Does Environmental Factor Influence the Rating of Creditworthiness? A Comparative Analysis of Developed versus Developing Countries

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Abstract: This paper examines the influence of environmental factor in the determination of a country's creditworthiness given the world's agenda to contain the rise in global temperature. This paper leverages on two environmental factor proxies, CO_2 emissions per capita and renewable energy per capita, to assess whether the environmental factor plays a significant role in determining the sovereign credit ratings (SCRs) issued by three leading credit rating agencies (CRAs), i.e., Moody's, S&P and Fitch for 49 countries spanning the period of 2000 to 2021. The empirical results show that the environmental factor is being considered by the CRAs. Since the signing of the Paris Agreement in 2015, the environmental factor has turned significant for the determination of the SCRs of developing countries, but not for the developed countries. The creditworthiness of developing countries is subjected to a penalty for CO_2 emissions. While the level of renewable energy adoption is higher amongst the developed countries, the evidence does not show that their level of CO_2 emissions is lower. This paper recommends the CRAs to explicitly state the environmental factor criteria and update their SCR methodologies to ensure uniformity in application.

Keywords: Sovereign credit ratings, ESG, environmental impact, renewable energy
JEL classification: F64, G24, Q42, Q54

1. Introduction

The environmental, social and governance (ESG) ratings are gaining traction among policy makers, institutional investors, and affluent investors. This is evident from the professionally managed investment portfolios. In 2019, the US alone, 33% of the USD51.4 trillion professionally managed assets are sustainable investment assets, and that translates to an increase of 43% as compared to 2017.[1] This sizeable market attracted many stakeholders such as the ESG standards providers (e.g., Global Reporting

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[1] https://www.ussif.org/Files/Trends/2020%20Trends%20Report%20Info%20Graphic%20-%20Overview.pdf

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Initiative (GRI), Sustainability Accounting Standards Board (SASB), Task Force on Climate-related Financial Disclosures (TCFD), Principles for Responsible Investment (PRI)), ESG rating providers (e.g., MSCI, FTSE, Beyond Ratings, Sustainability, NASDAQ, Bloomberg, Thomson Reuter), and ESG data providers (e.g., World Bank, Bloomberg, Thomson Reuter). Although all are using the Sustainable Development Goals (SDGs) advocated by United Nations as anchor principles, the level of adoption varies among these stakeholders. These variabilities lead to inconsistency. As pointed out by Boffo and Patalano (2020), investment portfolios with favourable ESG ratings do not necessary outperform the market, and not all portfolios with unfavourable ESG ratings underperform the market either. The known causes of variability in the adoption of the sustainability factor by the different stakeholders are the adopted variables, weights, and methodologies (Avramov et al., 2022; Berg et al., 2022; Christensen et al., 2020; Gibson et al., 2021). In addition, the materiality of the selected ESG variables also has significant influence on the scores (Eccles & Krzus, 2014; Khan et al., 2016).

In the sovereign segment, the issuing of "green" bonds to finance carbon-neutral initiatives globally is projected to reach USD2.36 trillion in 2023.[2] Although minuscule in size as compared to corporate assets, these "green" bonds demonstrate the commitment of global organisations (e.g., International Monetary Fund (IMF), Bank for International Settlements (BIS)) and key countries (e.g., United States, China, European Union) towards endorsed goals of the Paris Agreement.[3] The MSCI, Robecco, Sustainalytics and FTSE are pioneer sovereign ESG raters. The three leading credit rating agencies (CRAs), Moody's, S&P and Fitch are also coming on board. Like the sovereign credit ratings (SCRs), the sovereign ESG ratings also attract much scrutiny. Empirically, Gratcheva et al. (2022) studied the correlation between the SCRs of 115 countries with the individual pillars of average ESG scores from six different ESG rating providers. Their study showed that the environmental pillar has a 66.5% correlation with SCRs, followed by the social pillar with a 83.1% correlation, and the governance pillar with a 81.6% correlation. Klusak et al. (2023) employed the simulated CO_2-induced GDP contraction trajectory, and reported that the CO_2 emissions impact would lead to broad SCR downgrades. Semet et al. (2021) explored the potential of three ESG pillars in predicting the SCR notches. Their model consists of 16 extra-financial variables (i.e., representing the three ESG pillars), and produced an average prediction accuracy of 95%. Their results implied that all the three ESG pillars are already embedded in the SCR assessment.

In June 2018, Moody's acknowledged that the ESG factors have certain influence on the issued SCRs. Moody's further qualified that the risk in association with the governance factor has already been accounted for in their four key variables: economic strength, institutional strength, government fiscal strength and susceptibility to event risk. The risks of the environmental and social factors, although less explicit, continue to influence Moody's assessment on the economic and institutional strength

[2] https://www.weforum.org/agenda/2020/11/what-is-green-finance/

[3] Paris Agreement is a legally binding international treaty on climate change adopted by 196 countries in December 2015. See https://unfccc.int/process-and-meetings/the-paris-agreement

of a rated country.[4] S&P stated that the ESG presents both risks and opportunities to the creditworthiness assessment. S&P also claimed that the risk of the governance factor is part of their existing credit assessment criteria. The risk of the social factor is embedded and the material effect will be reflected in the government's effectiveness in rolling out sound policies, economic growth and political stability. Although S&P acknowledged the risk of the environmental factor, they reckoned that the economic effect caused by the environmental factor is not immediate. S&P further clarified that the environmental factor would become prominent in the SCRs determination in the coming 5–10 years horizon.[5] In a February 2021 commentary, S&P reiterated that environmental risks have a limited impact on its SCRs determination, as outlined in its Sovereign Rating Methodology published in 2017. However, S&P also stated that physical climate risks deemed significant in the economic assessment could result in a one-notch downward adjustment.[6] In April 2019, Fitch introduced sovereign ESG scores but discounted their influence on the sovereign credit ratings.[7] In February 2022, Fitch reemphasised how ESG is incorporated in their SCRs issuance. Extra-financial variables representing the risks of the social and governance factors that are deemed material to creditworthiness are already part of their credit assessment criteria. However, the risk of the environmental factor (i.e., climate change, etc.) is beyond the near-term consideration for Fitch to form their forward-looking opinion on the creditworthiness of rated countries.[8]

These developments from the three leading credit rating agencies suggest that the ESG factors, particularly the environmental pillar, are gaining prominence in the determination of SCRs. Given the stated timeframe and the growing negative economic effects linked to climate change, this paper aims to examine the influence of the environmental factor in the determination of SCRs issued by the three leading CRAs, Moody's, S&P and Fitch. Leveraging on the CO_2 emission per capita and renewable energy per capita as proxies of the environmental factor, the core objective is to determine whether these two proxies are statistically significant for SCRs. Another objective is to examine if the Paris Agreement (COP21) leads to the environmental factor to become prominent in the SCR determination. The key contribution of this empirical study is that it offers a first glimpse into the alignment of the SCR determination and the environmental factor. The empirical outcomes will provide insights for policy makers on the importance of climate related policies that could strengthen creditworthiness.

The rest of the paper is organised as follows. Section 2 summarises the literature that is pertinent to this empirical study. The data and methodology are described in

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[4] https://www.moodys.com/researchdocumentcontentpage.aspx?docid=PBC_1113476

[5] https://www.spglobal.com/en/research-insights/articles/how-environmental-social-and-governance-factors-help-shape-the-ratings-on-governments-insurers-and-financial-institutions

[6] https://www.spglobal.com/ratings/en/research/articles/210203-environmental-social-and-governance-esg-overview-global-sovereigns-11793174

[7] https://www.fitchratings.com/research/sovereigns/esg-relevance-scores-for-sovereigns-20-07-2021

[8] https://www.fitchratings.com/research/sovereigns/esg-is-longstanding-increasingly-important-sovereign-rating-factor-10-02-2022#:~:text=Fitch%20Ratings-London%2FFrankfurt-10%20February%202022%3A%-20Environmental%2C%20Social%20and%20Governance,which%20addresses%2012%20questions%20frequently%20posed%20by%20investors.

Section 3. The empirical results are reported in Section 4, and discussion of the findings is presented in Section 5. Finally, the paper is concluded in Section 6.

2. Literature Review

SCRs and ESG are two broad subjects of interest to policymakers, investors and researchers. The former focuses specifically on economic health and debt serviceability to determine sovereign creditworthiness. The latter has a broader context in which the economic health of a country is one part of the sustainability considerations. In the context of sovereign's default probability and the associated borrowing cost, the relation between the SCR ratings and ESG scores is still ambiguous. For instance, countries rated with favourable SCRs are historically proven to have a low default probability but are not necessarily rated with favourable ESG scores. On the other hand, countries rated with favourable ESG scores have mixed default probability as reflected in their respective SCR ratings and borrowing costs. The following sub-sections provide greater elaboration into these two subjects.

2.1 Sovereign Credit Ratings (*SCRs*)

The proprietary sovereign credit rating methodologies of Moody's, S&P and Fitch provide an essential overview of the SCRs assessment criteria and determination. Moody's categorises the SCRs assessment criteria into four key pillars: economic strength, institutional strength, fiscal strength and susceptibility to event risk. The economic resiliency is established using the economic strength and institutional strength pillars. The economic resiliency is weighed against the fiscal strength pillar to formulate the government's financial strength. The event risks (e.g., geopolitical risk, economic crisis, spillover risk, etc.) assessed in the susceptibility to event risk pillar are factored in to weigh the overall financial strength and shock mitigation capability of a rated country (Moody's, 2019). In the case of SCRs issued by S&P, the assessment criteria are categorised into five key pillars: the institutional assessment, economic assessment, external assessment, fiscal assessment and monetary assessment. The first and second pillars form the institutional and economic profile, and the remaining three pillars determine the flexibility and performance profile of the rated countries. These two profiles are merged using their proprietary matrix table to derive the SCR notches (Standard & Poor's, 2017). The assessment criteria employed by Fitch are categorised into structural features, macroeconomic performance, policies and prospects, public finances, and external finances. Fitch adopted the econometric methods to weigh the four pillars to form their forward-looking opinions of the rated countries' credit-worthiness (Fitch Ratings, 2021). The SCR methodological frameworks of the respective CRAs are compiled in Figure 1.

Further examination reveals that the inputs of SCRs assessment criteria (Fitch Ratings, 2022; Moody's, 2022; Standard & Poor's, 2022) can be categorised into publicly available information and non-disclosure information. Since the latter category of information is not publicly available, empirical studies on SCRs are mainly performed using the publicly available information. The most common determinants of SCRs were

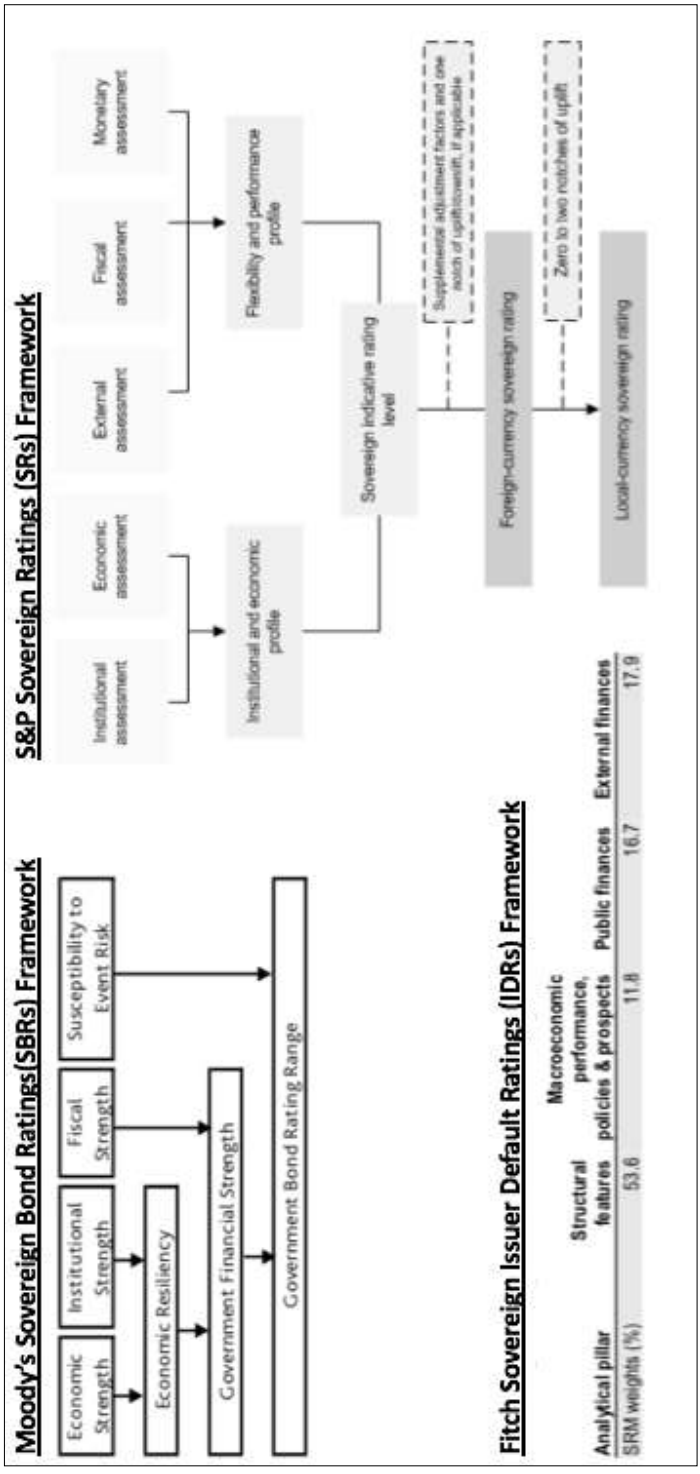

Figure 1. Sovereign credit rating frameworks

Note: Moody's SBRs framework is sourced from Moody's (2019, exhibit 3, page 4), S&P SRs framework is sourced from Standard & Poor's (2017, page 2), and the Fitch sovereign IDRs framework is sourced from Fitch Ratings (2021, April 26, page 6).

the eight variables employed by Cantor and Packer (1996). As reported in their study, these eight variables had high predictive power (i.e., above 90%) on the SCRs of 48 countries issued by Moody's and S&P. The eight variables were GNP per capita, GDP growth, inflation, fiscal balance, current account balance, external debt, economic development indicator, and default history indicator. Subsequent researchers expanded the list of SCR determinants. For instance, Afonso (2003) added the external debt to export as the ninth determinant, and Rowland (2004) added the debt to current account receivables and foreign reserves to GDP to form the 12-determinant model.

Acknowledging the discreet characteristic of SCRs, Mellios and Paget-Blanc (2006) employed the ordered logistic model (OLM) to examine the predictive power of 13 selected SCR determinants. Employing both ordered probit and logit models, Afonso et al. (2009) examined a list of 24 SCR determinants, and reported that only half of the 24 determinants are statistically significant at 5% level in predicting SCRs. These significant determinants were reclassified into short-term and long-term determinants in another study and remained robust in predicting SCRs (Afonso et al., 2011). These robust SCR determinants were GDP per capita, GDP growth, unemployment, inflation, government debt, fiscal balance, government effectiveness, external debt, current account balance, foreign reserves, default history, EU indicator, industrial indicator, and Latin America and Caribbean indicator. Reusens and Croux (2017) repurposed the SCR determinants to examine the pre- and post-effect of the European debt crisis in 2010, and these determinants remain robust in predicting SCRs. Lim et al. (2023) conducted an analysis between the investment grade and speculative grade SCRs using eight determinants. Their empirical results showed that the eight determinants remain robust in predicting SCRs issued by Moody's, S&P and Fitch in the pre- and post-global financial crisis periods.

2.2 Sovereign Environmental, Social, and Governance (ESG) Ratings

After the signing of the Paris Agreement in 2015, the green initiatives began to take shape. For instance, the Network for Greening the Financial System (NGFS) to broaden the green and low-carbon initiatives and investments was launched in December 2017. The NGFS alone has gathered the commitment of 108 central banks and regulators, and 17 observers (e.g., Asia Development Bank, Bank for International Settlement, etc.).[9] The Green Bond Principles initiated by the International Capital Market Association in June 2018 aimed to improve transparency, disclosure and reporting on the uses of green bond proceeds.[10] The taxonomy on the climate bonds' standard and certification was initiated by a non-profit organisation, the Climate Bonds Initiative (CBI). The CBI sets USD100 trillion as the target to fund climate change solutions.[11] In 2019, the United Nations Principles for Responsible Investment (UN PRI) rolled out the practical guideline on the ESG and sovereign debt integration.[12]

[9] https://www.ngfs.net/en/about-us/governance/origin-and-purpose

[10] https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/?showiframe=true

[11] https://www.climatebonds.net/

[12] https://www.unpri.org/

On the academic front, Crifo et al. (2017) examined the ESG scores issued by Vigeo on 23 OECD countries and reported that the informational content of the ESG scores was significant and had negative relation to sovereign borrowing costs on bonds with maturities of 2-year, 5-year and 10-year. Capelle-Blancard et al. (2016) also examined the ESG scores in explaining sovereign bond yields. Their study reported that the informational content of ESG scores was more profound on the debts of developed countries with longer maturity. Nemoto and Liu (2020) examined the ESG scores issued by MSCI and FTSE Russell/Beyond Ratings in explaining the sovereign bond spreads of emerging countries. They reported that the social factor is more profound among Asian countries as compared to the governance factor in OECD countries.

Gratcheva et al. (2020) conducted a comparative study on seven sovereign ESG raters: FTSE Russell/Beyond Ratings, ISS, MSCI, RepRisk, Robeco, Sustanalytics, and V.E. Their study showed that the weight contributed by the governance factor is 43%, followed by the social factor of 28%, and the environmental factor weighted 29%. Amongst these seven ESG raters, the issued sovereign ESG scores have high correlations, ranging from 69% to 98%. The social factor scores had the highest correlation at 85%, followed by the governance factor at 71%, and the environmental factor, was the least, at 42% correlation. In a separate paper, Gratcheva et al. (2022) conducted a correlation study of three ESG factors with SCRs. In their study, the environmental factor was correlated with SCRs at 66.5%, whereas the social factor and governance factors were correlated with SCRs at 83.1% and 81.6%, respectively. On a cluster basis, the high-income countries exhibited relatively the same level of correlation as compared to the lower-income countries. Their study showed that the correlations of the social factor and governance factor with SCRs were weak but positive for lower-middle-income and low-income countries. The correlation of the environmental factor with SCRs for the lower-middle-income and low-income countries was negative. The weak correlation between the environmental factor and the SCRs is also reported by Nemoto and Liu (2020).

Findings from these studies raised the question on the legitimacy of existing sovereign ESG scores. As critically highlighted by Gratcheva et al. (2021), existing ESG scoring methodologies are found to be income-biased. They urged the stakeholders to revisit their sovereign ESG frameworks and recommended five key areas, namely, transparency in terms of investment objectives, methodology, data, forward looking, and unbiasedness from income factor, for improvement.

3. Framework of Analysis

While the ESG scoring methodology is being scrutinised and under revision, the integration progress between ESG scores and SCRs remains opaque. This is especially the case with regards to the environmental factor in the SCRs determination. The environmental factor is generally disassociated from the SCRs due to its existential nature. This is because the timing of material effect rendered by the climate change is beyond the consideration horizon in the SCRs determination. The studies of Semet et al. (2021) and Gratcheva et al. (2022) support this disassociation claim between the

environmental factor and the SCRs. However, the leading CRAs in 2018 acknowledged and anticipated that the environmental factor influence in the SCRs determination will become prominent in 5 to 10 years down the road.[13]

To examine the association between the environmental factor and determination of SCRs, it is essential to acknowledge the differences in the SCRs and ESG scores. The SCR notches are creditworthiness ranking or the likelihood of rated countries going default in the near term (e.g., in 2 to 3 years). On the other hand, the ESG scores have a broader coverage under the term "sustainability". The effects could be existential (e.g., physical and transitional climate risks), and typically in an acute manner (e.g., fat-tailed events) and/or a long-term manner. These suggest that the issued sovereign ESG scores cannot be equated with the issued SCRs. This means the individual environmental, societal and governance scores or the aggregated ESG scores are not rated in the context of creditworthiness. In order to examine the environmental factor in the context of creditworthiness, appropriate and objective variables (e.g., CO_2 emissions per capita, renewable energy per capita, etc.) should be considered as the environmental factor proxies.

Before the influence of the environmental factor proxies could be examined, the common SCR determinants stated in the earlier section will serve as control variables in forming the baseline model. According to the SCR methodologies (Fitch Ratings, 2021; Moody's, 2019; Standard & Poor's, 2017), the vector of economic variables can be categorised into four key factors: economics, institutional, fiscal and susceptibility to external events. The inputs to these four key factors of SCRs determination are further categorised into publicly available information and non-disclosure information. With constraint imposed by information accessibility and availability, this means only observable inputs are examined empirically. These observable economic variables are termed as the common SCR determinants. On that note, the X_n in the SCR function, as expressed in Equation (1), represents the common SCR determinants.

$$SCRs = f(X_n) \tag{1}$$

It is essential to highlight that the non-disclosure information has significant influence on the issued SCRs. For instance, the rating committee of the respective CRAs is provisioned with two-notch discretion over the quantitatively derived SCR notches (Fitch Ratings, 2022; Moody's, 2022; Standard & Poor's, 2022). This means while the quantitative inputs would rank a country Baa1 (i.e., Moody's rating convention) or BBB+ (i.e., S&P and Fitch rating conventions), the final SCR notch being issued could be Baa3/BBB-, Baa2/BBB, A1/A+, A2/A or maintained as Baa1/BBB+, depending on the discretion of the respective rating committee. Due to this, it is imperative to acknowledge these limitations in the models that rely only on the common SCR determinants. Some levels of flexibility must be catered for to accommodate the two-notch discretion when assessing the model's predictive power.

[13] https://www.spglobal.com/en/research-insights/articles/how-environmental-social-and-governance-factors-help-shape-the-ratings-on-governments-insurers-and-financial-institutions

There are two options to introduce the environmental factor in the SCRs determination. The first option is to leverage on the individual ESG score (e.g., environmental factor scores) issued by the respective ESG raters. These ESG scores may be income-biased as highlighted in earlier studies (Gratcheva et al., 2020, Gratcheva et al., 2022). This implies subjectivity inherited in the issued ESG scores. Moreover, the variability in ESG rating methodologies also renders the ESG scores not appropriate as the environmental factor proxies. The second option is to leverage on the objective and common variables used in issuing ESG scores. In specific to the climate change risks, the two common variables pertinent to the greenhouse gas emissions are CO_2 emissions and renewable energy. The general expectation is that an increase in the CO_2 emissions would lead to higher greenhouse gas emissions, therefore lead to higher temperature. Rising temperature would lead to acute physical climate risks that in retrospect affect the GDP negatively (Dietz & Stern, 2015; Nordhaus, 1991, 2018). On the same deduction, an increase in CO_2 emissions would have a negative effect on a country's creditworthiness. On the contrary, the adoption of renewable energy is expected to reduce CO_2 emissions. Hence, an increase in renewable energy adoption is anticipated to have a positive effect on creditworthiness. Motivated by the objectivity and availability of these two variables, this paper proceeds with option two to examine the environmental factor influence using both variables. To accommodate these two environmental factor variables (i.e., E_n), the SCR function is modified as expressed in Equation (2).

$$SCRs = f(X_n, E_n) \tag{2}$$

The framework for this empirical examination is defined in Figure 2. Estimates and predictive power of the model derived using only the common SCR determinants serve as the baseline. The two environmental factor proxies (i.e., CO_2 emissions and renewable energy) are introduced into the baseline model for examination.

To ensure the selected common SCR determinants are appropriate, the predictive power of the baseline model must satisfy the 30% cut-off point. This cut-off point is an average predictive power derived from previous studies (Afonso, 2003; Afonso et al., 2009; Afonso et al., 2011; Bissondoyal-Bheenick, 2005; Cantor & Packer, 1996; Lim et al., 2023; Mellios & Paget-Blanc, 2006; Reusens & Croux, 2017; Rowland, 2004).

On the environmental factor proxies, if the estimated parameters are significant at the 5% level and have the expected sign, the environmental factor is deemed prominent in the SCR determination. The hypotheses to be examined in this paper are summarised as follows:

H1 – A higher level of CO_2 emissions per capita is associated with a lower SCR,
H2 – A higher level of renewable energy per capita is associated with a higher SCR.

The examination of these two hypotheses is repeated to compare the influence of the environmental factor on the SCRs for developed and developing countries, and to determine if the COP21 has any influence on the SCR determination amongst the three leading CRAs.

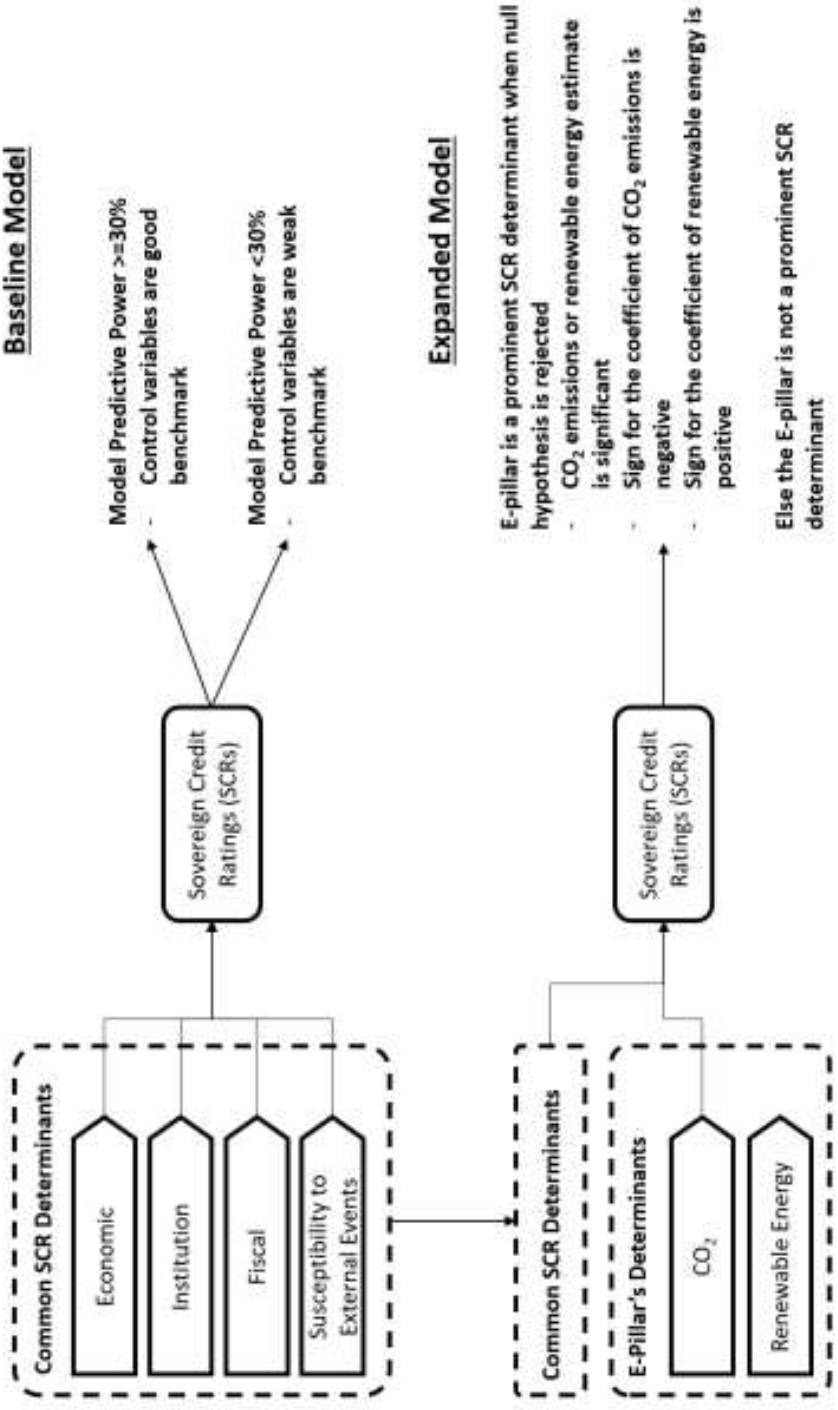

Figure 2. Framework of analysis
Note: E-pillar refers to the environmental pillar.

4. Data and Methodology

4.1 Data

Only countries rated by all the three leading CRAs, Moody's, S&P and Fitch, are included in the analysis. After dropping some countries due to data quality and unavailability, the final list of 49 countries is presented in Table 1. Details on the SCRs, CO_2 emissions per capita and renewable energy per capita for these countries in 2021 are given in the Appendix. The SCRs are sourced from the respective CRAs. The alpha-numeric SCRs (e.g., Aaa, Aa1, Aa2, Aa3, etc.) and alpha-symbol SCRs (e.g., AAA, AA+, AA, AA-, etc.) are converted to ordinal scales, following the common convention employed in similar studies (Canuto et al., 2012; Hill et al., 2010; Lim & Kwek, 2021; Lim et al., 2021; Lim et al., 2023; Mellios & Paget-Blanc, 2006, Reusens & Croux, 2017). These ordinal scaled SCRs are defined in Table 2.

The control variables (X_n in Equation (2)) are GDP growth, GDP per capita, government effectiveness index, financial development index, debt to GDP ratio, current account balance to GDP ratio, inflation and total reserves to GDP ratio. They were also examined in earlier studies (Afonso, 2003; Afonso et al., 2009; Afonso et al., 2011; Bissondoyal-Bheenick, 2005; Cantor & Packer, 1996; Canuto et al., 2012; Hill et al., 2010; Lim et al., 2021; Lim et al., 2023; Reusens & Croux, 2017). These variables are selected to represent the four key dimensions of economic, institution, fiscal and susceptibility to external events in the SCR determination (see Lim et al., 2023 for further discussions). Data for these variables are extracted from the World Bank and International Monetary Fund.

The government effectiveness index is of particular interest that concerns the integration of ESG in SCR determination. As stated by Moody's, the variable is embedded with the elements of the societal factor and governance factor effects, and this variable is also being assessed by S&P and Fitch (Moody's, 2019; Standard & Poor's, 2017; Fitch Ratings, 2021, April 26). GDP per capita is a relative proxy for the

Table 1. List of 49 developed and developing countries

Argentina[E]	Croatia	Ireland	New Zealand	Slovenia
Australia	Czech	Israel[E]	Norway	South Korea[E]
Austria	Denmark	Italy	Peru[E]	Spain
Belgium	Egypt[E]	Japan	Philippines[E]	Sweden
Brazil[E]	Finland	Kazakhstan[E]	Poland	Switzerland
Bulgaria	France	Latvia	Portugal	Thailand[E]
Canada	Germany	Lithuania	Romania	Turkey[E]
Chile[E]	Hungary	Malaysia[E]	Russia[E]	United Kingdom
China[E]	Iceland	Mexico[E]	Singapore[E]	United States
Colombia[E]	India[E]	Netherlands	Slovakia	

Note: [E] Indicates developing countries and those without any superscript are developed countries as per the UN classification retrieved from https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf

Table 2. SCR definitions and ordinal scales

Description	Moody's	S&P	Fitch	Ordinal Scale
		Investment Grade		
Highest credit quality	Aaa	AAA	AAA	21
Very high credit quality	Aa1	AA+	AA+	20
	Aa2	AA	AA	19
	Aa3	AA-	AA-	18
High credit quality	A1	A+	A+	17
	A2	A	A	16
	A3	A-	A-	15
Good credit quality	Baa1	BBB+	BBB+	14
	Baa2	BBB	BBB	13
	Baa3	BBB-	BBB-	12
		Speculative Grade		
Speculative	Ba1	BB+	BB+	11
	Ba2	BB	BB	10
	Ba3	BB-	BB-	9
Highly speculative	B1	B+	B+	8
	B2	B	B	7
	B3	B-	B-	6
Substantial credit risk	Caa1	CCC+		5
	Caa2	CCC	CCC	4
	Caa3	CCC-		3
Very high level of credit risk / Near default	Ca	CC	CC	2
	C		C	1
Default		SD	RD	1
		D	D	1

Note: Moody's does not provide a rating on defaulted countries. SCRs are from Bloomberg and S&P Capital platforms, and definitions are compiled from Moody's (2017), Standard & Poor's (2018), and Fitch Ratings (2021, April 24).

societal factor as it reflects economic inclusivity. For the environmental factor, the CO_2 emissions per capita and the renewable energy per capita are selected as proxies. These two variables are sourced from the website of Our World in Data (https://ourworldindata.org) instead of the World Bank because the latter source only have data up to 2019. These two variables are also objective inputs to the Network for Greening the Financial System and the Climate Bonds Initiative. The sample constitutes annual observations spanning from the year 2000 to 2021. The descriptive statistics are presented in Table 3.

Table 3. Descriptive statistics

	GG	GPC	GEI	INF	CAB	DTG	FDI	TRG	CO_2	RE
Mean	2.99	26,082	75.64	3.66	0.46	58.05	0.57	0.18	7.33	8,924
Median	3.00	19,533	80.10	2.40	0.00	49.73	0.57	0.14	6.81	2,922
Maximum	24.40	103,703	100.00	55.00	27.10	262.49	1.00	1.46	21.30	151,235
Minimum	-14.80	449.79	11.35	-1.70	-23.90	3.90	0.10	0.00	0.76	9.00
Std. Dev.	3.72	21,425	19.36	5.25	5.85	36.39	0.21	0.18	4.13	20,909
Skewness	-0.45	0.89	-0.59	5.38	0.46	1.77	0.01	2.84	0.84	4.73
Kurtosis	6.06	3.21	2.28	43.49	5.69	8.36	1.94	14.22	3.67	27.67

Note: The annual data points are gathered from the year 2000 to 2021 of 49 selected countries. The variables are GG (GDP growth), GPC (GDP per capita in USD), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita in metric tonnes), and RE (renewable energy per capita in kWh). The sample consists of 1,073 observations.

4.2 Methodology

The econometric method to handle the multicategory and ranking characteristics of scaled SCRs is the ordered response models. Both the ordered probit model and the ordered logit model (OLM) have been employed in similar studies (Afonso et al., 2009; Afonso et al., 2011; Lim et al., 2023; Mellios & Paget-Blanc, 2006; Reusens & Croux, 2017). This study uses the OLM to model the modified SCRs function in Equation (2) as follows:

$$y_{it}^{*} = \beta_0 + \sum_j \beta_{1j} x_{j,it} + \beta_2 z_{it} + v_{it} \tag{3}$$

where y_{it}^{*} is the latent variable underlying the ranking of SCRs for country-*i* at time-*t*, $x_{j,it}$ represents the control variables, z_{it} is the variable representing the environmental factor, and the error term is represented by v_{it} assumed to follow a logistic distribution. The ranking Y_{it} is to be predicted using threshold values γ_n that are estimated from the maximum log-likelihood function[14] for Equation (4) as follows:

$$y_{it} = \begin{cases} 1 \; if \; y_{it}^{*} \le \gamma_1 \\ 2 \; if \; \gamma_1 < y_{it}^{*} \le \gamma_2 \\ 3 \; if \; \gamma_2 < y_{it}^{*} \le \gamma_3 \\ \quad \cdots \\ M \; if \; \gamma_M < y_{it}^{*} \end{cases} \tag{4}$$

where *M* is the number of SCR categories. The predicted SCRs are compared against the observed SCRs to establish the predictive power for determining the accuracy of the model.

[14] $l(\beta,\gamma) = \sum_{i=1}^{N}\sum_{j=1}^{M} \log(\Pr(y_i = j \mid x_j, z, \beta, \gamma) \bullet I(y_i = j))$, where $I(\bullet)$ is the indicator function which takes the value of 1 if the argument is true, and 0 otherwise, $\beta = (\beta_0, \beta_{1j}, \beta_2)$ and $\gamma = (\gamma_1, \gamma_2, \ldots, \gamma_M)$.

For the environmental factor to be concluded as a prominent determinant of SCRs, the estimated coefficient (i.e., β_2) of the selected environmental factor proxy must be statistically significant with the expected signs, i.e., negative for the coefficient of carbon dioxide emissions per capita and positive for the coefficient of renewable energy per capita. With regards to the predictive power of the model, predictions with one error notch and two error notches are considered to accommodate the two-notch discretion made available to the rating committee of the respective CRAs.

5. Empirical Results

5.1 Full Sample

The estimates for Model 1 (baseline) on the full sample to predict the SCRs issued by Moody's, S&P and Fitch are reported in Table 4. Amongst the eight control variables, or the common SCR determinants, all except the current account balance to GDP ratio (CAB) and the total reserves to GDP ratio (TRG) are statistically significant in predicting the SCRs issued by all the three leading CRAs. Table 5 shows that the predictive power of Model 1 on the SCRs issued by all the three CRAs satisfies the 30% cut-off point at zero error notch. If the two-notch discretion of the rating committee is taken into consideration, the predictive power of Model 1 at one-error notch is above 60% and at two-error notch is above 80%. These results show that the selected control variables are robust in predicting the SCRs issued by the three CRAs and the baseline model is adequately specified.

In Model 2, the CO_2 emissions per capita (CO_2) is introduced. The estimated coefficients of CO_2 are statistically significant at 1% level but are not of the expected negative sign. The differences in the predictive powers of Model 2 at zero-error notch, one-error notch and two-error notches as compared to Model 1's predictive power are negligible. In Model 3, the renewable energy per capita (RE) is added as a determinant. The estimated coefficients are statistically significant at 1% level but the sign is negative instead of the expected positive sign. The predictive power of Model 3 does not improve compared to the baseline model. In Model 4, both the CO_2 and the RE variables are included. They remain statistically significant at 1% level, but do not have the expected signs. Its predictive power is also close to that of the baseline model.

5.2 Developed Versus Developing Countries

The models are estimated separately for the developed and developing countries. In Model 1 of Table 6 for the developed countries, majority of the control variables are significant determinants in predicting SCRs. Total reserves to GDP ratio (TRG), although significant in some cases, is rendered irrelevant due to the sign of the estimated coefficient for S&P and Fitch. The CO_2 emissions per capita (CO_2) and renewable energy per capita (RE) included in Models 2, 3 and 4 are statistically significant, but they do not have the expected signs for all the three CRAs.

In the case of the developing countries, the estimates reported in Table 7 show that all the eight control variables are statistically significant for Model 1. The signs of

Table 4. Ordered logit model estimates of SCRs by CRAs for the full sample

	Moody's SCRs				S&P SCRs				Fitch SCRs			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
GG	0.030*	0.025	0.030*	0.025	0.031*	0.028*	0.031*	0.027	0.031*	0.027	0.032*	0.028*
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
GPC	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GEI	0.080***	0.078***	0.083***	0.081***	0.094***	0.093***	0.100***	0.099***	0.083***	0.083***	0.088***	0.088***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
INF	-0.095***	-0.110***	-0.089***	-0.105***	-0.109***	-0.123***	-0.102***	-0.115***	-0.088***	-0.100***	-0.082***	-0.095***
	(0.013)	(0.014)	(0.013)	(0.014)	(0.013)	(0.014)	(0.013)	(0.014)	(0.013)	(0.013)	(0.012)	(0.013)
CAB	-0.020	-0.025*	-0.029**	-0.033***	0.023*	0.024*	0.014	0.015	0.028**	0.026**	0.019	0.018
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
DTG	-0.029***	-0.026***	-0.029***	-0.027***	-0.029***	-0.027***	-0.030***	-0.029***	-0.027***	-0.025***	-0.029***	-0.027***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
FDI	4.871***	4.337***	4.576***	4.038***	4.862***	4.270***	4.400***	3.807***	4.807***	4.207***	4.336***	3.726***
	(0.455)	(0.463)	(0.459)	(0.466)	(0.445)	(0.458)	(0.449)	(0.460)	(0.444)	(0.457)	(0.449)	(0.461)
TRG	0.301	0.265	0.477	0.378	-0.251	-0.256	-0.026	-0.116	-0.521	-0.537	-0.345	-0.453
	(0.454)	(0.449)	(0.458)	(0.450)	(0.463)	(0.452)	(0.466)	(0.454)	(0.457)	(0.446)	(0.463)	(0.451)
CO_2		0.136***		0.143***		0.117***		0.126***		0.121***		0.131***
		(0.020)		(0.020)		(0.018)		(0.019)		(0.018)		(0.019)
RE			-0.000***	-0.000***			-0.000***	-0.000***			-0.000***	-0.000***
			(0.000)	(0.000)			(0.000)	(0.000)			(0.000)	(0.000)
Pseudo R^2	0.293	0.303	0.300	0.311	0.318	0.325	0.331	0.340	0.317	0.325	0.331	0.340
No. of obs.	1078	1078	1078	1078	1078	1078	1078	1078	1073	1073	1073	1073

Note: The full sample consists of 49 countries for the period 2000–2021. The dependent variable is the SCRs issued by Moody's, S&P and Fitch, respectively. The SCRs are converted into ordinal scale defined in Table 2. The explanatory variables are GG (GDP growth), GPC (GDP per capita), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita), and RE (renewable energy per capita). The figures in parentheses are standard errors. ***, **, * significant at 1%, 5% and 10%, respectively. No. of obs. refers to the number of observations. Fitch's SCRs have five fewer observations because Fitch only started rating Denmark from 2003 onwards and New Zealand from 2002 onwards.

Table 5. Models' predictive power by CRAs for the full sample

		Number of prediction errors by notches							No. of obs.	Correctly predicted	+/-1 Notch error (%)	+/-2 Notches error (%)
		≤-3	-2	-1	0	1	2	≥3				
Moody's	Model 1	78	95	135	422	114	92	142	1078	39	62	80
	Model 2	64	88	159	420	116	99	132	1078	39	64	82
	Model 3	78	96	134	420	116	102	132	1078	39	62	81
	Model 4	64	89	159	418	125	95	128	1078	39	65	82
S&P	Model 1	49	112	189	360	147	93	128	1078	33	65	84
	Model 2	39	110	204	370	140	91	124	1078	34	66	85
	Model 3	40	120	187	363	163	95	110	1078	34	66	86
	Model 4	38	106	191	394	149	95	105	1078	37	68	87
Fitch	Model 1	54	89	187	383	143	108	109	1073	36	66	85
	Model 2	52	89	180	391	168	85	108	1073	36	69	85
	Model 3	53	97	165	398	169	96	95	1073	37	68	86
	Model 4	48	89	178	407	170	89	92	1073	38	70	87

Note: No. of obs. refers to the number of observations. Correctly predicted refers to the percentage of observations that are predicted with zero notch error. The estimated models are reported in Table 4. Fitch's SCRs have five fewer observations because Fitch only started rating Denmark from 2003 onwards and New Zealand from 2002 onwards.

Table 6. Ordered logit model estimates of SCRs by CRAs for developed countries

	Moody's SCRs				S&P SCRs				Fitch SCRs			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
GG	o.022	0.009	0.012	-0.006	0.039*	0.028	0.024	0.008	0.038*	0.030	0.028	0.016
	(0.024)	(0.024)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
GPC	0.000**	0.000***	0.000***	0.000***	0.000**	0.000**	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GEI	0.119***	0.105***	0.136***	0.121***	0.124***	0.116***	0.154***	0.146***	0.104***	0.096***	0.128***	0.119***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)	(0.011)	(0.011)
INF	-0.079***	-0.098***	-0.055*	-0.075**	-0.070**	-0.084***	-0.030	-0.045	-0.038	-0.045*	-0.010	-0.019
	(0.030)	(0.031)	(0.030)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.026)	(0.026)	(0.027)	(0.027)
CAB	0.014	0.011	-0.012	-0.022	0.104***	0.106***	0.076***	0.076***	0.100***	0.100***	0.073***	0.071***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.017)	(0.017)
DTG	-0.037***	-0.036***	-0.037***	-0.037***	-0.039***	-0.039***	-0.040***	-0.041***	-0.034***	-0.033***	-0.035***	-0.035***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
FDI	7.634***	6.719***	6.670***	5.488***	8.624***	7.777***	7.473***	6.347***	7.707***	6.991***	6.554***	5.465***
	(0.712)	(0.720)	(0.725)	(0.723)	(0.686)	(0.702)	(0.701)	(0.713)	(0.678)	(0.700)	(0.695)	(0.716)
TRG	0.442	0.308	0.933*	0.768	-0.615	-0.647	-0.051	-0.150	-1.163**	-1.175**	-0.724	-0.819
	(0.546)	(0.555)	(0.568)	(0.567)	(0.544)	(0.536)	(0.568)	(0.562)	(0.516)	(0.508)	(0.535)	(0.529)
CO_2		0.226***		0.290***		0.152***		0.209***		0.110***		0.169***
		(0.037)		(0.039)		(0.030)		(0.032)		(0.030)		(0.032)
RE			-0.000***	-0.000***			-0.000***	-0.000***			-0.000***	-0.000***
			(0.000)	(0.000)			(0.000)	(0.000)			(0.000)	(0.000)
Pseudo R^2	0.309	0.324	0.323	0.346	0.339	0.348	0.365	0.381	0.321	0.326	0.345	0.356
No. of obs.	682	682	682	682	682	682	682	682	677	677	677	677

Note: The developed countries are listed in Table 1. The dependent variable is the SCRs issued by Moody's, S&P, and Fitch, respectively. The SCRs are converted into ordinal scale defined in Table 2. The explanatory variables are GG (GDP growth), GPC (GDP per capita), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita), and RE (renewable energy per capita). The figures in parentheses are standard errors. ***, **, * significant at 1%, 5% and 10%, respectively. No. of obs. refers to the number of observations.

Table 7. Ordered logit model estimates of SCRs by CRAs for developing countries

	Moody's SCRs				S&P SCRs				Fitch SCRs			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
GG	0.052*	0.048*	0.046*	0.045	0.066**	0.064**	0.068**	0.068**	0.068***	0.062**	0.058**	0.056**
	(0.027)	(0.027)	(0.027)	(0.027)	(0.026)	(0.027)	(0.027)	(0.027)	(0.026)	(0.026)	(0.026)	(0.027)
GPC	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GEI	0.050***	0.054***	0.048***	0.052***	0.071***	0.074***	0.072***	0.076***	0.062***	0.069***	0.058***	0.066***
	(0.008)	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)
INF	-0.111***	-0.121***	-0.111***	-0.120***	-0.114***	-0.120***	-0.114***	-0.121***	-0.092***	-0.104***	-0.092***	-0.102***
	(0.018)	(0.019)	(0.018)	(0.019)	(0.017)	(0.018)	(0.017)	(0.018)	(0.016)	(0.017)	(0.016)	(0.017)
CAB	-0.054**	-0.071**	-0.059**	-0.072**	-0.066**	-0.075***	-0.064**	-0.074**	-0.067**	-0.090***	-0.076***	-0.093***
	(0.027)	(0.029)	(0.028)	(0.029)	(0.028)	(0.029)	(0.028)	(0.029)	(0.028)	(0.029)	(0.028)	(0.029)
DTG	-0.032***	-0.028***	-0.033***	-0.029***	-0.037***	-0.034***	-0.036***	-0.033***	-0.042***	-0.036***	-0.045***	-0.039***
	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)
FDI	3.682***	3.382***	4.223***	3.732***	2.692***	2.451***	2.518***	2.072**	4.404***	3.938***	5.311***	4.591***
	(0.898)	(0.903)	(1.011)	(1.038)	(0.881)	(0.897)	(0.952)	(0.990)	(0.916)	(0.920)	(1.017)	(1.041)
TRG	5.541***	5.745***	5.118***	5.472***	7.863***	8.025***	8.004***	8.326***	6.508***	6.869***	5.814***	6.365***
	(1.267)	(1.273)	(1.317)	(1.332)	(1.279)	(1.287)	(1.312)	(1.331)	(1.281)	(1.294)	(1.322)	(1.345)
CO_2		0.068**		0.062*		0.044		0.052		0.101***		0.088***
		(0.032)		(0.033)		(0.032)		(0.034)		(0.032)		(0.033)
RE			-0.000	-0.000			0.000	0.000			-0.000**	-0.000
			(0.000)	(0.000)			(0.000)	(0.000)			(0.000)	(0.000)
Pseudo R^2	0.226	0.228	0.227	0.229	0.266	0.267	0.266	0.268	0.277	0.283	0.280	0.284
No. of obs.	396	396	396	396	396	396	396	396	396	396	396	396

Note: The developing countries are listed in Table 1. The dependent variable is the SCRs issued by Moody's, S&P and Fitch, respectively. The SCRs are converted into ordinal scale defined in Table 2. The explanatory variables are GG (GDP growth), GPC (GDP per capita), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita), and RE (renewable energy per capita). The figures in parentheses are standard errors. ***, **, * significant at 1%, 5% and 10%, respectively. No. of obs. refers to the number of observations.

the estimated coefficients for CO_2 are positive instead of the expected negative sign. The estimated coefficients for RE in Models 3 and 4 are mostly insignificant and of the wrong sign.

5.3 Paris Agreement 2015

To assess the influence of Paris Agreement (COP21) signed in 2015, the sample is split into pre- and post-COP21 subperiods. The estimates for these two subperiods are reported in Table 8 (Moody's SCRs), Table 9 (S&P SCRs) and Table 10 (Fitch SCRs). Model 5 is for the pre-COP21 subperiod and Model 6 is for the post-COP21 subperiod.

For the full sample, the coefficients of CO_2 and RE are statistically significant but their wrong signs reveal that the environmental factor influence has not become promi-

Table 8. Ordered logit model estimates of Moody's SCRs for the pre- and post-COP21 period

	All countries		Developed countries		Developing countries	
	Model 5	Model 6	Model 5	Model 6	Model 5	Model 6
GG	0.119**	-0.034	0.016	-0.165***	0.012	-0.016
	(0.047)	(0.028)	(0.077)	(0.045)	(0.082)	(0.043)
GPC	0.000***	0.000***	0.000***	0.000***	-0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GEI	0.042***	0.101***	0.056**	0.137***	0.047**	0.110***
	(0.013)	(0.014)	(0.023)	(0.022)	(0.021)	(0.024)
INF	-0.131**	-0.185***	-0.038	0.431***	-0.445***	-0.337***
	(0.055)	(0.035)	(0.104)	(0.149)	(0.095)	(0.064)
CAB	-0.103***	-0.107***	-0.083	0.040	-0.146*	-0.204**
	(0.037)	(0.035)	(0.056)	(0.049)	(0.081)	(0.098)
DTG	-0.036***	-0.029***	-0.039***	-0.034***	-0.019	-0.063***
	(0.005)	(0.004)	(0.006)	(0.005)	(0.013)	(0.013)
FDI	3.555***	3.033***	0.552	3.394***	4.015*	6.710**
	(0.918)	(0.800)	(1.475)	(1.315)	(2.290)	(2.891)
TRG	3.095***	2.200***	3.457**	1.783*	5.973**	-5.037
	(1.149)	(0.816)	(1.670)	(1.019)	(2.941)	(3.463)
CO_2	0.110***	0.027	0.407***	0.411***	0.286***	-0.140**
	(0.041)	(0.035)	(0.092)	(0.080)	(0.090)	(0.059)
RE	-0.000***	-0.000***	-0.000***	-0.000***	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pseudo R^2	0.307	0.317	0.362	0.355	0.295	0.367
No. of obs.	1078	1078	682	682	396	396

Note: The dependent variable is the SCRs issued by Moody's. The SCRs are converted into ordinal scale defined in Table 2. The explanatory variables are GG (GDP growth), GPC (GDP per capita), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita), and RE (renewable energy per capita). Model 5 and Model 6 are for the pre- and post-COP21 period, respectively. The figures in parentheses are standard errors. ***, **, * significant at 1%, 5% and 10%, respectively. No. of obs. refers to the number of observations.

Table 9. Ordered logit model estimates of S&P SCRs for the pre- and post-COP21 period

	All countries		Developed countries		Developing countries	
	Model 5	Model 6	Model 5	Model 6	Model 5	Model 6
GG	0.131***	-0.053**	0.048	-0.215***	0.070	-0.005
	(0.047)	(0.027)	(0.075)	(0.044)	(0.083)	(0.043)
GPC	0.000***	0.000***	0.000***	0.000***	-0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GEI	0.053***	0.120***	0.102***	0.189***	0.062***	0.137***
	(0.013)	(0.014)	(0.023)	(0.025)	(0.022)	(0.026)
INF	-0.106*	-0.195***	0.151	0.568***	-0.507***	-0.304***
	(0.056)	(0.035)	(0.103)	(0.139)	(0.100)	(0.054)
CAB	-0.033	0.011	0.029	0.180***	-0.203**	-0.127
	(0.034)	(0.033)	(0.050)	(0.042)	(0.082)	(0.096)
DTG	-0.030***	-0.031***	-0.038***	-0.036***	0.005	-0.056***
	(0.004)	(0.004)	(0.006)	(0.005)	(0.013)	(0.013)
FDI	3.048***	2.011**	2.320	2.451*	-0.426	5.954**
	(0.901)	(0.804)	(1.481)	(1.265)	(2.099)	(2.928)
TRG	1.414	0.242	1.164	-0.528	10.370***	-1.459
	(1.057)	(0.805)	(1.488)	(0.860)	(2.825)	(3.370)
CO2	0.091**	0.016**	0.251*	0.272***	0.428***	-0.116**
	(0.037)	(0.035)	(0.067)	(0.062)	(0.100)	(0.058)
RE	-0.000***	-0.000***	-0.000***	-0.000***	0.000**	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pseudo R^2	0.309	0.368	0.375	0.412	0.289	0.398
No. of obs.	1078	1078	682	682	396	396

Note: The dependent variable is the SCRs issued by S&P. The SCRs are converted into ordinal scale defined in Table 2. The explanatory variables are GG (GDP growth), GPC (GDP per capita), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita), and RE (renewable energy per capita). Model 5 and Model 6 are for the pre- and post-COP21 period, respectively. The figures in parentheses are standard errors. ***, **, * significant at 1%, 5% and 10%, respectively. No. of obs. refers to the number of observations.

Table 10. Ordered logit model estimates of Fitch SCRs for the pre- and post-COP21 period

	All countries		Developed countries		Developing countries	
	Model 5	Model 6	Model 5	Model 6	Model 5	Model 6
GG	0.128***	-0.050*	0.094	-0.205***	0.026	0.011
	(0.048)	(0.027)	(0.078)	(0.045)	(0.087)	(0.043)
GPC	0.000***	0.000***	0.000***	0.000***	-0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GEI	0.043***	0.128***	0.046**	0.175***	0.048**	0.123***
	(0.013)	(0.015)	(0.023)	(0.024)	(0.022)	(0.027)

Table 10. Continued

	All countries		Developed countries		Developing countries	
	Model 5	Model 6	Model 5	Model 6	Model 5	Model 6
INF	-0.123**	-0.197***	0.112	0.548***	-0.552***	-0.409***
	(0.055)	(0.039)	(0.103)	(0.145)	(0.104)	(0.067)
CAB	-0.023	-0.044	0.052	0.135***	-0.255***	-0.228**
	(0.036)	(0.034)	(0.053)	(0.047)	(0.084)	(0.105)
DTG	-0.029***	-0.033***	-0.038***	-0.040***	-0.008	-0.074***
	(0.004)	(0.004)	(0.006)	(0.005)	(0.014)	(0.014)
FDI	3.351***	2.631***	1.034	3.599***	5.534**	9.079***
	(0.903)	(0.812)	(1.497)	(1.334)	(2.413)	(3.125)
TRD	-0.033	1.092	-1.659	0.282	4.771	-1.817
	(1.063)	(0.816)	(1.528)	(0.947)	(2.989)	(3.445)
CO2	0.129***	0.103***	0.461***	0.408***	0.462***	-0.009
	(0.041)	(0.037)	(0.092)	(0.074)	(0.099)	(0.057)
RE	-0.000***	-0.000***	-0.000***	-0.000***	0.000	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pseudo R^2	0.335	0.393	0.414	0.437	0.325	0.443
No. of obs.	1073	1073	677	677	396	396

Note: The dependent variable is the SCRs issued by Fitch. The SCRs are converted into ordinal scale defined in Table 2. The explanatory variables are GG (GDP growth), GPC (GDP per capita), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita), and RE (renewable energy per capita). Model 5 and Model 6 are for the pre- and post-COP21 period, respectively. The figures in parentheses are standard errors. ***, **, * significant at 1%, 5% and 10%, respectively. No. of obs. refers to the number of observations.

nent in determining SCRs. The status has remained the same even after the signing of COP21 in 2015. These outcomes remain consistent for the developed countries.

For the developing countries, the RE estimates are mostly insignificant or of the wrong sign. Due to these findings, the RE influence in the SCR determination for the developing countries is deemed irrelevant. The CO_2 estimates are statistically significant in the pre- and post-COP21 periods. In the post-COP21 period, the CO_2 estimates have changed from positive to negative sign, reflecting the negative impact of the CO_2 emissions on a country's creditworthiness. This change is unanimous for the SCRs issued by the three CRAs. However, the CO_2 influence is significant only for the SCRs issued by Moody's and S&P in the post-COP21 period.

6. Discussion

The empirical estimates presented in Section 5 clearly demonstrated that the selected control variables are relevant, and the baseline model is adequately specified with good predictive power. The baseline model is robust in predicting the SCRs issued by Moody's, S&P and Fitch. Using the CO_2 emissions per capita (CO_2) and renewable energy

per capita (RE) as proxies of the environmental factor, the estimates obtained from the full sample revealed that these proxies are statistically significant, but they do not have the expected signs to be classified as prominent SCR determinants. The estimates for the developed countries show the same outcome. The estimates for the developing countries also have the signs that are contrary to expectation and this finding rules out the relevance of the environmental factor.

Greater insights are revealed by regrouping the sample into the pre- and post-COP21 subperiods to examine the influence of the Paris Agreement signed in 2015 on the SCR determination. For the developed countries, the CO_2 and RE estimates are statistically significant but not with the expected signs. The results remain consistent in the pre- and post-COP21 subperiods. These findings imply that the CRAs have not incorporated the environmental factor impact in determining the SCRs of the developed countries. This means that the reward on higher level of RE adoption nor the penalty on the CO_2 emissions on the creditworthiness of developed countries is not yet established. For the developing countries, the signing of Paris Agreement in 2015 has influenced the CRAs in their SCR determination. Although the RE estimates remain broadly irrelevant, the CO_2 estimates are statistically significant and have the expected negative sign in post-COP21 period. This transition from significant and positive to significant and negative CO_2 estimates indicates that the leading CRAs begin to penalise developing countries on their CO_2 emissions. It is therefore evident that the environmental factor has become a prominent determinant of SCRs, specifically for the developing countries after the signing of the Paris Agreement.

The prevailing question is why the environmental factor is not a significant determinant for the SCRs of developed countries. The CO_2 emissions is the main contributor to greenhouse gas that leads to rising temperature. The renewable energy sources (e.g., solar, wind, hydro power, etc.) are currently the known green solutions to replace polluting energy sources (e.g., fossil, coal, methane gas, etc.). On that basis, the plausible explanation that the leading CRAs continue to deliberate instead of penalising the creditworthiness of the developed countries in the context of the environmental factor could be the level of RE adoption. In addition, developed countries are major contributors to fund for developing countries to adopt green energy sources. These justifications could be elaborated using the environmental Kuznets curve (EKC).

Comparing Figures 3 and 4, the mean CO_2 emissions per capita from the higher income countries in the post-COP21 period are on a gradual contraction trajectory and the mean renewal energy per capita is on a gradual expansion trajectory. For the countries with lower per capita income in the bands of USD1,000 to USD10,000 and USD10,000 to USD20,000, the mean CO_2 per capita has expanded, while their mean renewable energy per capita is relatively low. Earlier results suggested that the developing countries are penalised for their CO_2 emissions. However, the developed countries are not penalised for their CO_2 emissions, perhaps due to the reward for renewable energy adoption and funding provided to developing countries.

In Figure 5, the countries are grouped according to the ratio of renewable energy adoption to GDP. The countries with higher RE to GDP ratios do not necessarily have lower CO_2 emissions. Although in the post-COP21 period there is an apparent improvement in overall renewable energy adoption, the lowest mean CO_2 emissions

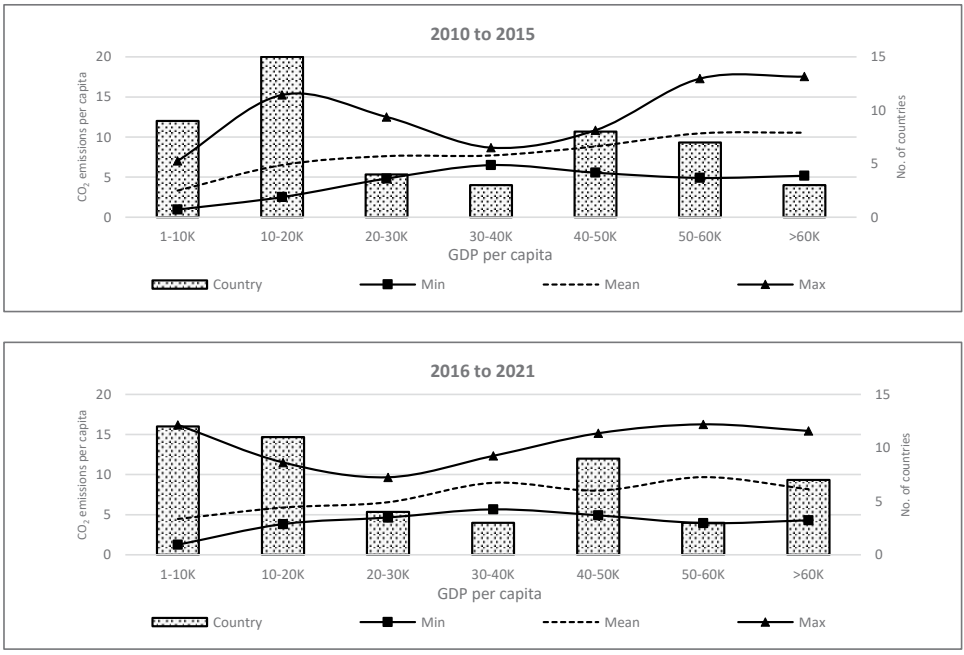

Figure 3. CO_2 emissions per capita by GDP per capita grouping

Note: The minimum, mean and maximum of the CO_2 emissions per capita (in metric tonnes) are computed for the six-year interval using the year 2015 as the cut-off point to demarcate the signing of the Paris Agreement. The GDP per capita is further grouped in the interval of USD10 thousand. The sample consists of 49 countries as listed in Table 1.

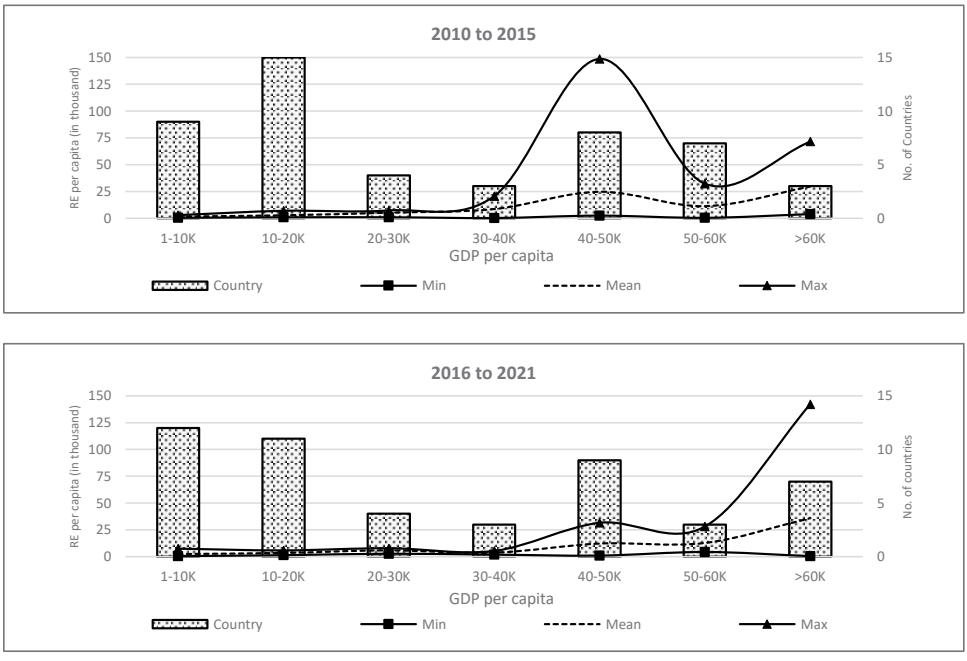

Figure 4. Renewable energy per capita by GDP per capita grouping

Note: The minimum, mean and maximum of the renewable energy per capita (kWh) are computed for the six-year interval using the year 2015 as the cut-off point to demarcate the signing of Paris Agreement. The GDP per capita is further grouped in the interval of USD10 thousand. The sample consists of 49 countries as listed in Table 1.

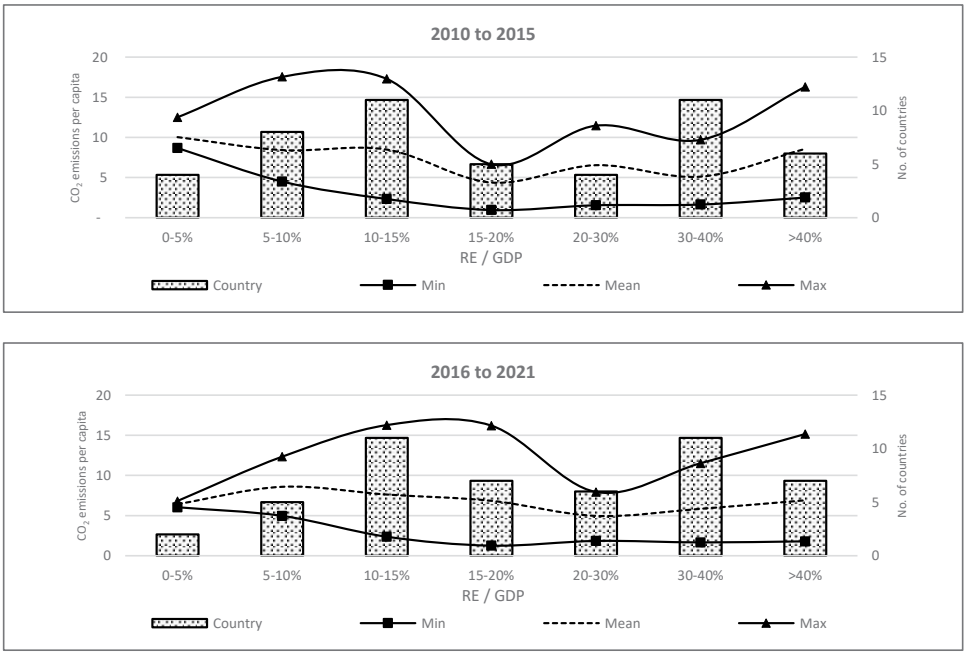

Figure 5. CO_2 emissions per capita by the ratio of renewable energy to GDP grouping

Note: The minimum, mean and maximum of the CO_2 emissions per capita (in metric tonnes) are computed for the six-year interval using the year 2015 as the cut-off point to demarcate the signing of the Paris Agreement. The ratio of renewable energy per capita to GDP per capita is computed by country and further grouped in tiers. The sample consists of 49 countries as listed in Table 1.

per capita appear among countries with 20% to 30% RE to GPC ratio. From this point onwards, the mean CO_2 emissions per capita begin to expand indicating that countries with high renewable energy adoption after scaling for the size of their economy do not necessarily lead to lower CO_2 emissions. This questions the lack of penalty for CO_2 emissions in the determination of the creditworthiness of developed countries.

7. Conclusion

There is growing intensity to contain global temperature from rising beyond 1.5°C above pre-industrial levels as championed by the Intergovernmental Panel on Climate Change (IPCC). This paper sets out to examine the influence of environmental factor in determining sovereign credit ratings. Using CO_2 emissions per capita and renewable energy per capita (RE) as proxies for the environmental factor, and principal SCR determinants as control variables, an empirical examination is performed on the SCRs issued by three leading CRAs, namely, Moody's, S&P and Fitch.

There is empirical evidence that shows the impact of environmental factor is being considered by the CRAs in determining SCRs, in particular after the signing of the Paris Agreement in 2015. While the effect of the environmental factor on the SCRs

of developed countries is still under review, the environmental factor has become a prominent determinant for the SCRs of developing countries. It is evident that the creditworthiness of developing countries is being penalised due to CO_2 emissions. In this case, the developed countries are not found to be subjected to penalty for CO_2 emissions. This could potentially be linked to their higher level of renewable energy adoption. Whereas for the developing countries, the penalty on CO_2 emissions could be perceived as the cost of low renewable energy adoption.

The three leading CRAs are recommended to update their SCR determination methodologies to explicitly state the environmental factor assessment criteria. This is to ensure uniformity when assessing the creditworthiness of developed versus developing countries. As illustrated in our analysis, not all developed countries with high renewable energy adoption would lead to lower CO_2 emissions. Hence, developed countries with high renewable energy adoption and high CO_2 emissions should be subjected to the same penalty on CO_2 emissions imposed on the developing countries.

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Appendix

SCRs, GDP per capita grouping, CO_2 emissions per capita and renewable energy per capita, 2021

Country	Status	Moody's	S&P	Fitch	GPC Grouping	CO_2	RE
Argentina	Developing	Ca	CCC-	CC	10–20K	4.12	2,385.65
Australia	Developed	Aaa	AAA	AAA	>60K	15.09	7,927.89
Austria	Developed	Aa1	AA+	AA+	50–60K	7.24	17,302.50
Belgium	Developed	Aa3	AA	AA-	50–60K	8.24	6,088.89
Brazil	Developing	Ba2	BB-	BB-	1–10K	2.28	7,527.20
Bulgaria	Developed	Baa1	BBB	BBB	10–20K	6.18	3,630.12
Canada	Developed	Aaa	AAA	AA+	50–60K	14.30	30,324.40
Chile	Developing	A1	A	A-	10–20K	4.38	6,287.51
China	Developing	A1	A+	A+	10–20K	8.05	4,590.17
Colombia	Developing	Baa2	BB+	BB+	1–10K	1.78	3,424.74
Croatia	Developed	Ba1	BBB-	BBB+	10–20K	4.36	6,921.53
Czech	Developed	Aa3	AA-	AA-	20–30K	9.24	2,880.95
Denmark	Developed	Aaa	AAA	AAA	>60K	5.05	12,506.81
Egypt	Developing	B2	B	B+	1–10K	2.29	600.98
Finland	Developed	Aa1	AA+	AA+	50–60K	6.79	20,123.21
France	Developed	Aa2	AA	AA	40–50K	4.74	5,535.21
Germany	Developed	Aaa	AAA	AAA	50–60K	8.09	8,189.97
Hungary	Developed	Baa2	BBB	BBB	10–20K	4.99	1,981.95
Iceland	Developed	A2	A	A	>60K	9.11	136,961.11
India	Developing	Baa3	BBB-	BBB-	1–10K	1.93	650.98
Ireland	Developed	A2	AA-	AA-	>60K	7.53	6,142.66
Israel	Developing	A1	AA-	A+	50–60K	6.13	1,684.21
Italy	Developed	Baa3	BBB	BBB	30–40K	5.55	5,471.87
Japan	Developed	A1	A+	A	30–40K	8.57	4,519.64
Kazakhstan	Developing	Baa3	BBB-	BBB	10–20K	14.41	1,644.69
Latvia	Developed	A3	A+	A-	20–30K	3.88	5,387.56
Lithuania	Developed	A2	A+	A	20–30K	4.98	2,390.33
Malaysia	Developing	A3	A-	BBB+	10–20K	7.63	2,794.66
Mexico	Developing	Baa1	BBB	BBB-	1–10K	3.21	1,564.98
Netherlands	Developed	Aaa	AAA	AAA	50–60K	8.06	6,823.67
New Zealand	Developed	Aaa	AA+	AA	40–50K	6.59	18,325.03
Norway	Developed	Aaa	AAA	AAA	>60K	7.57	75,242.40
Peru	Developing	Baa1	BBB+	BBB	1–10K	1.67	2,741.87
Philippines	Developing	Baa2	BBB+	BBB	1–10K	1.27	521.64
Poland	Developed	A2	A-	A-	10–20K	8.58	2,500.04
Portugal	Developed	Baa2	BBB	BBB	20–30K	3.97	8,444.29
Romania	Developed	Baa3	BBB-	BBB-	10–20K	4.10	3,525.51
Russia	Developing	Baa3	BBB-	BBB	10–20K	12.10	3,966.45
South Korea	Developing	Aaa	AAA	AAA	30–40K	11.89	2,510.53
Singapore	Developed	A2	A+	A	>60K	5.47	501.05

Appendix (continued)

Country	Status	Moody's	S&P	Fitch	GPC grouping	CO_2	RE
Slovak Republic	Developed	A3	AA-	A	20–30K	6.48	3,554.86
Slovenia	Developed	Aa2	AA	AA-	20–30K	5.92	6,640.83
Spain	Developed	Baa1	A	A-	30–40K	4.92	7,307.64
Sweden	Developed	Aaa	AAA	AAA	>60K	3.43	30,865.16
Switzerland	Developed	Aaa	AAA	AAA	>60K	4.02	12,601.87
Thailand	Developing	Baa1	BBB+	BBB+	1–10K	3.89	1,410.13
Türkiye	Developing	B2	B+	BB-	1–10K	5.26	3,694.93
United Kingdom	Developed	Aa3	AA	AA-	40–50K	5.15	5,319.54
United States	Developed	Aaa	AA+	AAA	>60K	14.86	8,166.11

Note: GPC denotes GDP per capita (USD), CO_2 denotes CO_2 emissions per capita (metric tonnes) and RE denotes renewable energy per capita (kWh).

Spearman's rank correlation

	Moody's SCRs	S&P SCRs	Fitch SCRs	GG	GPC	GEI	INF	CAB	DTG	FDI	TRG	CO2	RE
SCRs	1.000	1.000	1.000										
GG	-0.240	-0.242	-0.250	1.000									
GPC	0.781	0.802	0.813	-0.377	1.000								
GEI	0.852	0.869	0.862	-0.281	0.857	1.000							
INF	-0.443	-0.471	-0.470	-0.273	-0.484	-0.507	1.000						
CAB	0.224	0.273	0.274	-0.082	0.269	0.316	-0.380	1.000					
DTG	0.088	0.110	0.124	-0.274	0.330	0.266	-0.265	0.159	1.000				
FDI	0.703	0.719	0.728	-0.308	0.724	0.692	-0.424	0.280	0.366	1.000			
TRG	-0.342	-0.368	-0.376	-0.226	-0.393	-0.316	0.068	0.218	-0.240	-0.307	1.000		
CO_2	0.601	0.594	0.606	-0.152	0.579	0.548	-0.181	0.136	0.069	0.515	-0.269	1.000	
RE	0.373	0.381	0.389	-0.306	0.566	0.460	-0.237	0.070	0.125	0.344	-0.344	0.183	1.000

Note: The SCRs are converted into ordinal scale defined in Table 2. The variables are GG (GDP growth), GPC (GDP per capita), GEI (government effectiveness index), INF (inflation), CAB (current account balance to GDP ratio), DTG (debt to GDP ratio), FDI (financial development index), TRG (total reserves to GDP ratio), CO_2 (carbon dioxide emissions per capita), and RE (renewable energy per capita)