently granular way. Especially banks with regionally concentrated loan portfolios could be vulnerable to regionally concentrated shocks. Additionally, given the linearized dynamics of the model, any significant non-linearity that could be associated with amplifications effects even in an aggregated model, are not captured. There is also substantial uncertainty related to the scenarios, especially under future climate conditions.

CONCLUSIONS AND POLICY RECOMMENDATIONS

62. **The climate change physical and transition risk analysis should be considered exploratory.** There is a high degree of uncertainty associated with the modeling of the impacts of climate change physical and transition risks on the financial system. The physical risk analysis is subject to uncertainty related to the modeling of direct damages from physical risk events, in particular under future climate scenarios, the transmission channels in the macro-financial model, and the financial sector impacts. The transition risk analysis is subject to uncertainty from the modeling of the macroeconomic pathways and firm-level behavior. The analysis of physical risks was further limited by a lack of comprehensive and granular data on banks' loan-level exposures to firms, firms' location of assets, and firms' insurance coverage. Similarly, the lack of loan-level exposure data of banks prevented a more granular analysis of individual banks' exposures to transition risks. The limitations of the analysis and the restriction of the scope of the analysis to only a subset of potential climate-related risks (e.g., chronic physical risks and drought risks were not

quantified), mean that the results of the analysis could underestimate climate risks. Further, there may be large differences in the impacts of climate risks on different financial institutions – this heterogeneity is not captured in the analysis.

63. BI and OJK should further build their understanding of climate-related financial risks to inform the development of supervisory practices. Key policy recommendations focus on building capacity to conduct climate analysis, data collection, and improved collaboration across agencies:

64. The capacity to conduct climate risk analyses, including climate risk stress testing, should be expanded. While a comprehensive climate risk assessment for the financial sector is pending, BI is actively collaborating with development partners in risk assessments for the energy sector. Meanwhile, OJK has launched a bottom-up pilot climate risk analysis with selected banks. Looking ahead, BI and OJK should enhance their climate risk analysis and stress testing capacity, considering a joint pilot exercise that could serve as a starting point for an informed macro-prudential and micro-prudential approach to climate risk. They should work towards developing macro-financial scenarios and models to assess climate impacts comprehensively – covering both transition and physical risk scenarios. In this context, technical assistance from the World Bank and IMF could be considered to build up capacity.

65. Data collection should be strengthened to enable more comprehensive and granular analyses of climate-related risks to the financial system. This should include collecting information from locally available natural catastrophe models and location-specific data on banks' loan exposure to allow for the analysis of regional heterogeneity in physical risk. Similarly, data on asset-level insurance coverage for hazards would be helpful to assess the exposure of financial institutions to physical risks. To conduct detailed transition risk analyses more granular data on firm-level greenhouse gas emission and loan-level data of bank exposures should be collected. Further work could also be done to address modeling uncertainties. For example, for physical risk, modeling refinements could focus on enabling the analysis of drought scenarios in the macro models used for the analysis, improved modeling of key transmission channels (e.g., refinement of assumptions related to TFP impacts), and exploration of modeling options that would enable sub-national heterogeneity of impacts and uncertainties to be better captured throughout the modeling chain.

66. Given the cross-sectoral nature of climate risk, collaboration among government agencies, research institutions, and the private sector should be improved. Measuring climate-related financial risks requires additional data and methodologies not typically available to regulators and financial institutions. Authorities need to improve data and knowledge sharing across agencies, such as BMKG and BNPB. In addition, collaboration and data sharing between BI and OJK on climate risk analysis should be strengthened.

Appendix I. Sectoral Mapping

Appendix I. Table 1. Indonesia: Sectoral Mapping	
NACE	**MANAGE**
A.2, A.3	Forestry and fishing
B.5	Coal
B.7, B.8, B.9	Other extraction
C.19	Products of oil and gas refinary
C.11	Beverages and Tobacco
C.10	Food Manufacturing
C.12	Beverages and Tobacco
C.13, C.14, C.15	Textile
C.16; C.17; C.22; C.23; C.33; C.28; C.32	Other Manufacturing
C.20	Chemicals
C.27; C.26	Electronic equipment
C.29; C.30	Motor vehicles and parts
C.31	Furniture
C.21	Pharmaceuticals
F.41; F.43	Construction
G.45; G.47; G.46	Trade
H.49; H.53	Road Transport
H.50	Water Transport
H.51	Air transport
I.55; I.56	Hotels and Rest
J.61	Communication
K.64; K.66	Finance
Q.86; Q.87	Health
A.1	Crops & Livestock and livestock product
B.6	Crude oil & Natural gas and geothermal
C.24	Basic iron and steel & Nonferrous basic metal
C.25	Materials and products from metal & Metal based
D.35	Electricity gas & Electricity hydro & Electricity solar & Electricity coal & Electricity other
Other sectors	Other services

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