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2020 Student Research Case Study Challenge
Actuarial Valuation of Carbon Credits

Overview

In general, a carbon credit is a government-issued permit that gives the holder, such as a company, the legal right to emit one metric tonne (one thousand kilograms) of carbon dioxide or an equivalent amount of other greenhouse gases. To reduce emissions of carbon dioxide and other greenhouse gases, a government will make available a finite number of carbon credits to entities that emit carbon dioxide and other greenhouse gases.

A carbon bond is a bond whose periodic coupons are carbon credits. Governments that generate carbon credits and carbon bonds take on risks related to their proper pricing. Similarly, the firms or other entities that buy them take on risks.

Pullanta is a fictitious, economically developed country whose government recently set a goal of reducing carbon emissions to 25% below the 2018 level by the end of the year 2030. Pullanta's Department of Environmental Concerns has been charged with but does not yet have a specific program in place to achieve the goal. In this context, Pullantians refer to the emissions of carbon dioxide and other greenhouse gases as "carbon emissions".

The Department of Environmental Concerns has been tracking carbon emissions in Pullanta at an aggregate level for many years. In addition, the Department recently began collecting carbon emission reports from companies.

Eliza Wright, the Pullanta Minister of Environmental Concerns, has hired your team of actuarial consultants[1] to design a carbon credit program that encourages reducing carbon emissions and generates revenue to fund climate change mitigation and recommend a comprehensive implementation plan for your program. A successful program will allow Pullanta to expand its program to encourage further reduction of carbon emissions and to fund additional climate change mitigation efforts.

To inform the development of your program, Ms. Wright has made available to you some general information about Pullanta, as well as Pullanta's carbon emissions data. Refer to Appendix A for more information about the data.

Deliverable Requirements

The Department of Environmental Concerns needs a carbon credit program that is expected to result in total carbon emissions staying within 90% of Pullanta's goals with 90% certainty. Ms. Wright has identified the following primary objectives for this engagement:

[1] Your team must include at least 2 students, and may include up to 5 students, from the same university.

1. Using the data and background information about Pullanta that Ms. Wright provided,[2] design and recommend a carbon credit program that:
    a. Defines annual aggregate carbon emission reduction targets to achieve the goal of reducing carbon emissions to 25% below the 2018 level by the end of the year 2030;
    b. Is expected with 90% certainty to result in aggregate carbon emissions staying within 90% of the annual and ultimate goals;
    c. Reflects the perspectives of the Pullanta government, businesses and consumers.
2. Develop and recommend a comprehensive implementation plan, including key metrics to gauge its success.

Your consulting team has been asked to deliver a report, informed by your research and analysis, that addresses each of the following items in bold. The considerations listed after each bold deliverable are related questions or comments that may assist in the development of deliverables. The considerations may, but are not required, to be explicitly addressed.

1. **RISKS: Which risks should Pullanta consider as it creates a carbon credit program? What are the impacts on various stakeholders?**
   Considerations:
    a. Specific Risks: What are the specific risks that the various stakeholders will face and to what degree?
    b. Impact: How does the impact of risks on various stakeholders factor into your recommended program?
    c. Costs: What are the risks and costs associated with implementing versus not implementing a program? Are some costs non-financial?
    d. Alternatives: Are there alternative approaches or mechanisms to encourage reduction of carbon emissions? What are their pros and cons?

2. **REVENUE AND EXPENSE: How many carbon credits should Pullanta make available and at what price? How much revenue should Pullanta expect from the program? How does your program address each of the significant risks that various stakeholders face?**
   Considerations:
    a. Aggregate Emissions: How much aggregate carbon emissions should Pullanta allow in each year? Should the number of available carbon credits vary by industry sector? How much carbon should Pullanta allow a single entity to emit without purchasing carbon credits?
    b. Frequency and Limits: How frequently should the Department of Environmental Concerns issue carbon credits and for what period should a carbon credit be valid before it expires? Should there be a limit on the number of carbon credits that a single entity can purchase in each issuance period?

[2] Refer to Appendix A for more information about the background information and data provided.

c. Social Cost of Carbon: What is the social cost of carbon for Pullanta? Should your program's price for carbon credits equal the social cost of carbon? Should the price of a carbon credit change over time? How does the present value of revenues from your program compare to the present value of the social cost of carbon?
d. Secondary Market: Pullanta expects that entities who purchase more carbon credits than they can use may want to sell them to companies who are at risk of emitting more carbon than they have carbon credits.
    i. Which entities are likely to buy or sell carbon credits on the secondary market and how many carbon credits are they likely to trade?
    ii. How much might carbon credit be worth on the secondary market?
    iii. Does the government receive any revenue from carbon credit sales on the secondary market?
e. Consequences: What should be the legal, environmental and economic consequences for entities that exceed carbon emissions limits without enough carbon credits to cover their emissions? What are the consequences for the government?
f. Neighboring Countries: Should the relevant programs and practices of neighboring countries be considered?

3. **DESIGN: Design and price at least three carbon credit financial instruments, including at least two bonds, for Pullanta to issue. Discuss pricing, periodic payments, solvency, sensitivity to disasters, liquidity and market designs. Consider the possibilities of fixed credits versus floating credits tied to levels of carbon emission, as well as functions of stakeholders, industry sectors and neighboring countries.**
   Considerations:
    a. Compare and Contrast: How does each financial instrument design influence carbon emissions reductions? Why might an entity purchase a carbon credit financial instrument instead of periodically purchasing carbon credits?
    b. Risks: What are the risks that each stakeholder group faces that may not be present with the purchase or sale of carbon credits compared to the purchase or sale of carbon credit financial instruments?
    c. Aggregate Number of Carbon Credits: How does the number of carbon credits available via these financial instruments affect the total number of available carbon credits at any one time?

4. **IMPLEMENTATION PLAN: Recommend a comprehensive implementation plan that spans from 2020 through 2030, including expected carbon emission reductions, revenues, metrics to measure the program's success. How volatile are results likely to be? How do your recommended metrics address each of the significant risks that stakeholders face?**
   Considerations:
    a. Items above: How might your implementation plan reflect each of the considerations for RISKS, REVENUE AND EXPENSE, AND DESIGN?

b. Markets: Through what type of market should Pullanta deliver carbon credits and carbon financial instruments to purchasers? Which type of market would be best suited for creating liquidity on the secondary market?
c. Regulations: What types of regulations will Pullanta need to develop and implement for your program to be successful?
d. Engagement: How should the Pullanta Department of Environmental Concerns engage all stakeholders to enable a successful program?

5. ENTERPRISE RISK MANAGEMENT: Include a sensitivity analysis for relevant assumptions on Pullanta's likelihood to achieve its carbon emissions reduction goal. A sensitivity analysis quantifies and summarizes the impact on the likelihood of achieving goals if actual experience differs from key assumptions.
   Considerations:
   a. Assumptions: Which assumptions have the greatest impact, positive or negative, on economic and environmental goals? Do they vary by industry sector?
   b. Extreme deviations: What are the likely impacts on economic and environmental goal achievement of extreme deviations in actual experience from your assumptions?

6. ASSUMPTIONS: Identify the assumptions underlying your recommended program. Include your rationale for including each assumption as well as your rationale for the specific assumption you chose.

7. DATA LIMITATIONS: Identify any data limitations and the impact of the limitations on your analyses. Throughout your report, identify the limitations where they are relevant to the narrative.

Evaluation Criteria

The Minister of Environmental Concerns has explained that the Department of Environmental Concerns evaluates its consulting teams on their methodological soundness based on the following criteria:

- Organization, form, clarity and cohesiveness of the report,
- Report includes a concise executive summary that provides a comprehensive overview of key recommendations and conclusions,
- Clear and complete responses to all "Deliverable Requirements" that have been requested to be addressed,
- Robust rationale for each recommendation and key assumption,
- Thorough analysis,
- Creative and strategic recommendations,
- Appropriate level of technical information for high-level officials with varying, often non-technical, backgrounds,
- Consideration of secondary research—including, as necessary, an appendix showing a reference list of all sources cited throughout the report,

- Consideration of the provided data, including documentation of data limitations,
- Documentation of assumptions, including currency assumptions, and
- Adherence to all "Submission Requirements."

Submission Requirements

Your team's submission should contain a written report and supporting calculations that meet the criteria outlined below. Please refer to the 2020 Student Research Case Study Challenge official rules <link to rules> for further information.

Written Report

Submit a written report designed for high-level government officials of varying backgrounds and expertise to read. The report should meet the following criteria:

1. In PDF format, without any passwords; no other format will be accepted
2. The filename includes the team name and a brief description of content for quick identification
3. Written in English
4. Include your team's university affiliation and each team member's name[3]
5. In 12-point, double-spaced font with standard margins
6. Maximum of 2,500 words, excluding the following items which do not count toward the 2,500-word limit
    a. Graphs or charts
    b. Captions of graphs or charts that summarize key findings
    c. Citations of external research
    d. Reference list of cited sources at the end of your report
    e. Supporting calculations and/or code, including any detailed explanations
7. The report and supporting calculations must be original work of your team for this case study. Previously published work should not be repurposed or submitted.

Supporting Analysis

Submit your report and all calculations, models and/or code completed during your analysis in PDF or Excel formats. Additionally, and optionally, you may submit original R code in R-file or text format. These are the only file formats that will be accepted. Analysis is not required to be conducted using R.

When and Where to Submit

Send your final submission to research@soa.org by 11:59 pm Central Standard Time on Sunday, March 1, 2020. In your submission email, include your university affiliation as well as the names and email addresses of each team member.

[3] Winning reports will be posted on the Society of Actuaries website. For privacy, the Society of Actuaries does not recommend showing email addresses in or on the report.

Appendix A: Pullanta Background and Carbon Emissions Data

Ms. Wright has provided the following information about Pullanta and the CO2e emissions data found in the accompanying Excel file.

About Pullanta

Pullanta is a fictitious, economically developed country. In 2019, Pullanta covered approximately 163,000 square kilometers and had an estimated population of 20 million people.
Roughly 28% of Pullanta's population lives in urban areas with populations of at least 1 million.

Currency in Pullanta is the Pulo (₱). Estimated 2019 Gross Domestic Product (GDP) was about ₱726 billion. Currently, one Pulo (₱1.00) is currently equivalent to approximately 55% of one Euro (€0.55) and 60% of US dollars ($0.60).

The interest rate market in Pullanta has been similar to that of the United States.

Carbon Emissions Data

Estimated emissions in 2019 of carbon dioxide and equivalents of other greenhouse gases (CO2e) were 45.4 metric tonnes per capita. Pullantians refer to the emissions of carbon dioxide and other greenhouse gases as "carbon emissions".

- Aggregate carbon emissions by sector and other aggregate data for 1995–2019.
- Reported carbon emissions by company for 2015–2019.

Note that data for 2019 are estimated based on mid-year reporting.

CO2e emissions data entries that are zero signify one of the following situations:

- The company did not report,
- The company reported emissions of zero metric tonnes,
- The company did not exist, or
- The data entry is missing from the Department of Environmental Concerns database.

The Department of Environmental Concerns classifies CO2e emissions by the following sectors, or sources of emissions. These definitions are similar to those used the Food and Agriculture Organization of the United Nations.[4]

- **Buildings and Land Use (B):** emissions from residential, commercial and institutional buildings as well as land use such as agriculture, forestry, fishing and other land use sources.
- **Energy, Manufacturing and Construction (E):** energy, manufacturing and construction industries, as well as fugitive emissions. Fugitive emissions are unintended emissions, often because of equipment leaks or accidental releases of greenhouse gases.

[4] Food and Agriculture Organization of the United Nations (FAO) categorizes sources of emissions by sector. FAO documents its methodology here: http://fenixservices.fao.org/faostat/static/documents/EM/EM_e.pdf

- **Industrial Processes and Product Use (I):** production of metals, minerals, chemicals, pulp, paper, food, drink, electronics and electrical equipment; also includes industrial use of refrigeration and air conditioning, solvents, lubricants, fire extinguishers and aerosols.
- **Other (O):** other sources, such as fossil fuel fires, indirect emissions from non-agricultural nitrogen oxides and ammonia, and other sources of emissions.
- **Transport (T):** all transport activity, including transportation to support other sectors. Includes commercial and private road transport, railway transport, pipeline transport and other transport, aviation and marine transportation.

Pullanta excuses small companies from reporting carbon emissions. The Department of Environmental Concerns includes estimates for small companies in its aggregate CO2e values.

Appendix B: Glossary of Terms

This appendix shows a glossary of selected terms related to emissions of carbon dioxide and other greenhouse gases. To the extent that these terms apply to this case study, the definitions below should be used.

Biocapacity

A measurement of the productivity of a geographical area's ability to absorb the waste generated within the area, especially emissions of carbon dioxide and other greenhouse gases. Biocapacity is expressed in global hectares, a standardized measurement of world-average productivity per hectare.

Carbon dioxide equivalent (CO_2e or CO2e)

A means of comparing the potential effect on climate change of emission of various greenhouse gases by expressing it in terms of the amount of carbon dioxide emission required to produce the same effect. For example, say that 100 metric tonnes of greenhouse gas "X" emissions produces the same potential effect on climate change as emission of 1,200 metric tonnes of carbon dioxide. The carbon dioxide equivalent, or CO2e, of one metric tonne of greenhouse gas "X" emission is 12 metric tonnes.

Carbon emissions

Emissions of carbon dioxide or the equivalent amount of other greenhouse gases. When expressed numerically, carbon emissions are in metric tonnes, unless specified otherwise.

Ecological footprint

A measurement of the ecological assets that a population requires to produce the natural resources it consumes and to absorb the associated waste, especially emissions of carbon dioxide and other greenhouse gases. Ecological footprint is expressed in global hectares, a standardized measurement of world-average productivity per hectare.

Metric tonne

One thousand kilograms.

Sectors

The Pullanta Department of Environmental Concerns used the following definitions of industry sectors or sources of carbon emissions. These definitions are similar to those used the Food and Agriculture Organization of the United Nations.[5]

- Buildings and Land Use (B): emissions from residential, commercial and institutional buildings as well as land use such as agriculture, forestry, fishing and other land use sources.

[5] Food and Agriculture Organization of the United Nations (FAO) categorizes sources of emissions by sector. FAO documents its methodology here: http://fenixservices.fao.org/faostat/static/documents/EM/EM_e.pdf

- **Energy, Manufacturing and Construction (E):** energy, manufacturing and construction industries, as well as fugitive emissions. Fugitive emissions are unintended emissions, often because of equipment leaks or accidental releases of greenhouse gases.
- **Industrial Processes and Product Use (I):** production of metals, minerals, chemicals, pulp, paper, food, drink, electronics and electrical equipment; also includes industrial use of refrigeration and air conditioning, solvents, lubricants, fire extinguishers and aerosols.
- **Other (O):** other sources, such as fossil fuel fires, indirect emissions from non-agricultural nitrogen oxides and ammonia, and other sources of emissions.
- **Transport (T):** all transport activity, including transportation to support other sectors. Includes commercial and private road transport, railway transport, pipeline transport and other transport, aviation and marine transportation.
- **Waste (W):** waste handling, including wastewater, waste incineration, solid waste disposal on land.

Social Cost of Carbon

An economic measure of the harm to a society caused by the emission of one metric tonne of carbon dioxide or the equivalent amount of other greenhouse gases.