TECHNICAL ASSISTANCE REPORT

BARBADOS

Climate Risk Analysis

January 2025

Prepared By

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This technical assistance mission Climate Risk Analysis component was made possible thanks to the financial support of the IMF-Germany Climate Change Capacity Development Program 2019-2026, which is funded by the Government of Germany, represented by the Federal Ministry for Economic Cooperation and Development (BMZ).

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Glossary

BBD	Barbadian dollar
BSS	Barbados Statistical Service
CARTAC	Caribbean Regional Technical Assistance Centre
CBB	Central Bank of Barbados
CIS	Credit Information System
CRA	Climate risk analysis
CMIP	Coupled Model Intercomparison Project
CZMU	Coastal Zone Management Unit
FEMA	Federal Emergency Management Agency from the United States
FSC	Financial Services Commission
GDP	Gross Domestic Product
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
l.h.s.	left hand side
MCM	Monetary and Capital Markets Department
NGFS	Network for Greening the Financial System
NPLs	Non-performing loans
NCRIPP	National Coastal Risk Information and Planning Platform
SSP	Shared Socioeconomic Pathways
ST	Macroprudential stress test
READ	Research & Economic Analysis Department
RCP	Representative Concentration Pathway
r.h.s.	right hand side
TA	Technical Assistance

Preface

At the request of the Central Bank of Barbados (CBB), a Monetary and Capital Markets (MCM) Department mission visited Bridgeton, Barbados, from July 8 to July 12 to assist the authorities in climate risk analysis.

The mission met with CBB Governor Dr Kevin Greenidge, Mr. Alwyn Jordan CBB Deputy Governor, Mr. Anton Belgrave CBB Director Research & Economic Analysis Department (READ), Dr Saida Teleu CBB Chief Research Economist READ, Ms. Alexis Lescott CBB Deputy Director READ, other staff from the CBB READ, Jennifer Clarke-Murrell CBB Deputy Director Bank Supervision Department, other staff from the CBB Bank Supervision Department, Mr. Warrick Ward Financial Services Commission (FSC) Chief Executive Officer, Mr. Omar Best-Delice FSC Manager of Research & Policy, other FSC staff from the Research & Policy Division, and Mr. Ramon Roach Coastal Zone Management Unit (CZMU) Coastal Information Systems Manager. The mission wishes to thank CBB and the other authorities for their cooperation, productive discussions, and hospitality.

Executive Summary

The mission aimed to enhance the climate risk analysis (CRA) approach within the banking solvency stress testing framework of the CBB developed during a previous CARTAC TA mission. It sought to help the CBB integrate the CRA more deeply, involving identifying data sources, developing expertise for data utilization, and refining the climate risk component of their macroprudential stress test (ST) framework. Authorities aim to assess the resilience of the financial sector by incorporating the CRA. This TA supported the CBB in both short- and long-term climate-related efforts, including further integration of the climate component in CRA, improving understanding of data, and considering framework expansions based on hazard projections, exposures, and vulnerabilities for stress testing.

The mission engaged with the CBB to discuss and identify the necessary data for conducting analysis of climate-related physical risk. Discussions covered the data required for a CRA, the availability of country-specific data and estimates, and how to manage and use this data. The mission emphasized the critical role of damage rates, which are available from the Coastal Zone Management Unit, in integrating the climate effects within their stress testing framework and advocated for the ongoing development and refinement of CRA, including the integration of more granular and region-specific data over time to better assess and mitigate climate-related risks in the financial sector.

Similar to the macroprudential ST, CBB's CRA leverages the current macro framework to develop its scenarios. In the short term, damage estimates to touristic activity and buildings should inform impacts on economic variables for ST, exploring further linkages using the damages from the CZMU. At the same time, long-term strategies should advocate for keep developing their macroeconomic framework to comprehensively integrate climate implications. CBB is already and should keep collaborating with climate experts and initiatives to refine damage estimates and adapt to emerging climate scenarios. CBB should initially use CZMU's location-specific damage estimates for its CRA and, in the long term, adopt advanced methods, such as multivariate approaches or macro models, which will enrich the analysis of climate impacts.

Authorities must enhance the CRA framework and continue collaboration efforts to understand the banking sector’s resilience against climate-related risks. This entails the CBB deepening its knowledge and familiarity with climate hazards, exposures, and vulnerabilities and incorporating detailed banking sector data and region-specific considerations into its analysis. Leveraging existing damage estimates, such as those from CZMU, and expanding the scope to include diverse climate scenarios and hazards will help refine the assessment. Further developing economic linkages for stress testing, as discussed in the TA mission, is crucial for a comprehensive understanding of climate impacts on banking stability.

Recommendations

Table 1. Key Recommendations

Recommendations and Authority Responsible for Implementation	Priority	Timeframe 1/
Data		
1. Develop further capacity in understanding and using the data required for Climate risk analysis – CBB **(Para 19.)**	High	Short term
2. Close the identified data gaps on exposures from the banking system to integrate a micro component or approach – CBB and FSC **(Para. 15)**	Medium	Medium term
3. Gather damage or impact-related data for integrating specific considerations into the Climate risk analysis – CBB and FSC **(Para. 16)**	Medium	Long term
Climate risk analysis framework		
4. Define the framework to be implemented among the set of options and a clear timeline for conducting a first exercise - CBB **(Para. 25)**	High	Short term
5. Expand the framework to integrate further considerations among the set of options – CBB **(Para. 25)**	Medium	Long term
Interagency collaborations		
6. Establish and foster collaborations to share or begin to gather data to integrate further considerations in the Climate risk analysis – CBB, and CZMU **(Para. 23)**	High	Medium term

1/ Short term: < 12 months; Medium term: 12 to 24 months; Long term > 24 months.

Introduction

1. **The mission aimed to help the CBB strengthen its CRA approach.** The TA mission focused on the integration of the CRA in the banking solvency stress testing framework and covered identifying data sources for actual and future exercises, developing expertise to understand and use the data, integrating estimates in the current framework, and discussing how to expand it in the future. This mission will allow authorities to refine the climate risk component and leverage the macroprudential stress test (ST) CARTAC TA mission conducted in August 2023.

2. **Authorities aim to foster a climate-resilient financial sector, continuing to integrate CRA into the financial stability work**. The CBB has made significant progress with the recommendations from the CARTAC TA on macroprudential stress test, strengthening their current framework, and making it viable to better incorporate the CRA component, focused on physical risk, to contribute to building a climate-resilient financial sector; with the current work limited to the impact on the tourism sector, with the inputs from CZMU .

3. **The TA work would allow the CBB to continue its short- and long-term climate work**. A first step for the CBB would be to integrate the climate component further in their CRA; this process entails achieving a better understanding of the data and exploring further the links from the damage estimates from the CZMU into the variables needed for the ST. As data becomes available, the CBB can explore expanding its framework, considering refinements in hazard projections, exposures, vulnerabilities, and links to the ST. The mission considered options for expanding the framework in the long term, taking account of the [existing/expected/etc.] constraints in terms of data availability, methodologies, and capabilities.

Background

4. **Barbados' real GDP recovered to pre-pandemic levels in 2023, mainly due to the recovery in the tourism and related sectors.** Following a 15.3 percent decline in 2020-21, real GDP expanded by 17.8 percent and 4.1 percent in 2022 and 2023, respectively. The recovery was driven by a rebound in tourism[1] and related activities from COVID-19 lows, albeit partially offset by adverse climate conditions that affected agricultural production. The economy continued to grow in 2024, posting a 3.9 percent expansion during the first nine months of the year, led by tourism, business services and construction activities, with tourism (Accommodation and Food services accounting for 13.2 percent of the GDP as of 2023) stimulating other related sectors such as wholesale and retail trade, entertainment, construction, and manufacturing. Construction activity grew by 7.2 percent in Q3 2024, supported by tourism-related and public sector investments, including water and road infrastructure rehabilitation.

5. **The labor market remained relatively strong despite temporary increases in unemployment claims.** While employment contracted slightly in 2023, the unemployment rate declined to 7.9 percent from 8.4 percent in 2022, well below the 8.9 percent pre-pandemic level. Unemployment claims temporarily increased within 2023, due to the severance of workers under the national clean-up program

[1] Tourist arrivals in 2023 increased by around 18 percent from 2022, with monthly arrivals at end-2023 surpassing pre-pandemic levels and continued to grow by 14.8 percent year-on-year in Q1 2024, driven by expanded airlift capacity and marketing initiatives.

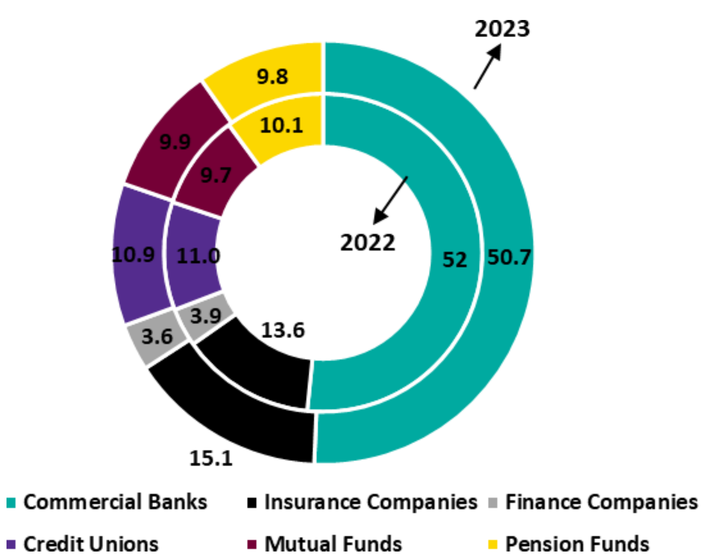
and the restructuring of the Arawak Cement Plant but have recently declined with claims in Q1 2024 falling by 8.4 percent compared to Q1 2023 levels.

6. **Inflationary pressures moderated in 2024.** Year-on-year retail price inflation fell to 4.8 percent at end-2023, from 5.7 percent at end-2022. In 2024, inflation rates continued to slow, reaching 2.4 percent in August 2024 year-on-year, down from 3.4 percent in 2023. This gradual decline was driven by the easing of global energy prices and reduce cost for transportation, communication and recreation but offset by higher domestic food prices, driven by adverse weather conditions.

7. **Barbados' banking sector is relatively large and mainly lends to individuals and corporates.** The banking system, together with finance companies, amounts to about 123 percent of GDP and corresponds to about 54 percent of total financial sector assets (Figure 1). There are six banks (93 percent of the sector total assets) and four finance and trust companies (7 percent of the sector total assets), at the end of 2023. All banks are universal banks, lending to both individuals and corporates. Finance and trust companies have a similar business model, with two of them mostly lending to individuals. Loans and advances are the main asset item, accounting on average for about 44 percent of total assets at the end of 2023, with slightly more than half of it reflecting loans to households and the rest to corporates and other sectors. The remaining assets are composed of investments (19 percent), deposits with the central bank and other financial institutions (22 percent of assets, mainly compulsory reserve requirements) and other assets (15 percent).

Figure 1. Distribution of Financial Sector Assets

Percentage of total assets



Source: Central Bank of Barbados, Financial Services Commission

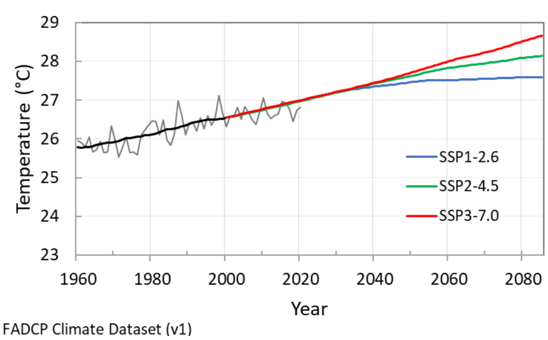
8. **Financial system conditions continued to improve.** In 2023, credit growth to the non-financial corporations (NFCs) private sector grew by 2.7 percent, driven by higher lending to businesses and households. In Q1 2024, new lending to the NFCs private sector remained relatively strong, up 36 percent from Q1 2023. The banking system remains resilient, as shown by the ample capital buffers; the capital adequacy ratio rose to 21.3 percent at the end of March 2024, from 17.6 at the end of 2022, well

above the 8 percent prudential requirement. In 2023, the increase in bank profits stemmed mainly from higher interest earnings on deposits held abroad, lower interest payments on local deposits and reduced provisioning costs. Asset quality also improved, with the non-performing loans (NPLs) to total loans ratio declining to 5.1 percent at the end of March 2024 versus 5.9 percent at the end of 2022. Meanwhile, provisioning remains well above the required levels. Financial soundness indicators for finance and trust and credit unions remained stable but not reassuring, with NPLs between 12-13 percent of total loans and capital adequacy ratios of 21 and 11 percent, respectively, at the end of 2023.

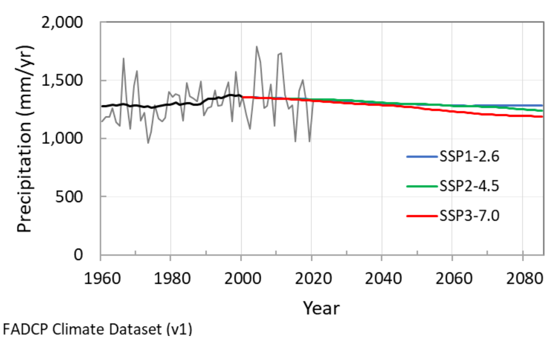
9. **Barbados' climate conditions would deteriorate under different scenarios, a risk that can be exacerbated by changes in storms in the region.** For Barbados, considering data from Coupled Model Intercomparison Project (CMIP) sixth phase (CMIP6) and three climate scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0), there is a clear increasing trend in temperature, which will range from 0.9 and 1.2°C by 2050 and between 1.0 and 2.1°C in 2085, with respect to the period of 1985 – 2000, with a level of 26.5 °C (Figure 2, l.h.s.).[2] For precipitation, which tends to be more noisy data, annual estimates have a decreasing trend and could be linked to water scarcity effects, such as droughts (Figure 2, r.h.s.); still, this needs to be interpreted with caution, as the annual averages can hide extreme behaviors, which would be associated with more severe storms. While Barbados is on the edge of the tropical cyclone area, any changes in where hurricanes from the North Atlantic basin originate, their paths, and intensity would increase the risk of storms threatening the country (Figure 3).

Figure 2. Future Climate Conditions in Barbados

Annual average temperature
In degree Celsius



Annual average precipitation
mm per year

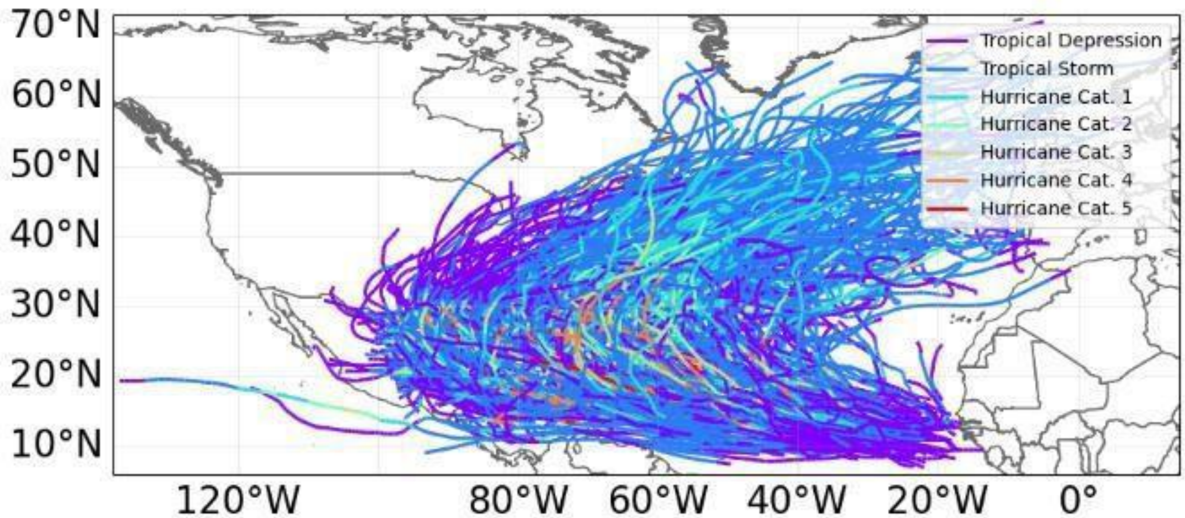


Source: FADCP Climate Dataset (Massetti and Tagklis, 2024), using CRU data (Harris et al., 2020), and CMIP6 data (Copernicus Climate Change Service, Climate Data Store, 2021).

[2] The scenarios denote the combination of the Shared Socioeconomic Pathway (SSP) and the Representative Concentration Pathway (RCP).

Figure 3. Tropical Cyclones in the North Atlantic Basin

Storms 1980 – 2023 and categories; Barbados' location in the basin



10. **Climate change endangers the Barbadian economy and can directly affect the banking system.** Climate deterioration could directly impact the tourism infrastructure or deter tourism, impacting the sector income and the related ones, affecting the whole economy, and diminishing the capacity to repay the loans. The banking system's concentration on mortgages (Figure 5) exposes it to the effects of more severe climate-related events in the physical collateral backing the loans, which could impact the value of the underlying asset and the income from households; these more severe events could also affect other sectors whose loans are backed with physical collateral, or that rely on it to generate income.

I. Identifying and using the data

11. **The mission explained and discussed with CBB staff the data required for physical risk CRA.** First consideration was on climate scenarios used to explore how the future would evolve under a range of alternative socioeconomic, technological, and policy conditions and the implications for greenhouse gas (GHG) emissions and climate, which can come from the Intergovernmental Panel on Climate Change (IPCC) or Network for Greening the Financial System (NGFS), both which consider outputs from CMIP. The second consideration was about the data used for the physical risk analysis on a CRA. To support this discussion, the TA reviewed the hazard projections, exposure, and vulnerability considered in different FSAPs, emphasizing that understanding the data allows for its correct use and allows the users to acknowledge assumptions and sources of uncertainty.[3]

[3] Philippines: Financial Sector Assessment Program-Technical Note on Bank Stress Test for Climate Change Risks, Bank Stress Testing of Physical Risks under Climate Change Macro Scenarios: Typhoon Risks to the Philippines (imf.org); Mexico: Financial Sector Assessment Program-Technical Note on Climate Risk Analysis; Maldives: Financial Sector Assessment Program-Technical Note on Bank Stress Testing and Climate Risk Analysis; Kingdom of the Netherlands–The Netherlands: Financial System Stability Assessment (imf.org); Japan: Financial Sector Assessment Program-Technical Note on Systemic Risk Analysis and Stress Testing (imf.org)

12. **CBB can leverage country-specific and publicly available sources for their CRA framework.** A CRA requires data on hazard projections, exposures, and vulnerability. For hazard projections, the TA used three datasets: (i) historical data from ERA5 Reanalysis for windspeed and precipitation, to exemplify the backend of the country's available calculations and set the basis to treat more granular data in the future; (ii) tropical cyclone tracks from International Best Track Archive Climate Stewardship (IBTrACS) to showcase and explain an event-based approach; and (iii) the estimates provided by the CZMU from the National Coastal Risk Information and Planning Platform (NCRIPP). For exposure, the TA covered global and country-specific datasets with different granularities. Although the CZMU estimates already consider an exposure, the different datasets allow a better understanding of the structures and integrate further granularity as it becomes available, such as banks-specific exposure from the Credit Information System (CIS) or CBB-specific request, and promote a more lean and interactive collaboration with the country climate experts, CZMU. On vulnerability, the mission discussed damage functions available from the literature for tropical cyclones and the one available from CZMU.[4]

13. **There is country-specific data available for different hazards and ongoing efforts to produce further estimates.** The CZMU is the country's main agency handling climate-related data. Moreover, the CZMU has already produced climate damage estimates for different hazards, with location-specific estimates on windspeed, rainfall floods, and storm surges for 1-in-50 and 1-in-100-year return period (Figure 4); the last two incorporate a climate-change consideration and differ by location, while windspeed does not consider climate change due to uncertainty and is not differentiated by location. The estimates correspond to RCP 4.5 (IPPC AR5) and do not include estimates without climate change effects (for comparison). While the underlying data has a high granularity (~100x100 m), it was aggregated to the parish and country level for the mission. Future work from CZMU would consider an event-based approach, which would allow for differentiated effects throughout the country, i.e., that different areas could be impacted with different intensities, which is not feasible with the current estimates.

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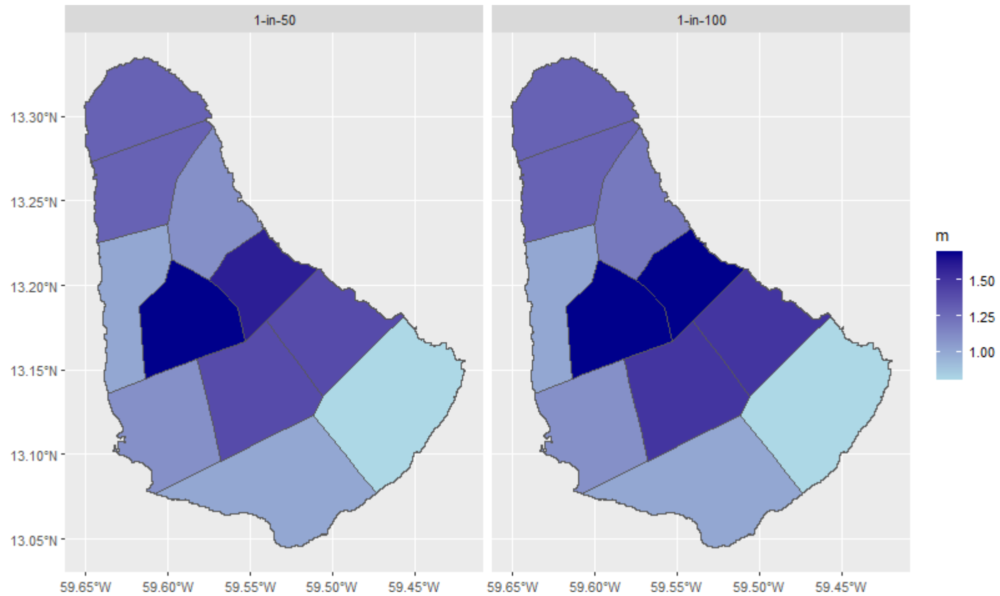
[4] The mentioned damage functions correspond Eberenz et al. (2021) and Emanuel et al. 2011:

- *Eberenz, S., Lüthi, S., & Bresch, D. N. (2021). Regional tropical cyclone impact functions for globally consistent risk assessments. Natural Hazards and Earth System Sciences, 21(1), 393-415.*
- *Emanuel, K.: Global Warming Effects on U.S. Hurricane Damage, Weather Clim. Soc., 3, 261–268, https://doi.org/10.1175/WCAS-D-11-00007.1, 2011*

Figure 4. Hazards Projections with Climate Change, RCP 4.5

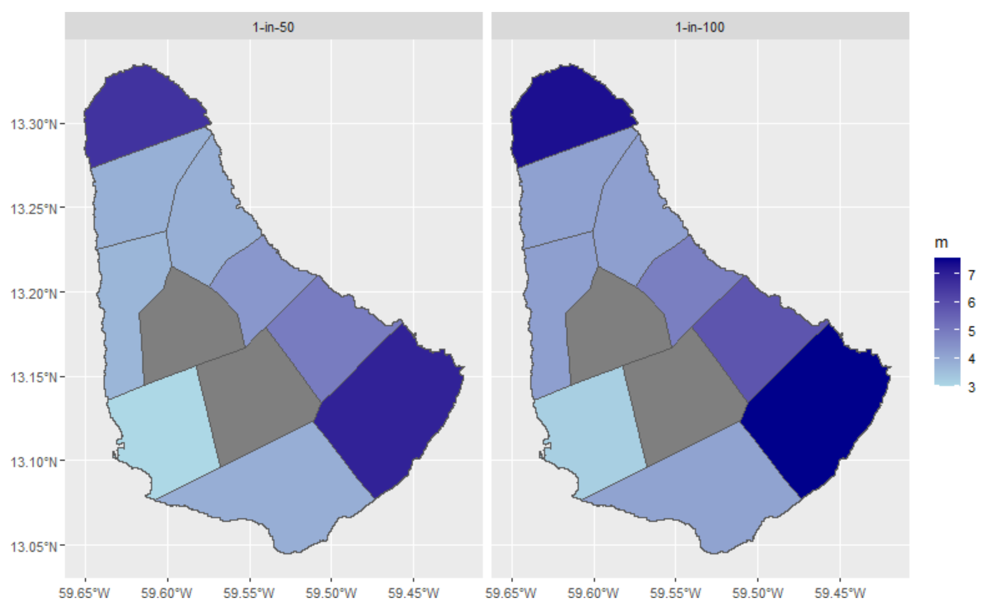
Rainfall flood by return period

In meters



Storm surge by return period

In meters



Source: Coastal Zone Management Unit; GADM; IMF staff

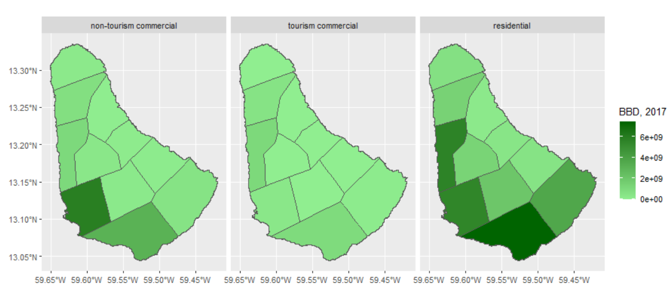
Note: The data corresponds to the average of the grids (~100x100 m) within each parish.

14. The exposure is differentiated by building type; other exposures must be considered outside the climate experts' model. The NCRIPP integrates an exposure layer of buildings which can be differentiated by residential, non-tourism commercial, and tourism commercial in constant BBD, 2017 (Figure 5). The exposure layer is the main consideration for defining a granularity of the NCRIPP estimates because it approximates to properties scale and allows for comparison with land surface, while hazards underlying granularity might be higher. Due to be a completed development, the exposure layer cannot be easily substituted in the calculations within the model, so, at this stage, different exposures, such as banking sector portfolios, would need to be considered outside the model. Future iterations can consider further exposure considerations, such as differentiating between public and private exposures, integrating infrastructure, or analyzing bank-specific exposures (e.g., mortgages), either integrated or outside the model. If not fully integrated, this would require some assumptions on the exposure distributions, such as that mortgages in a parish follow the residential building distribution within the parish. Furthermore, the current exposures align with other available datasets at a parish level, which were explored in the hands-on exercise.[5]

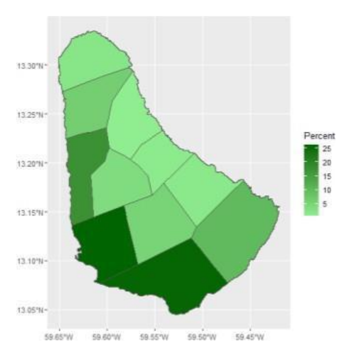
15. Additional information on granular geographical exposures would allow CBB to analyze climate-related effects on the banking system further. The banking system has a relevant exposure to mortgages, for which climate-related physical risk events could impact the underlying assets. In the long-term, the CIS could be a source to endeavor in the individual loan analysis (micro approach); still, the actual conditions do not allow the use of the underlying information, and its quality and completeness still need to be assessed. CBB should ensure that sufficient location information becomes available. Until this information becomes available, CBB could explore a specific request for banks on loans and credit characteristics to appropriately assess the impact of physical risk, starting with aggregates at sub-national geographical areas and for the mortgage portfolios. To better reflect the impact, the analysis should leverage information on corresponding insurance coverage and damages (i.e., claims information).

Figure 5. Exposures by Building Type and Aggregate

Buildings by building type
In BBD, 2017



Aggregate exposure
In percent



Source: Coastal Zone Management Unit; GADM; IMF staff

[5] Annex I. Exposure datasets

16. In the initial stage, the CRA should leverage available damage functions and aim to integrate country or region-specific considerations in the future. The mission discussed the relevance of damage functions, available from different sources, and which links the hazard intensity and the percentage loss or damage to the exposure. Estimates from the CZMU consider the Federal Emergency Management Agency from the United States (FEMA) Hazus damage functions, a widely used function developed for the United States; therefore, these damage functions might not accurately capture the Barbadian buildings and infrastructure characteristics, such as building codes. The insurance claims data, post-disaster surveys, and disaster relief transfers, available or that could become available from different agencies, would be useful for understanding or calibrating these impacts. Furthermore, similar regional information could better inform this effort, given that this data is scarce due to the nature of extreme events.

17. The damage rate is crucial for linking the climate component to the ST for developing a CRA. The CZMU provided the estimates for damages and exposures in each parish for rainfall, storm surge, and windspeed for two return periods. From this data, it is feasible to estimate a percentage of damage (Table 2 includes country-level estimates, and Figure 6 areas estimates for the hazards with climate change consideration, rainfall, and storm surge), i.e., the percentage of the total exposure that the specific hazard would damage under a specific return period. This percentage of damage or damage rate is the main input for linking the CRA with the ST. It is important to consider and understand the structure of the data from the CZMU, as a specific hazard and return period would account for the total exposure and mixing them would not be correct. Considering hazard projections, exposures, and damage rates, CBB, in a first step and to further familiarize with this type of data, can develop a climate diagnosis or exposure assessment; this process involves considering different climate hazard parameters and exposures, as well as other data sources and reports, and defining which are the most suitable for a CRA (Figure 7).

Table 2. Country Hazard Damage Rate

In percent of total exposure

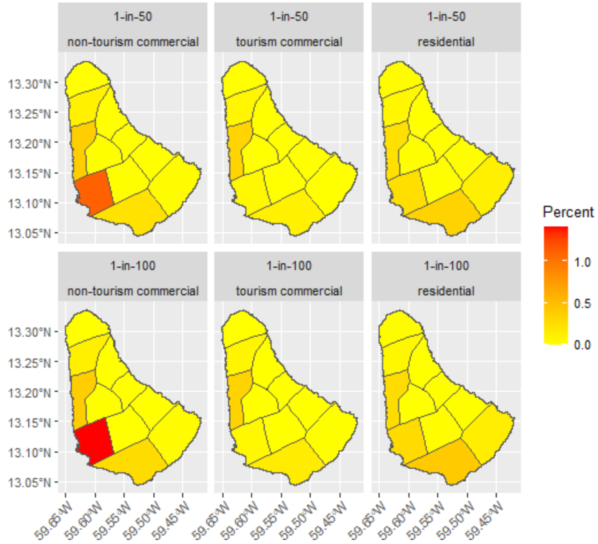
Hazard	Return period	
	1-in-50	1-in-100
Rainfall	3.5%	4.1%
Storm surge	5.0%	9.1%
Windspeed	1.8%	4.1%

Source: Coastal Zone Management Unit

Figure 6. Hazards Damage Rates

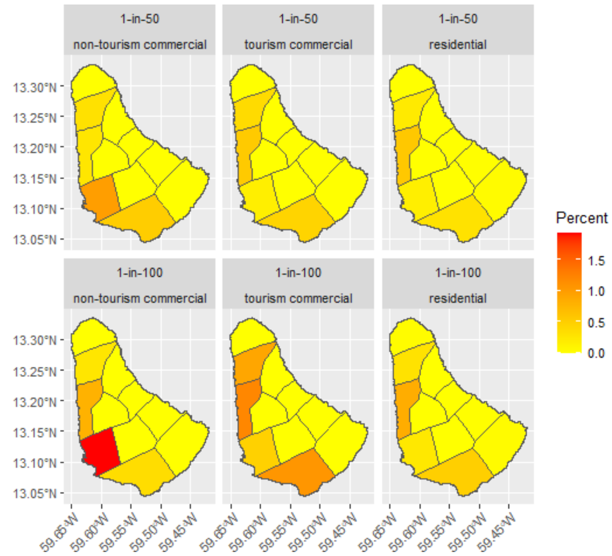
Rainfall flood damage rates

In percent, by building type and return period



Storm surge damage rates

In percent, by building type and return period

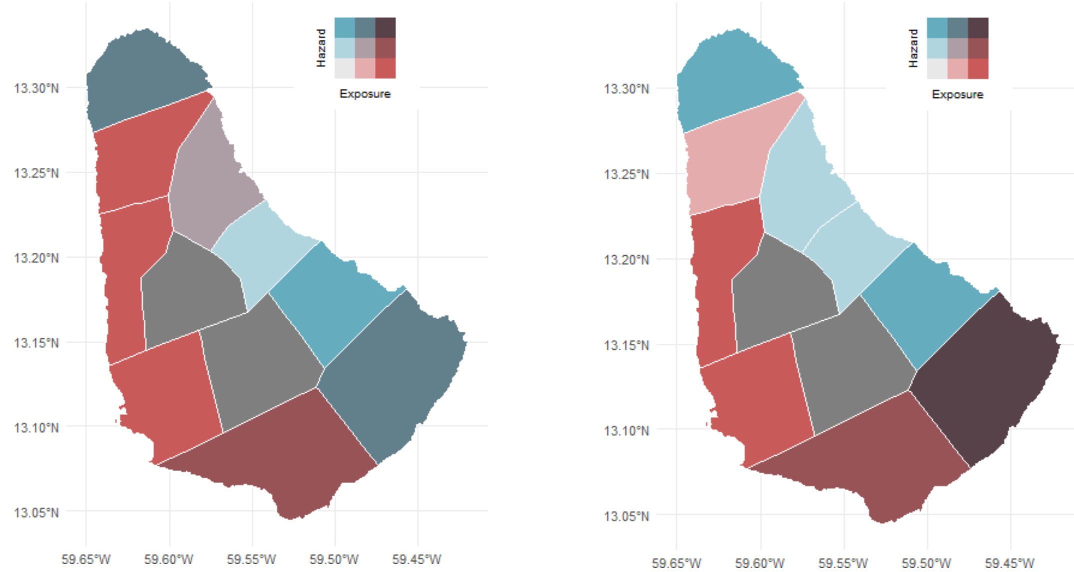


Source: Coastal Zone Management Unit; GADM; IMF staff

Figure 7. Exposure Assessment for Storm Surge by Parish

Storm surge 1-in-100
In meters; Tourism building exposure

Storm surge 1-in-100
In meters; Residential building exposure



Source: Coastal Zone Management Unit; GADM; IMF staff

Note: Considers quantile style classification for plotted variables

18. Understanding geospatial data is key for CRA and enhancing collaborations with climate experts. The TA explained different geospatial data structures for climate and exposure data and how to handle them. Central banks and banks do not typically use the data required for a physical risk CRA, which integrates a geospatial component; therefore, the mission explained this type of data and how to deal with the different formats and common operations, many of them covered through the practical examples in R and Python, which are a starting point to getting familiar with the data, structures, and operations. While CBB is on the right track to develop capabilities and use this data further, preferably with the open-source software mentioned, staff working on CRA would benefit from further knowledge and usage of this data, which should allow them to engage further in future collaborations as they refine their framework. The above can be done by getting familiar with the climate data structures, geospatial data usage, and methods used by their climate counterparts to produce estimates, considering a broad background on the different inputs needed.

19. The CBB personnel, involved in the CRA, should further comprehend the data, to keep refining their work and enabling more dynamic interactions with climate experts. The mission widely discussed and showcased hazards and exposure data, as well as damage functions, leveraging the CZMU data and other sources. Damage estimates constitute the main input for CRA. Therefore, CBB should keep building knowledge on the data and methods to integrate implications into the banking system assessment, identify and acknowledge the sources of uncertainty in the estimates, and refine approaches to CRA; this would also lead to more efficient collaborations with climate experts in the country.

II. Linking Damage Estimates and Macroprudential Stress Test

20. The ST leveraged the current macro framework and other models for developing scenarios, which were also used for the CRA. The current CRA framework from CBB considers linking damage estimates by impacting tourist arrivals; then, the effects on tourist arrivals are considered with the CBB macro framework, which integrates different econometric techniques with an accounting structure with four main components: real sector, fiscal sector, balance of payments, and monetary sector. The framework is utilized to assess the economic situation, develop economic policy, and provide forecasts, and used to obtain the GDP for the ST scenarios. The ST satellite models consider NPL ratios for total loans, personal loans, mortgages, and NFCs, and the relevant macro variables are GDP, tourist arrivals, unemployment rate, and inflation. Inflation is mainly imported and modeled with past inflation and international oil and food prices, unemployment is modeled outside the macroeconomic framework.

21. The TA explained the damage estimates and different linkages to the ST variables. The mission discussed previous FSAP approaches and how the damage rate, measured with different exposures, hazard projections, and damage functions, affect macro variables. In general, the damage rate, i.e., the percentage loss of the total exposure, has been used as (i) direct destruction of capital, decreasing the capital stock, and (ii) a long-lasting decline in total factor productivity (TFP). Subject to the ST satellite models and country-specific considerations, other links have been considered, such as (i) impact on unemployment, informed by the unemployment to capital elasticity, (ii) effects on financial markets, (iii) house prices shocks, among others. The different considerations depend on the quality of the data, variables relevant to the banking system, and the macro modeling framework. In this context, it was also discussed that damages need to be assessed, i.e., define if estimates are plausible; this can be done using historical databases, comparing to other studies or models from own or similar countries; still, information might be limited or lack quality.[6]

22. There are several options for linking the damage estimates from CZMU to the ST that CBB should analyze further. The mission discussed options for using the damages available, some for the short term and others that would require further work from CBB. In the short term, the CBB can leverage the damage rate from tourism buildings and total buildings; the first can be used to impact tourist arrivals, while the other can be used as a capital stock and get effects through a production function (GDP) and unemployment elasticities.[7, 8] Some preliminary estimations were made during the mission, and codes were shared but should be further analyzed and refined. In the long-term, some multivariate approaches can offer a more integrated and consistent approach, such as Vector Autoregressive (VAR) models, co-

[6] EM-DAT - The international disaster database (emdat.be) and DesConsultar on-line Main Menu (desinventar.net) are some options mentioned for assessing the estimates. For this type of comparison, it needs to be clear what does damages represent, given that multiple representations are followed (e.g., damages as percentage of GDP, damages as percentage of total exposure, loss to GDP due to damages).

[7] Annex II

[8] Annex III

movement of sectors with copulas, or setting a macro framework that is able to handle damage estimates specifically, such as DIGNAD.[9]

23. **The CBB should keep engaging with climate experts and foster collaborations with other climate initiatives relevant to financial stability.** Country-specific damage estimates are available; these estimates could be expanded to understand the banking sector stability implications better. The CZMU is the country's main agency producing climate-related damage estimates from hazards through the NCRIPP and handles climate projections. While CZMU has already produced damage estimates for the country under RCP 4.5, various stakeholders, like the CBB, would benefit from considering more recent scenarios (e.g., IPCC AR6 or NGFS Phase), as well as integrating other country-specific considerations, in terms of further exposure granularity by sectors, and country or region-specific damage functions. As other agencies develop their climate work, it is essential that CBB is aware of the different initiatives to foster alignment within the country and foresee further implications to the banking system (e.g., natural disaster considerations in financial instruments).

III. Set Options for a Climate Risk Analysis Framework

24. **The actual CBB's framework is a macro approach that considers the available estimates and the macro modeling setup.** The exposures in the CRA framework are for the whole country, and while granular (~100x100 m), they consider three subcategories and are not differentiated by banks. The mission discussed the two main approaches for CRA: (i) the macro approach, which considers country-wise exposures to estimate damages and links them to the macro variables, and (ii) a micro approach, which considers bank-specific exposures that could be impacted considering the climate estimates. Depending on the data, the approach could be something in between, considering country and bank-specific assumptions to model the exposures.

[9] User Manual for the DIGNAD Toolkit (imf.org)

Table 3. Options for Possible Frameworks

Hazard	Exposure	Vulnerability	Other
Consider an approach using location-specific information for hazards from CZMU (currently available) Long-term: consider event estimates and incorporate other climate effects (such as coastal erosion, and rising water temperatures and coral reef bleaching)	Country-specific information on building values available from the CZMU (currently available) Long-term: consider expanding into other exposures, such as differentiating between public and private infrastructure Medium-term: mortgage sector exposure considering credit characteristics aggregated by parish Long-term: Expand to financial sector exposures, and/or to individual exposures	Use FEMA-Hazus damage function (currently available) Discuss with the CZMU and other relevant stakeholders, such as the FSC, and countries in the region to incorporate Barbados/region-specific considerations to damage functions: (i) medium-term start collecting data (ii) long-term function calibration	Consider variable-specific links, using damage rates of total buildings and tourism buildings Long-term: Consider multivariate approaches to jointly model satellite model variables as a function of the capital stock delta of natural disasters or macro to model effects in an integrated way.

Source: IMF staff

25. **There are options for hazard, exposure, and vulnerability components to estimate damages; CBB should consider available estimates in the first exercise but aim to refine them.** The mission discussed several data options for a CRA. For an initial framework, CBB could consider the damage estimates available from the CZMU, which are location-specific, consider the building's values as exposure, and use available damage function; still, authorities should explore other options to refine their framework in the long-term such as: (i) for hazards, incorporating an event-based approach, or other hazards; (ii) for exposures, incorporating banking system specific exposure, refining the granularity by sectors, or differentiating between private and public exposures; (iii) on vulnerability, incorporate country or region-specific considerations, as data becomes available. Along the same line, the economic linkages between the climate-related impacts and the variables needed for ST should be refined further; in the long term, CBB could benefit from considering other approaches to produce scenarios more integrated and consistent, such as multivariate approaches or a macro model that captures the climate-related impact.

Conclusion

26. **Authorities must enhance their CRA and collaborations to build a more resilient banking sector.** CBB personnel involved in CRA must deepen their knowledge of hazards, exposures, and vulnerability data, ensuring further integration of these estimates in the banking system assessments and fostering more collaborations with their climate experts. CBB should aim to incorporate granular exposure

data from the banking sector to enhance the analysis of climate-related effects and plan to include more tailored, region-specific considerations in the future, acknowledging that current estimates have uncertainty from different sources. The assessment of physical risks to the banking sector can benefit from utilizing additional data sources to calibrate impacts more accurately, thereby facilitating a more resilient banking system.

27. CBB should consider current damage estimates and progressively refine them with broader scenarios and considerations. The CBB should leverage existing damage estimates from country climate experts, CZMU, for their CRA, which are location-specific damages considering granular hazard projections and building values data. Authorities must refine and enhance their framework over time, incorporating other climate scenarios, different hazards and approaches, detailed banking system exposure, further differentiating country-wide exposure, and considering country- or region-specific vulnerability data. Additionally, strengthening economic linkages for ST will bolster the understanding of climate impacts on banking stability.

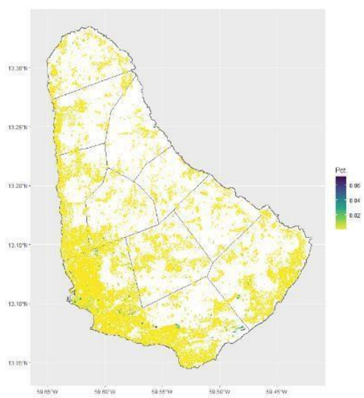
28. The TA mission discussed the recommendations, materials, codes, and possible dissemination at the closing meeting. During the meeting, the mission discussed all the recommendations for their CRA framework, considering priorities and timelines, as well as the materials and codes provided. Also, the mission highlighted the IMF dissemination policy for capacity development, and the authorities will consider publishing the TA. A follow-up TA could be scheduled upon completion of CBB's first climate risk analysis and when data becomes available to integrate further considerations or a micro approach.

Annex I. Exposure Datasets

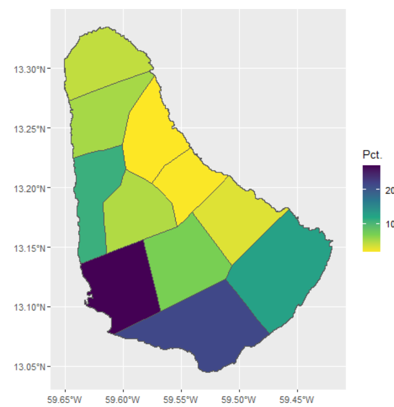
The hands-on work from the mission considered handling and analyzing different datasets. While exposures can be further differentiated in the future, the current total exposures in the NCRIPP seem aligned when compared to different datasets. Analyzing these datasets involved wrangling the data to achieve the same geographical granularity (Figure 8) as that provided at the parish level by the CZMU. Similarly, using the data on the population from the Barbados Statistical Service (BSS), the mission showcased how to work from parishes specific information (Figure 9), a format that could be used with a first set of possible banks' exposure.

Figure 8. Exposure Upscaling

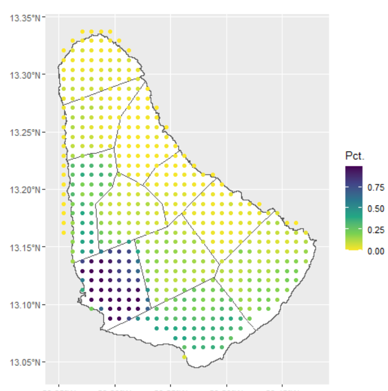
Individual buildings
Percentage of total square meters



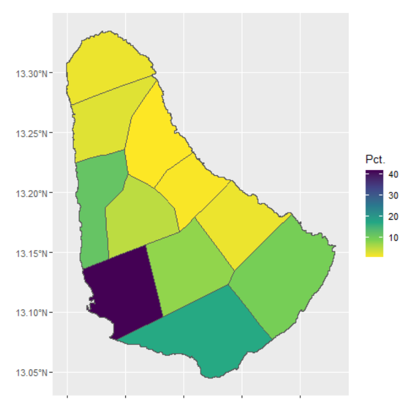
Buildings aggregated by parish
Percentage of total square meters



Gridded assets
Percentage of total assets



Assets aggregated by parish
Percentage of total assets

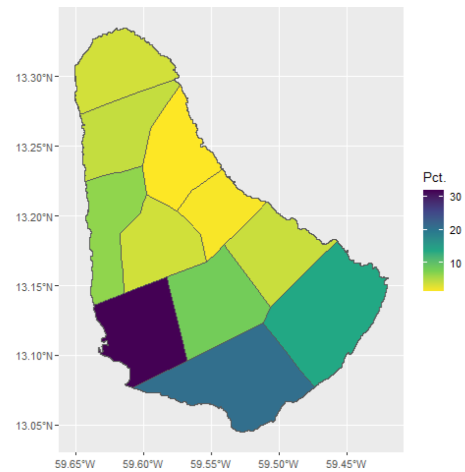


Source: GADM; Open Buildings[10]; LitPop[11]; IMF staff

[10] Open Buildings (research.google)

[11] Eberenz, S., Stocker, D., Röösli, T., & Bresch, D. N. (2019). LitPop: Global Exposure Data for Disaster Risk Assessment: Asset exposure data for global physical risk assessment.

Figure 9. Population Distribution
Percentage of total population



Source: GADM; Barbados Statistical Service; IMF staff

Annex II. Estimating Elasticities

Elasticity of Unemployment to capital

Measures how changes in capital affect unemployment rates; in theory, an increase in capital, which could include investments in machinery, buildings, or technology, might lead to a decrease in unemployment because more capital usually means more production capacities and potentially more jobs.

$$E_{uc} = \frac{\%\Delta\, unemployment}{\%\Delta\, capital}$$

Elasticity of Unemployment to GDP

Measures how sensitive the unemployment rate is to changes in GDP. An increase in GDP, which signals economic growth, generally leads to lower unemployment rates as businesses expand and hire more workers.

Calculating the elasticities

Estimating the elasticity of unemployment to capital using percentage changes involves creating variables that represent the percentage changes of unemployment and capital and then using these transformed variables in a linear regression model.

$$\%Change_{unemployment} = \beta_0 + \beta_1 \%Change_{capital} + \varepsilon$$

Another common approach for estimating elasticities is using a log-log regression model, where both the dependent and independent variables are in logarithmic form.

$$\ln(unemployment) = \beta_0 + \beta_1 \ln(capital) + \varepsilon$$

Preliminary elasticity estimates

Some preliminary elasticities estimates were obtained using economic data provided by the CBB and economic data time series from Penn Table and the United States Federal Reserve Economic Data (FRED).

Table 4. Elasticity unemployment to capital percentage change

	CBB + FRED
	$\%\Delta\, unemployment$
$Intercept$	0.03365 ( )
$\%\Delta\, capital$	-2.84970 (.)
R-squared	0.1221
Adjusted R-squared	0.08548

Significance codes: 0.001 (***), 0.01 (**), 0.05 (*); 0.1 (.)

Table 5. Elasticity unemployment to capital logarithms

	CBB + FRED
	$\ln(unemployment)$
$Intercept$	12.5952 (***)
$ln(capital)$	-1.0111 (***)
R-squared	0.4324
Adjusted R-squared	0.4097

Significance codes: 0.001 (***), 0.01 (**), 0.05 (*); 0.1 (.)

Table 6. Elasticity unemployment to GDP percentage change

	CBB	CBB + FRED
	$\%\Delta\, unemployment$	$\%\Delta\, unemployment$
$Intercept$	0.05097 ( )	0.007247 ( )
$\%\Delta\, GDP$	-3.24796 (***)	-2.857210 (***)
R-squared	0.3824	0.5211
Adjusted R-squared	0.373	0.5012

Significance codes: 0.001 (***), 0.01 (**), 0.05 (*); 0.1 (.)

Table 7. Elasticity unemployment to GDP logarithms

	CBB	CBB + FRED
	$\ln\,(unemployment)$	$\ln\,(unemployment)$
$Intercept$	23.6635 (***)	23.2968 (***)
$\ln\,(GDP)$	-2.8087 (***)	-2.5944 (***)
R-squared	0.5459	0.8163
Adjusted R-squared	0.5394	0.8089

Significance codes: 0.001 (***), 0.01 (**), 0.05 (*); 0.1 (.)

Annex III. Estimating the Production Function

Estimating a Cobb-Douglas production function involves econometric analysis, typically using regression techniques to fit your data to the functional form of the Cobb-Douglas equation. The Cobb-Douglas production function general form is:

$$Y = A \times L^{\alpha} \times K^{\beta}$$

where:

Y is the total production,

A is a constant term representing total factor productivity,

L is the labor input,

K is the capital input,

α and β are the output elasticities of labor and capital, respectively, which measure the percentage change in output resulting from a percentage change in labor and capital.

To estimate the parameters of the Cobb-Douglas production function using linear regression:

$$\ln(Y) = \ln(A) + \alpha \ln(L) + \beta \ln(K)$$