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Rajneel Narayan & Rup Singh

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Revisiting sovereign credit risk in Fiji: New evidence from high-frequency contingent claims analysis

Rajneel Narayan and Rup Singh

School of Accounting, Finance and Economics, The University of the South Pacific, Fiji

ABSTRACT

This study applies Contingent Claims Analysis (CCA), based on the Black-Scholes option pricing framework, to assess Fiji's sovereign credit risk and generate forward-looking risk indicators. While prior studies have used this method for Fiji, this analysis extends the literature by incorporating a broader array of indicators, high-frequency data from January 2016 to December 2022, and detailed sensitivity tests. The findings reveal that the distance to distress is highly volatile, with a sharp drop to three standard deviations in 2020 during the COVID-19 crisis compared to eight in 2018. The risk-neutral default probability surged to 90 percent during the pandemic period. Despite these concerns, the asset-to-distress barrier ratio remained relatively stable over the seven-year period, and credit risk indicators generally moved in line with economic growth. The sensitivity analysis highlights that volatility in local currency liabilities has a strong effect on risk metrics. To address concerns regarding benchmarking, we explicitly compare our findings to sovereign credit ratings and similar comparable models. The study also incorporates climate contingencies in measuring the risk indicators. Several robustness exercises are employed to validate the findings. We argue that these findings support the application of CCA in sovereign risk monitoring and policymaking in small developing economies such as Fiji.

IMPACT STATEMENT

This study applies Contingent Claims Analysis (CCA) to sovereign risk assessment in Fiji, developing a high-frequency, policy-oriented framework suited to small island developing states. Building on Jain et al. (2020), it extends the literature using monthly data from 2016 to 2022, a richer set of balance sheet indicators, and detailed sensitivity and robustness analyses. Key methodological improvements address limitations in distress barrier specification, asset volatility estimation, and data harmonization, enhancing the reliability of CCA-based risk measures. To improve policy relevance, the study introduces a quantile-based classification of Distance-to-Distress (D2D), resolving the problem of non-transferable distress thresholds, and complements this with stress testing and a sovereign risk dashboard linking D2D to liability volatility, debt composition, and reserve adequacy. Climate-related contingencies are also incorporated, and results are benchmarked against sovereign credit ratings to strengthen external validity. Empirically, Fiji's sovereign risk profile shows significant volatility, with a sharp deterioration during COVID-19, marked by a steep D2D decline and rising risk-neutral default probabilities. Local-currency liability volatility emerges as a key driver of sovereign risk dynamics. Overall, the study bridges methodological rigor with practical applicability, offering a scalable early-warning framework for data-constrained and shock-prone economies.

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1. Introduction

Over the years, sovereign credit risk assessment has garnered considerable attention and become a major issue in international public finance. The risk imposed has predominantly been unique to developing economies, largely attributable to the requisites of financing budget deficits denominated in foreign

CONTACT Rajneel Narayan rajneelnarayan31@gmail.com School of Accounting, Finance and Economics, The University of the South Pacific, Fiji.

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currencies. As such, sovereign states have borrowed for hundreds of years, and episodes of sovereign defaults have thus been a common phenomenon. These defaults have been a direct consequence of various events, some of which have been directly triggered by macro-financial risks imposed by major economic events such as the global financial crisis[1] in late 2008 and the COVID-19[2] virus in 2019. Among the many sovereign defaults noted in history, the hugest, according to Tomz and Wright (2013, p.15), was the 2012 Greek restructuring[3], followed by the Argentine debt crisis in 2001[4] and Russia in 1918[5]. However, this issue has recently garnered considerable attention and discourse among researchers, policymakers, and scholars. Thus, several structural models have been devised by researchers, such as Robert Merton's model on a corporate equivalent in 1974, which was first extended by Gray et al. (2007) for sovereign debt assessment using the contingent claims analysis model (CCA).

Contingent claims analysis is one of the most widely adopted methodologies by financial empiricists for comprehending the possibility of default. Although CCA was initially devised to assess corporate default possibilities, its applicability has extended to the sovereign and banking sectors over time. This sheds significant light on its foreseeing capabilities and relevance in today's dynamically evolving market situation. However, employing this model in any other setting, except at the country level, has proven to be less tedious. This is because it is difficult to ascertain the true value of a country's total assets and volatility. Therefore, the CCA model allows the calculation of implied sovereign asset value and implied volatility by using contingent claims of sovereign liabilities on the risk-adjusted balance sheet.

Therefore, the primary objective of this research is to quantify and measure sovereign risk stemming from Fiji's risk-adjusted balance sheet. Estimating such risks has been unequivocally relevant and has existed in financial theory since the late 1900s. This approach has been widely adopted in the corporate sector for credit risk assessments, and its productive outputs have encouraged scholars to extend it to the financial sector. However, at the sovereign level, the analysis gap remains, particularly for small developing economies. Thus, this study is an important attempt to gauge the model's efficacy and usefulness in small developing economies, such as Fiji.

Section 2 examines relevant literature on the CCA framework. Section 3 presents how to transpose corporate credit risk analysis to a sovereign level, including constructing a risk-adjusted balance sheet and modelling sovereign credit risk. Section 4 provides information on data origination, derivations, and sources. Section 5 documents the empirical findings on the Fijian economy. Section 6 concludes the paper with relevant findings, recommendations, and policy implications.

2. Literature review

The history of structural credit risk modelling comes from the seminal contributions of option pricing theory (OPT),[6] first laid in 1973 by Black and Scholes. Using Black and Scholes (1973) ideologies, Merton (1974) devised groundbreaking insights into capital structure and firm theory. According to Merton (1974), a firm's equity is a call option for its assets, while the strike price mirrors the firm's debt level. This approach is widely used in finance, mostly for investment purposes, where investors can easily derive the probabilities of default of companies using data pertaining to their historical stock prices and book value of debt (Crosbie & Bohn, 2019). However, the same assumptions ascertained by Merton (1974) cannot be assumed to hold for a sovereign (Allen et al., 2002). This is primarily because the sovereign case requires further assumptions, as it is denominated by various assets and liability instruments. Gray et al. (2007) posit that for a sovereign, the local currency liabilities, that is, monetary base and domestic debt, can be analogized as equity, while foreign currency debt can be likened to the debt level or distress barrier. Table 2 comprehensively outlines consolidated sovereign risk-adjusted balance sheets. Thus, as previously mentioned, one can compute various sovereign risk metrics similar to a firm using historical data on local currency liabilities and foreign currency debt.

The application of contingent claims and option-based frameworks with respect to sovereigns predates the modern applications such as that developed by Gray et al. (2007). Early work by Gennotte et al. (1987) shows the development of valuation models that treat developing country debt as a contingent claim whose value ultimately hangs on the possibility of renegotiation and rescheduling. In particular, they show the ability to restructure sovereign obligations can be interpreted as an option embedded in debt contracts, affecting both lending incentives and country creditworthiness. Theoretical foundations in sovereign debt studies was further developed by Grossman and Van Huyck (1988), where they modeled sovereign debt as a contingent claim where repayment depends on economic states and introduced the concept of 'excusable default'. They emphasized that sovereign defaults may be driven largely by adverse macroeconomic conditions rather than representing outright repudiation. In parallel, Krugman's (1988) work on debt overhang theory demonstrated how large external debt burdens distort incentives for repayment and investment, providing a theoretical basis for sovereign debt restructuring and forgiveness policies. Related empirical and policy-oriented contributions by Claessens and Diwan (1990) examined how debt overhang and liquidity constraints affect investment incentives and sovereign repayment capacity, highlighting the role of debt relief and conditional lending in reestablishing sustainability. Building on these earlier theoretical contributions, later work in the literature has formalized the structural sovereign balance-sheet approach using contingent claims analysis. Recent surveys by Cassimon et al. (2025), further highlights the relevance of option-based frameworks in analyzing sovereign credit risk.

Therefore, a pivotal reference point for this study is the research pioneered by Gray et al. (2007), which established the ideals for employing CCA for sovereign risk assessment. They adopted a dual philosophy to test the efficacy of the CCA framework. First, it was tested using a longitudinal panel of 11 countries from to 2002–2005 using weekly data and Brazil alone. In both scenarios, the results reveal a high explanatory power, above 80%, when regressing distance to distress (d2d) with credit default spreads (CDS). This underscores the adeptness of CCA to forecast nonlinear movements in the market, which is nonexistent in traditional models. Gapen et al. (2008) extended the debate to understand the merits of CCA from a policy perspective. Using 12 emerging market economies, they provide convincing evidence that the approach is robust and has a significant mover advantage over traditional macroeconomic vulnerability indicators. Regression analysis, scenario analysis, and robustness tests demonstrate that risk indicators outperform market-based indicators. In addition, the study outlined that the model could be calibrated in a manner unique to each country, thus offering unique policy options. Souto et al. (2007) investigated the CCA approach in Turkey. Assessing the risk profile of the country, similar results were registered, as the CCA outputs were found to be significantly correlated with market data (CDS[7] and Emerging Market Bond Index (EMBI)[8]) and risk-neutral default probabilities. Further, using 14 emerging market economies, Duyvesteyn and Martens (2015) report strongly correlated outcomes of distance-to-distress (d2d) and default probability with CDS spreads. However, interestingly, this study reinforces the observation that past variations in distance to distress could help forecast fluctuations in future CDS spreads. Deviating markedly from the above discussion is the result of Aktug's (2014) study of Turkey, Mexico, and Brazil. Aktug (2014) finds that the CCA model requires calibration for volatility estimations because it marginally underestimates the default probabilities in the sample mentioned above. A 'calibration constant'[9] similar to Souto et al. (2007) is recommended herein by Aktug (2014).

Southeast Asia and mainly developing countries have the tendency to suitably apply CCA because of their portfolio of debt, which is profoundly denominated in foreign currency. Brière et al. (2016), from the Asian Development Bank (ADB), apply CCA's balance sheet approach to a sample of Southeast Asian countries to measure debt sustainability. While their model proved a negative correlation between five- & 1-year CDS spreads and distance to distress (d2d), it did report similar caveats to Aktug (2014) mentioned previously. Using a similar approach, Lai (2016) found that the model performs well; however, when faced with structural breaks or crisis situations, credit risk indicators tend to worsen. More relevantly, in a small developing country, Jain et al. (2020) tested Fiji's sovereign credit risk rating. Using the CCA approach, they conclude that Fiji, although largely drenched in debt holdings, has very low sovereign default risk. Their study also suggests CCA as an effective analysis technique for gauging sovereign risk, particularly unique to small and developing economies.

However, despite the inapposition of CCA for advanced countries, few researchers have succeeded in this realm. Gray and Jobst (2011) and Altăr et al. (2014) investigate sovereign credit risk in Sweden and Eastern-Central European countries, respectively. The results point towards CCA as a great mechanism for apprehending macro-financial linkages and applying monetary policy models because of its high predictive power for financial risk indicators in the former study, while in the latter, it is found that CCA struggles to offer sound insights using the risk indicators for shock transmissions across sectors. However, the distance to distress (d2d) risk indicator proved instrumental in both the studies. Singh et al. (2019) affirmed, in the case of eleven Euro Area (EA) countries using quarterly data from to 2004–

2019 that apart from the various credit risk indicators in the CCA analysis, distance to distress is by far the foremost indicator absorbing most market information and is less affected by market sentiment. In a further extensive analysis, Kahlert et al. (2017) in Eurozone member states from 2008 to 2016, acknowledging the caveat emphasized by Aktug (2014), introduced a jump-diffusion model that incorporates a calibration constant to address the volatility in the sovereign asset value to market data. Their findings, while consistent with Singh et al. (2019), affirm that the modified jump-diffusion model is better at forecasting credit contagion[10], sovereign credit risk, and probability of default. In addition, they acknowledge the significance of using structural credit risk models in a macroeconomic context to better unravel sovereign default risk and credit contagion.

In contrast to the studies above, we adopt a unique methodology, using monthly data with a longer timeframe than that of Jain et al. (2020), spanning from January 2016 to December 2022, which also includes the turbulent COVID-19 phase. Emphasizing mere market correlations with risk indicators, we focus on documenting distance-to-distress, probability of default, volatility of sovereign asset value, and other credit risk indicators for the Fijian economy. A critical limitation of Jain et al. (2020) is that their analysis is confined to the period 2014–2017 and relies on low-frequency quarterly data. As a result, their reported distance to default (DD) and cumulative probabilities remains nearly constant across years, failing to capture fluctuations in sovereign credit risk. This renders the risk metrics uninformative, especially during periods of economic distress. In contrast, our high-frequency monthly analysis (2016–2022) aims to capture sudden shocks, such as the COVID-19 pandemic, with accurate and robust estimations of risk metrics. Additionally, we enhance the comprehensiveness of the study by including a distinct sensitivity analysis recommended by Brière et al. (2016), comparing four distinct events under a baseline model.

3. Overview of Fiji's public debt profile

Fiji's sovereign risk dynamics must be interpreted against the backdrop of a marked increase in public and external debt over the past decade. Public debt rose sharply following successive natural disasters and expansionary fiscal responses to the COVID-19 pandemic, with the debt-to-GDP ratio increasing from moderate levels in the mid-2010s to historically high levels by 2022. The discussion below provides a brief overview on Fiji's debt profile.

3.1. Trends in public debt

Fiji's total stock of public debt has been volatile for the past few years considering the vast array of economic challenges the country has been exposed to. In 2022, Fiji recorded an increase in its public debt portfolio from FJD 7,663.7 million in 2021 to FJD 9,131.5 million at current price, an increase of 19.2 percent. Interest and principal payments are the major disruptors as they roughly represent more than 20 percent or one fifth of the total expenditure by the government. The trend in the total public debt is shown in the following Figure 1.

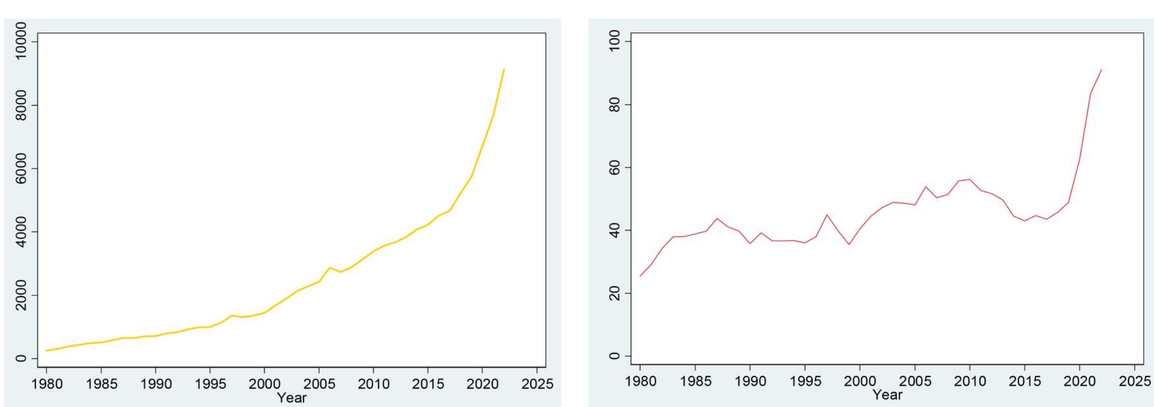

Figure 1. Total public debt of Fiji in millions of FJD (left) and percentage of GDP (right), 1980–2022.
Source: (s): Ministry of Economy and Reserve Bank of Fiji (2024).

The Figure above clearly shows that the total public debt for Fiji has demonstrated an increasing trend in nominal terms from 1980 to 2021–2022 fiscal year. The Figure also highlights that the total debt holdings by the government witnessed sharp increases after the period 2017–2018 and onwards. Despite this increasing trend noted in nominal terms, total public debt as a percentage of GDP in Fiji has witnessed both increasing and decreasing tendencies from 1980 to 2016–2017 periods, as presented in Figure 1 on the right. This reveals that while total debt as a percent of GDP was at 25.4 percent in 1980, it has increased substantially to 91.1 percent at the end of July 2022.

Figure 1 also outlines that the public debt as a percentage of GDP has dropped from 2011 to 2012 to 2016–2017 periods. This phase is attributed to the enactment of strict rudimentary fiscal policies and debt management. However, from periods 2018–2019 to 2021–2022, the country has been challenged tremendously following the onsets of the COVID-19 pandemic. As a result of the turbulence created by the Wuhan virus, the government resorted to securing debt excessively from external sources, considering it was risky to extract liquidity from the system through the issue of additional treasury bills. It is during this period when debt surged from 48.8 percent in 2018–2019 period to 91.1 percent in the 2021–2022 fiscal year. This was unequivocally imperative considering the contagious nature of the disease which required the need to support businesses, generate stimulus packages, as well as to ensure foreign reserves are kept intact.

3.2. Public debt profile

Table 1 documents Fiji's disaggregated government debt components and amounts outstanding at the end of 2021–2022 fiscal year.

3.2.1. Domestic debt

In 2021–2022 fiscal year, Fiji recorded 63.15 percent of domestic debt as a ratio of all outstanding debt by the government (see Table 1). The domestic debt in Fiji is majorly embraced by Treasury bills and Government bonds, denominated in local currency, and traded in short-and long-term maturities. Maturities for government bonds spans from 3 years to 20 years and is mutually agreed upon market conditions, while treasury bills on the other hand have short term maturities of 3 months, 6 months, and a year. Treasury bills are largely issued to the commercial banks in Fiji to finance shortfalls in revenue collection. While government bonds are primarily held by superannuation funds and non-bank financial institutions. More specifically, in 2021–2022 fiscal year, FNPF was the largest holder of domestic government bonds, 66.9 percent, followed by non-Bank financial institutions, 16.1 percent, and the Reserve Bank of Fiji (RBF), 4.3 percent.

Interest rates on governments bonds and treasury bills are market determined according to interplay of factors such as liquidity in the market, monetary policy, inflation, economic growth, and fiscal policy to name a few. However, the government has fixed the Viti bond coupon rates at 4 percent, 4.5 percent, and 5 percent for 5 years, 7 years and 10 years, respectively.

Table 1. Composition of the public debt portfolio in Fiji, fiscal year ended 2022 (1st august 2021 to 31st July 2022).

Domestic debt	Percent of domestic debt	Percent of total public debt	FJ $(millions)
Government Bonds	95.08	60.05	$5,483.90
Treasury Bills	4.92	3.10	$283.5
Total Domestic Debt	**100**	**63.15**	**$5,767.40**
External Debt by the Creditor	**Percent of External Debt**	**Percent of Total Public Debt**	**FJ $(millions)**
Bilateral	25.12	9.25	$845.1
of which			
China	12.82	4.72	$431.4
JICA	12.29	4.53	$413.7
Multilateral	74.88	27.59	$2,519.1
of which			
ADB	40.11	14.78	$1,349.4
World Bank Group	30.94	11.40	$1,040.8
AIIB	3.28	1.21	$110.3
EIB	0.55	0.20	$18.6
Total External Debt	**100**	**36.84**	**$3,364.1**
Total Public Debt		**100**	**$9,131.5**

Source: Compiled from the Ministry of Economy, Fiji, Debt Status Report, 2021–2022.

3.2.2. External debt

The Fijian government over the course of the past few decades has also secured fiscal financing from the ADB and the World Bank Group. Apart from these major multilateral lenders, Fiji has also secured funding from bilateral partners such as China, Japan, and other countries and that to on concessionary terms. The ADB as of 2022 has been the largest multilateral lender to Fiji worth Fijian 1,349.40 million dollars or 53.57 percent of all multilateral debt. This is followed by the World Bank Group which has lent Fiji with a sum of Fijian 1,040.8 million dollars and 41.31 percent of the category. Asian Infrastructure Investment Bank, European Investment bank and International Fund for Agricultural Development hold the remainder of the category. On the other hand, China Exim Bank (Export-Import Bank of China) and the Japan International Cooperation Agency (JICA) hold 51.04 and 48.95 percent, respectively of all bilateral debt at the end of fiscal year 2021–2022.

Fiji's external debt portfolio shares a mixture of fixed and floating interest rates. However, predominantly most debt secured is denominated in fixed rates. A succinct study of the balance sheets of Fiji revealed that fixed interest rate loans were secured through bilateral lenders while floating interest rate loans came from multilateral lenders such as ADB and World Bank on concessionary terms and grace periods. A detailed documentation of the interest rate on external debt is relatively challenging considering the elusive nature of information dissemination by the Fijian government.

In terms of currency composition of the debt issued, the US dollar held the largest share at 74.9 percent followed by Chinese Yuan and Japanese Yen at 12.8 and 12.3 percent, respectively. The primary cause of the large differential noted between currency denominations are because of the increased pragmatic borrowing and infrastructure financing from multilateral lenders, such as ADB and the World Bank group. Although it is noted in 2022 that the composition of Chinese Yuan and Japanese Yen had risen, the principal explanation is exchange rate movements rather than new loans denominated in the currency.

3.2.3. Interest payments

The illustrative depiction in Figure 2 presents Fiji's mounting interest payment commitments on debt.

The graphs above reveals that while interest payments in nominal terms have been growing, on the other hand, in real terms it has been fluctuating. Fiji's strong economic growth has allowed it to maintain low interest payments as a percentage of GDP less than 5 percent. The highest interest payments as a ratio to GDP is noted in 1998 at 4.01 percent. Factors behind this had been the devaluation of the FJD by 20 percent in January 1998, coupled with rising borrowing levels following the natural disasters in 1997.

4. Methodology

4.1. Background of contingent claims analysis

Contingent claims analysis is dedicated to modelling the value of a financial asset, the payoff of which can be indirectly ascertained through option pricing. In the corporate sector, this can be easily affirmed using available market information without the need for complex processes. However, for a sovereign,

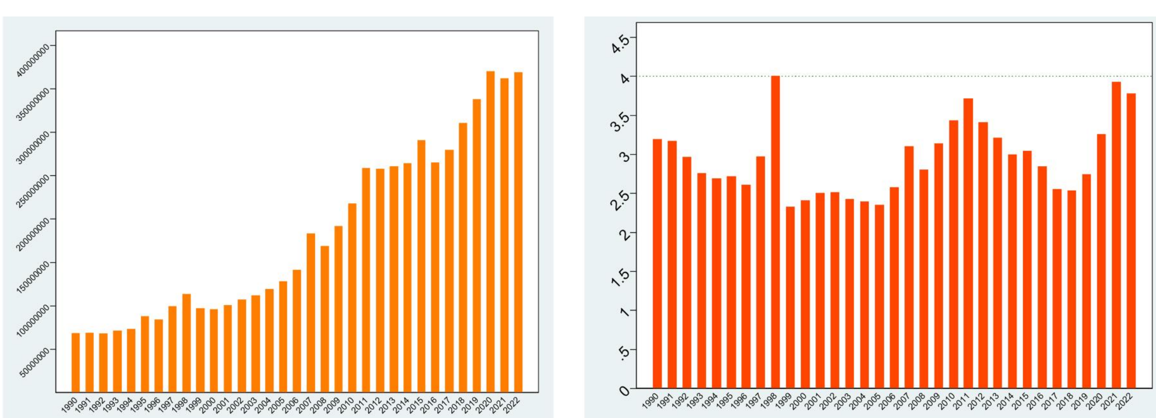

Figure 2. Interest payments on public debt for Fiji in nominal terms (left) and percentage of GDP (right), 1990–2022.
Source(s): World Development Indicator and Report of the Auditor General Fiji (2024).

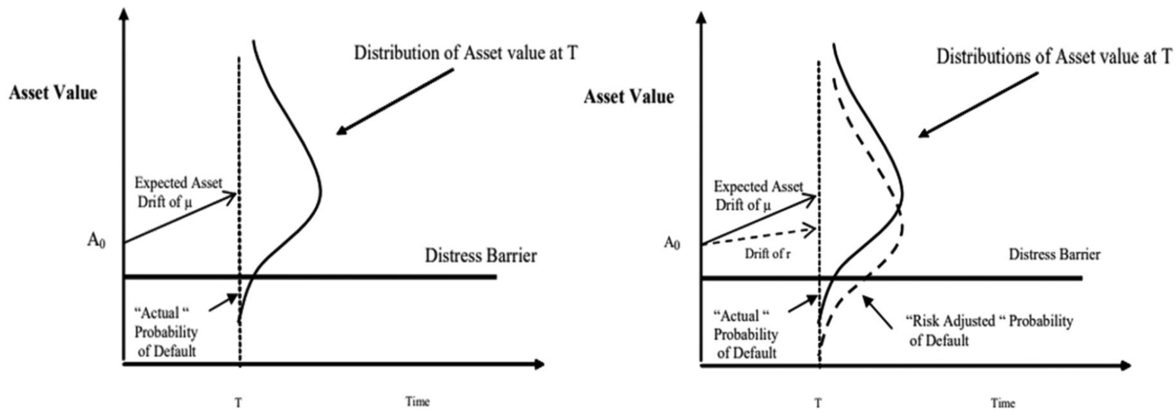

Figure 3. Basic intuition behind understanding the CCA framework.
Source: Adapted from Gray et al. (2007).

as we will understand later, it requires a daunting process of practicing multiple iterations before it converges to an appropriate representation of market outcomes. Merton's contributions in 1973, 1974, and 1977, alongside Black and Scholes (1973) option pricing theory, serve the broader framework for introducing the application of contingent claims that permits the assessment of credit risk seamlessly across firms and now extends further to different fields.

At the core of CCA is the need to ascertain junior and senior claims, more specifically equity and debt, respectively, for a firm. This can be established using a well-devised risk-adjusted balance sheet[11] for companies, consistent with Gray et al. (2007). Figure 3 fundamentally provides the basic intuition underlying CCA analysis. This indicates that a financial risk situation is apparent when asset values fall below the necessary debt repayment requirements (Gray & Malone, 2008).

In Figure 3, the value of assets starting at A(0) and reaching A(1) follow a fluctuating trend. This variability arises from the stochastic nature of asset returns, creating uncertainty in the market values of assets. Gapen et al. (2008, p. 15) also confirm that asset values follow a log-normal distribution pattern. Specifically, if the asset values fall below the distress barrier while exhibiting fluctuating trends, a default is likely to occur. Measuring its probability entails computing the distribution area under the distress barrier. However, in contrast to firm-level CCA analysis, where expected asset returns are used, for a sovereign case, a different proxy such as the government bond rate and risk-free rate is used, which yields inflated risk-neutral default probabilities (Gapen et al., 2008, p. 8). Moreover, the stochasticity and uncertainty surrounding the valuation of sovereign asset values, particularly the measurement of sovereign intangibles, pose a unique challenge for CCA implementation. Leveraging the risk-adjusted balance sheet, this study addresses the above-mentioned stochasticity by encapsulating claims on assets from the liabilities side.

As mentioned previously, CCA has long been established and has been recognized in the mainstream literature for evaluating bankruptcy risks for private firms. However, this approach has recently been extended to sovereign risk analysis, primarily led by Gray et al. (2007) from the International Monetary Fund (IMF) and has since been led by many researchers. The initial step involves collating the sovereign's different country balances to construct a risk-adjusted balance sheet similar to a firm.

4.2. Construction of sovereign risk-adjusted balance sheet

To formulate a sovereign risk-adjusted balance sheet for Fiji, it is important to design a basic accounting balance sheet that contains line items for both the monetary authorities and the government. Drawing inspiration from the methodology recommended by Gray et al. (2007) and Gapen et al. (2008) and a few additional arguments, this paper presents a balance sheet for CCA analysis. Table 2 outlines the fundamental structure of a country's balance sheet.

The assets comprise of:

- Foreign Reserves represent foreign currencies held by the central bank to stabilize exchange rates and manage international transactions. It also includes liquid assets such as gold and special drawing rights[12].

Table 2. Sovereign basic accounting balance sheet.

Assets	Liabilities & equity
Foreign Reserves	Base Money
Net Fiscal Asset	Local Currency Debt
Credit to Government	Foreign Currency Debt
Other Government-held Assets	Guarantees

Source: Author's own compilation.

- Net Fiscal asset. This is simply the difference between the present value of the taxes and revenue items and discretionary outlays such as education, health, and defense spending, which remain unchanged even under stressful situations for governments.
- Credit to government includes loans sanctioned by monetary authorities to the government, either in the form of loans or bonds.
- Other Government-held assets. This encompasses a range of financial and non-financial holdings. Financial factors such as equity holdings in public corporations, for example, shares in Fiji Airways and Energy Fiji Limited. Non-financial holdings are spread from various public infrastructures to state-owned lands.

Liability side of the balance sheet comprises of:

- Base Money. It is also known as high-powered money. It includes currency in circulation, excess reserves, vault cash, and the required reserves.
- Local currency debt. It represents debt delineated in domestic currency by the government and monetary authorities held by entities outside these institutions.
- Foreign currency debt. Debt holdings by the government and monetary authorities to corporations and individuals from other countries in their currencies.
- Guarantees. Assurances issued by the government, implicit or explicit, to financially aid banks, insurance companies, and financial institutions in meeting their indispensable obligations.

4.2.1. Quantitative frameworks to estimate sovereign asset unobservables

Having defined the balance sheet items, it becomes fundamentally clear that although liabilities are effortlessly ascertainable, the rather more intricate challenge is to determine the market values of sovereign assets and their corresponding volatility. Therefore, to solve for asset unobservables, three approaches, each exhibiting their own pros and cons, are offered in the literature. They are as follows. First, is the market value approach. However, this approach is problematic and tedious at the same time. This is because, while items such as foreign reserves are easily observable with market prices, other items such as net fiscal assets and other government-held assets have counterparts that are difficult to quantify. The second is the present value approach for discounted cash flows. This approach relies on extensive discounting of both tangible and intangible items using a discount rate that must be adjusted for risk. Additional indicators, such as growth rate, political developments, and real interest rates, are used; however, owing to their oscillating nature, it emits another formidable challenge. More importantly, it is worth noting that neither of the methods mentioned above addresses the calculation of sovereign asset volatility.

Third, we used the contingent claims approach. Capitalizing the relationship between the unobservable asset side and observable liability side of the balance sheet, sovereign asset value and sovereign asset volatility are indirectly ascertained. Because the values are indirectly estimated from the observable liability side of the balance sheet, they are identified as implied values[13]. According to Gray et al. (2007), the reasoning behind the adoption of this approach is that it captures the collective view of market participants from the liability side, and therefore, the changes in the market prices of these liabilities will effectively offer a volatility measure. Overall, this approach circumvents the problems highlighted in the aforementioned methods and was therefore adopted in this study.

Table 3. Risk-adjusted balance sheet.

Assets	Liabilities & equity	
Foreign Reserves Net Fiscal Asset	Base Money Local Currency Debt	Local Currency Liabilities
Other Government-held Assets less Guarantees	Foreign Currency Debt	Risky-Debt

Source: Author's own compilation.

4.2.2. Sovereign consolidated accounting balance sheet

In the next step, we rearranged certain items in the basic balance sheet, as presented in Table 3. We begin by subtracting the guarantees to the too-important-to-fail entities from the asset side[14]. This makes the asset side now consisting of foreign reserves, net fiscal assets, and other government-held assets less guaranteed to be important-to-fail. Liabilities consist of local currency liabilities (i.e. base money (BM) and internal debt) and external debt denominated in a foreign currency.

Thus, having constructed a risk-adjusted sovereign balance sheet for Fiji, it still exhibits a caveat. That is, there exists a fundamental mismatch between the currency denominations of the different asset and liability items. However, this issue only exists in emerging market economies, where their soft reserve currencies[15] need to be converted to hard reserve currencies[16], such as US dollars. However, for developed countries, this issue does not persist because they have the freedom to settle their obligations in hard reserve currencies. More importantly, since the purpose of this study is to consider credit risk stemming from foreign currency debt, it becomes less arduous to dismantle the analysis when converted into a hard currency, such as US dollars.

4.2.3. Derivation of model inputs

Following Gray et al. (2007), we first summarize the basic balance sheet relationship as follows:

$$A_{\$,t} = D_{\$,t} + LCL_{\$,t} \tag{1}$$

$$LCL_t = BM_t + LCD_t \tag{2}$$

$$LCL_{\$,t} = \frac{BM_t + LCD_t}{X_f} \tag{3}$$

Where BM is the monetary base in local currency, LCD is the market value of local debt, X is the forward exchange rate, t denotes the time subscript, and $\$$ represents foreign currency-defined items.

Here local currency liabilities, $LCL_\$$, is analogous to a call option for the value of sovereign assets denominated in foreign currency, with a strike price equal to the default barrier, DB_f Gray et al., 2007). Setting the default barrier right is central to the assessment of credit risk in a sovereign case. According to Rogoff (2011), the practical way to ascertain the default barrier is to assess past decisions of the government during episodes of sovereign default. However, due to scarce evidence in the historical literature, Gray et al. (2007) recommend setting an arbitrary default barrier, for example, as in the KMV model, that is, short-term plus half of long-term debt expressed in foreign currency terms or as the total sum of short-term debt in foreign currency terms (as in Brière & Bodie, 2014; Duyvesteyn & Martens, 2015). However, this study uses the latter approach because the data do not discern between short-term and long-term debt.

As in Gray et al. (2007), we assume that the value of local currency liabilities in foreign currency terms, $LCL_\$$, and the value of sovereign assets, A_{sov}, adhere to the lognormal process, characterized by a risk-free rate and constant volatility. Thus, utilizing Black and Scholes (1973) and European option pricing theory, we can compute the value of local currency liabilities in foreign currency terms using the following formulae (Merton, 1973, 1974, 1977):

$$LCL_\$ = A_{sov}N(d_1) - DB_f e^{r_f T} N(d_2) \tag{4}$$

where:

$$d_1 = \frac{\ln\left(\frac{A_{sov}}{DB_f}\right) + \left(r_f + \frac{\sigma_A^2}{2}\right)T}{\sigma_A\sqrt{T}}$$

$$d_2 = d_1 - \sigma_A\sqrt{T}$$

σ_A is the volatility of sovereign asset returns and N (d_1, d_2) is the cumulative standard normal distribution.

Thus, by defining the value of the local currency liability in foreign currency terms, $LCL_\$$, we compute the relative volatility of returns as:

$$\sigma_{LCL_\$} = \sqrt{\left(\frac{BM_\$}{BM_\$ + LCD_\$}\right)^2 \sigma^2{}_{BM_\$} + \left(\frac{LCD_\$}{BM_\$ + LCD_\$}\right)^2 \sigma^2{}_{LCD_\$} + 2\left(\frac{BM_\$}{BM_\$ + LCD_\$}\right)\left(\frac{LCD_\$}{BM_\$ + LCD_\$}\right)^2 \rho_{BM_\$, LCD_\$}\sigma_{BM_\$}\sigma_{LCD_\$}} \quad (5)$$

$$\sigma_{LCD_\$} = \sqrt{\sigma^2{}_{LCD} + \sigma^2{}_{X_F} - 2{*}\sigma_{X_F}{*}\sigma_{LCD}{*}\rho_{LCD,X_F}} \quad (6)$$

$$\sigma_{BM_\$} = \sqrt{\sigma^2{}_{BM} + \sigma^2{}_{X_F} - 2{*}\sigma_{X_F}{*}\sigma_{BM}{*}\rho_{BM,X_F}} \quad (7)$$

where the definition of the variables in Equations (5)–(7) is:

$BM_\$$ base money in foreign currency terms; $LCD_\$$ local currency debt in foreign currency terms;, σ_{X_F} volatility of the forward exchange rate;, $\sigma_{LCD_\$}$ volatility of the local currency debt in foreign currency terms, $\sigma_{BM_\$}$ volatility of the base money in foreign currency terms; $\rho_{BM_\$, LCD_\$}$ pairwise correlation between base money and local currency debt in foreign currency terms; ρ_{LCD,X_F} pairwise correlation between the forward exchange rate and local currency debt; ρ_{BM,X_F} pairwise correlation between the forward exchange rate and base money. The volatility of local currency debt and base money is shown by σ_{LCD} and σ_{BM} respectively. The volatility of these variables is estimated as the annualized standard deviation of their values over the past three months. Equation (5) can be further simplified as

$$\sigma_{LCL_\$} = \sqrt{(z_1)^2\sigma^2{}_{BM_\$} + (z_2)^2\sigma^2{}_{LCD_\$} + 2(z_1)(z_2)\rho_{BM_\$, LCD_\$}\sigma_{BM_\$}\sigma_{LCD_\$}} \quad (8)$$

where:

$$z_1 = \frac{BM_\$}{BM_\$ + LCD_\$} \quad (9)$$

$$z_2 = 1 - z_1 \quad (10)$$

Since the market values of sovereign assets cannot be observed, we use the risk-adjusted balance sheet to derive the implied sovereign asset value and implied volatility. Assuming that the assumptions of Black and Scholes (1973) are binding, we can establish the following relationship through Ito's lemma[17] and link the sovereign asset values with the risk associated with junior claims:

$$LCL_\$\sigma_{LCL_\$} = A_{sov}\sigma_{A_\$}N(d_1) \quad (11)$$

Equations (4) and (11) can be used to compute two unknowns simultaneously: $A_{sov}, \sigma_{A_\$}$ (Aktug, 2014; Altăr et al., 2014; Gapen et al., 2008, p. 12; Gray et al., 2007; Hai & Tran 2017, p. 22). Because sovereign asset values stochastically follow a Geometric Brownian Motion (GBM)[18], the two Equations are non-linear, and to find a mutual solution, this study employs an iterative procedure[19] for the best convergence of the results.

Since the sovereign asset value and its corresponding volatility are not directly observable, we adopt the framework developed by Merton (1974). Using this model, the implied sovereign asset value and its implied volatility are estimated implicitly from observed liabilities using a constrained nonlinear optimization procedure. For each time period, the model solves a system of nonlinear equations linking sovereign asset value, distress barrier, and the observed liabilities. The estimation minimizes the structural residual subject to the balance sheet identity constraint, simultaneously solving for implied asset value and its volatility. We implement the optimization procedure using the GRG nonlinear engine in Excel Solver. To ensure robustness of results that is numerical stability and economically meaningful solutions, we impose several important constraints. First, to enhance numerical accuracy, we tighten the convergence precision at 0.000001. Second, to preserve the structural consistency of the model, we verify that sovereign asset values exceed the distress barrier in all periods. Third, we impose lower bounds on both asset values and volatility parameters to ensure strictly positive solutions. The iterative procedure was applied sequentially across the full sample, and no non-convergent or economically infeasible solutions were observed. We argue that this implied estimation approach is theoretically consistent with that of the broader literature and particularly in line with sovereign contexts where no observable market equity value exists. Similarly, discounted cash flow methods are unsuitable due to the endogenous and non-project-based nature of sovereign fiscal capacities.

The primary debt sustainability indicator emanating from this analysis is the d_2 term in Equation (3.6), often referred to as the 'distance to distress'. Using this metric, sovereigns seamlessly can gauge their proximity to default by comparing the distress barrier against the implied values of sovereign assets. In essence, it helps ascertain the potential of future sovereign distress by highlighting the standard deviations separating the distress barrier and implied asset values. Taking the cumulative normal distraction for the d_2 yields the risk-neutral default probability.

4.2.4. Methodological considerations and structural assumptions

The structural model employed in this study is fundamentally grounded on the assumptions of the Black-Scholes-Merton's CCA approach. While this model provides analytical tractability and economic intuition by modelling sovereign equity as a call option on underlying assets, it relies on several assumptions that may not strictly hold in the context of small emerging market economies like Fiji. The assumptions inherent in the model are lognormally distributed asset dynamics, constant asset volatility, frictionless capital markets and a debt structure which is simplified by a single maturity zero-coupon liability. However, in practice, these assumptions merely hold for sovereigns. Primarily, because balance sheets of countries are exposed to regime shifts, macroeconomic shocks, exchange rate volatility, heterogeneous debt instruments with varying levels of maturity, coupon structure, and rollover risk. Thus, we can expect biased estimates of D2D and RNDP if deviations are observed from the above canonical assumptions. To give perspective, for example, if asset returns exhibit jump behaviour during periods of economic crisis such as the COVID-19 shock, the assumption of lognormally distributed asset dynamics may understate the tail risk and thus inflate the measured solvency. Similarly, if we assume constant volatility in the sovereign assets, this may smooth periods of stress and mechanically inflate D2D during tranquil periods while abating vulnerability during regime transitions. The simplified debt structure may also compress rollover and currency mismatch risk into a single distress barrier. These has strong implications on the risk metrics as default probabilities would be downward biased at a time when short-term external obligations are elevated. We recognize these limitations in a data constrained economy like Fiji and interpret the model outputs purely as structural indicators of relative risk rather than exact default forecasts. This methodological transparency allows to ensure inferences remains robust despite structural abstraction. Table 4 below summarizes the above discussion on assumptions.

Despite these structural simplifications in the Black-Scholes-Merton's framework, the model remains valuable as it provides consistent and market-based measures of sovereign solvency, comparable across time and scenarios. Rather than attempting to incorporate the jump-diffusion or stochastic volatility extensions in this study, which would substantially increase calibration complexity and parameter instability in data-constrained environments, we address robustness through sensitivity analysis and transparent acknowledgment of structural assumptions.

5. Data sources

Data for Fiji from 2016 to 2022 is obtained from four sources:

i. Reserve Bank of Fiji (RBF), for monthly series of base money, the market value of local currency debt measured on a quarterly basis, and domestic interest rates proxied by the 91-day treasury bill rate on a quarterly basis.
ii. World development indicators (WBG): Yearly series of foreign debt in United States dollar (USD).
iii. International Monetary Fund (IMF): Spot exchange rate of the Fijian Dollar (FJD) versus the United States dollar (USD) on a monthly basis.

Table 4. Structural assumptions and potential biases in the black–scholes–merton sovereign framework.

Assumption	Model representation	Sovereign reality	How are the model outputs potentially biased?
Lognormally distributed asset dynamics	Sovereign assets follow GBM.	Asset values may exhibit jumps, fat tails and crisis induced regime breaks	D2D maybe overstated while RNDP remains understated.
Constant asset volatility	Time invariant asset volatility	Volatility clustering and regime dependent shifts occur during shocks such as COVID-19	Inflated D2D during tranquil periods and understated during vulnerable periods. RNDP maybe hence mismeasured.
Frictionless markets	Perfect market access, no liquidity constraints, and no capital controls	Small economies face liquidity stress and rollover risk	D2D maybe overstated when liquidity tightens while RNDP is understated.
Simplified debt structure	One aggregate distress barrier representing total country debt	Sovereign debt is comprised of multiple maturities	D2D maybe overstated when risk is high in the short-term debt or foreign currency debt. RNDP may understate currency mismatch and rollover risk.
Risk-neutral valuation	Default probabilities are derived under risk-neutral assumption	Sovereign spreads in reality include time-varying risk premia	D2D and RNDP may not reflect pure default risk as they are sensitive to interest rate changes.

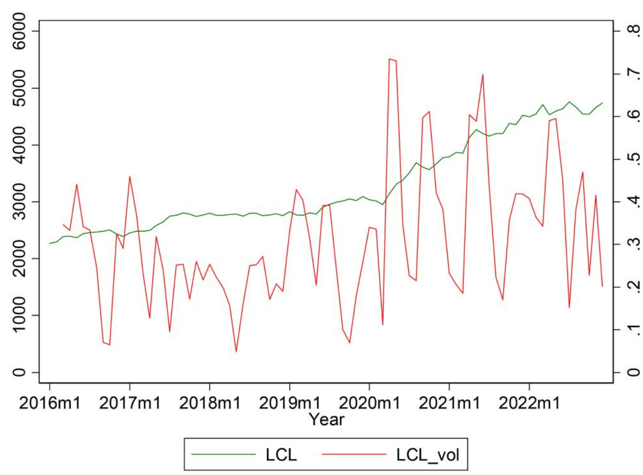

Figure 4. Estimated local currency liabilities and its volatilities for Fiji from Jan-16 to Dec-22.
Source: Author's calculation, Stata 13.
Note: LCL corresponds to left axis while its respective volatility corresponds to the right axis.

iv. Federal Reserve Economic Database (FRED): 1-year US government bond interest rate on a monthly basis.

To keep the volatility of local currency liabilities fairly stable and reactive to market sentiment, this study calculates volatility using the annualized standard deviations of its returns over the preceding three months. Further, due to data constraints on the monthly frequency of the market value of local currency debt, domestic interest rates, and foreign debt, this study employs the cubic spline interpolation technique to address the missing data points.

6. Empirical results

Benefiting from the methodology and data outlined in Section 4-5, we calculate monthly LCL and implied asset values and their corresponding volatilities. Further, in Figures 4 and 5 we present the mean values of these estimates on a yearly basis, with maturity assumed to be one year (Figures 4 and 5).

A few key insights can be drawn when analyzing the four major model inputs as represented in Table 5. An increasing trend is observed in both the local and sovereign asset values. This underscores Fiji's strengthening of its financial position and stability. Additionally, we find that the volatility estimates for assets and LCL are parallel. This could be notably associated with Equation (11), where LCL has a binding relationship with sovereign asset estimates.

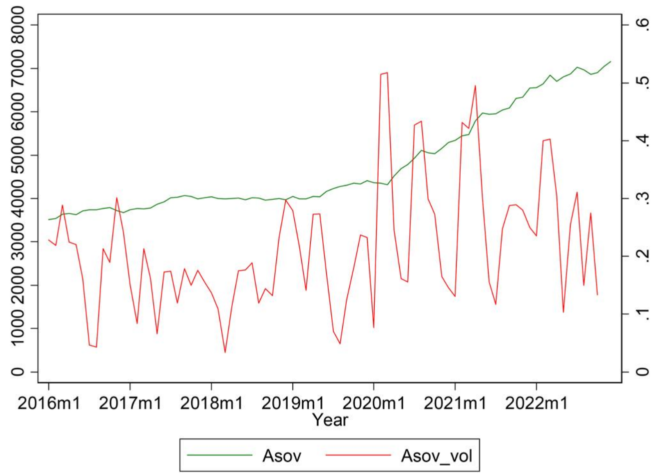

Figure 5. Estimated implied sovereign asset values and its volatilities for Fiji from Jan-16 to Dec-22.
Source: Author's calculation, Stata 13.
Note: A_{sov} values correspond to the left axis while its respective volatility corresponds to the right axis.

Table 5. Structural model inputs.

Year	$LCL_\$$	$\sigma_{LCL_\$}$	$A_{sov,\$}$	$\sigma_{A_\$}$
2016	2433.8136	0.2794	3676.0796	0.1833
2017	2646.4988	0.2494	3919.1344	0.1677
2018	2775.8089	0.1988	3995.7480	0.1381
2019	2915.6096	0.2764	4184.2979	0.1924
2020	3387.4463	0.4213	4800.1995	0.2977
2021	4161.9694	0.3777	5937.4692	0.2656
2022	4618.4328	0.3831	6865.5123	0.2581

Source: Author's calculation.
Note: $LCL_\$$ and $A_{sov,\$}$ are Local Currency Liabilities and Implied Sovereign Asset values in Billions of U.S. dollars. $\sigma_{LCL_\$}$ and $\sigma_{A_\$}$ are Volatility of the Local Currency Liabilities and Implied Sovereign Asset. Table and the Graphs are annually and monthly adjusted respectively.

Table 6. Sovereign credit risk indicators.

Year	D2D	RNDP	CDS
2016	5.128396761	21.85%	8.64%
2017	6.492587915	30.28%	2.17%
2018	8.348790841	26.26%	2.16%
2019	4.454363702	38.27%	2.35%
2020	3.093531508	92.21%	5.88%
2021	5.549909207	16.43%	2.26%
2022	4.963280054	8.23%	9.01%

Source: Author's calculation.
Note: D2D: Distance to Distress; CDS: Implied Credit Default Spread; RNDP: Risk-Neutral Default Probabilities.

Following the determination of the model inputs, the next step involves computing various sovereign credit risk indicators. Table 6 shows the annually adjusted mean values for credit risk indicators. These metrics provide a comprehensive snapshot of Fiji's evolving credit risk profile from 2016 to 2022. Using which government agencies can easily discern and formulate strategies for credit risk management.

The Table displays three different metrics: D2D is measured in standard deviations, while RNDP and Implied CDS are measured in percentages. Thoroughly scrutinizing the results above, it is found that both the D2D and RNDP series have a constantly fluctuating trend for Fiji. That is, for some periods like 2017–2018, 2018–2019, 2019–2020 and 2020–2021, the D2D and RNDP display an inverse relationship, which is consistent with theoretical credit risk modelling. However, for the periods 2016–2017, and 2021–2022, we find no inverse but positive correlation. This effectively underscores that the model fails to account for market sentiment for some time periods. Generally, it would be fundamentally unfair to classify Fiji's overall credit risk profile as deteriorating from 2016 to 2022, and we find both favorable and unfavorable movements in the risk indicators above.

In addition, we also factor contingency for future liabilities related to climate change shocks in our study. To achieve this calibration, we base our scenario on the economic impacts of Tropical Cyclone

Winston in Fiji in 2016 as reference for calculation. Comprehensive loss estimates from government and post-disaster valuations range from USD 0.9 billion to USD 1.3 billion, with direct physical damages estimated to be USD 0.5 billion (Fiji Government, 2016). We re-estimate our risk metrics by factoring this contingency of USD0.5 billion. As a result, Table 7 below reports decline in the D2D metric from 3.66 to 3.31, indicating a meaningful erosion of the sovereign's asset buffer relative to its distress barrier. Similarly, the RNDP observes a significant deterioration at 46.99 percent reflecting the combined effects of higher external borrowing requirements, elevated macro financial volatility, and exchange rate pressures following a large climate shock. The implied CDS rises from 1.76 percent to 4.43 percent, implying the cost of insuring Fiji's sovereign debt more than doubles once climate contingencies are incorporated.

Furthermore, we now try to decode the periods in which distance to distress was agitated by comparing it to Fiji's gross domestic product (GDP). Predominantly, we find similar expected trends between distance-to-distress and GDP growth. In 2018, 2019, and 2020, we found that decreases in GDP align well with decreases in distance to distress. This perfectly correlates with the COVID-19 crisis when Fiji had to undergo major structural changes, particularly in its debt portfolio, which experienced a sudden escalation. This period resulted in negative growth rates, and as a result, in Figures 6 and 7, we observe that distance to distress worsened significantly. Conversely, for 2016, 2017, and 2021, Fiji exhibited strong economic growth, which resulted in a distinct improvement in the distance to distress.

Furthermore, from Equations (5) and (6), we infer that the ratio of implied sovereign asset values to distress barriers plays a crucial role in underlining credit risk. Figure 8 illustrates the changes in sovereign assets and distress barriers from 2016 to 2022 on a monthly scale. Evidently, we find consistently large distances between the two estimated metrics, where sovereign assets are typically on average valued at 2.8 times more than the distress barrier. This substantial difference sheds light on Fiji's credit risk, which was relatively low. In addition, although the disparities between sovereign assets and distress barriers

Table 7. Climate contingencies incorporated in the risk metrics.

Contingent claim sovereign balance sheet (USD bn)	Baseline	Climate contingencies incorporated	Credit risk indicators	Baseline	New
Implied value of sovereign assets	6767.85	7167.64			
Value of risky foreign currency debt	2028.74	2428.52	D2D	3.66	3.31 (−0.36)
Distress barrier	2536.85	3036.85	RNDP	12.37%	46.99% (+34.62%)
PV of distress barrier	2028.75	2428.61			
PV of expected loss	0.02	0.09	CDS	1.76%	4.425% (+2.665)
Value of local currency liabilities	4739.11	4739.11			
Implied volatility of assets	14.10%	13.97%			

Note: Baseline corresponds to 31st December 2022.
Source: Authors estimate.

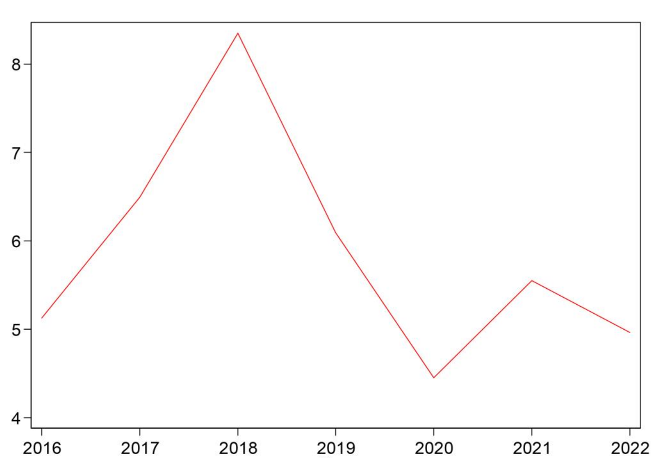

Figure 6. Distance to distress from 2016 to 2022 for Fiji.
Source: Author's calculation, Stata 13.

seem relatively stable, the major variations in credit risk stem from fluctuation trends in asset volatility, as shown in Figure 4 and 5.

To gain confidence in the results obtained from the earlier analysis, in Table 8 we compare the findings derived from both CCA and the naïve models alongside sovereign credit ratings issued by Moody's Investors service and S&P Global Ratings over the same period. This comparison allows us to benchmark the market-based risk signals generated by the CCA approach against conventional measures of risk assessment. The results indicate a high degree of consistency across the models, where periods characterized with deteriorating D2D metric coincides with credit rating downgrades and negative outlook revisions, while improvements in D2D align with rating upgrades and stabilizations. Hence, we find support and provide validity on the CCA approach as a forward-looking complement to traditional debt sustainability indicators.

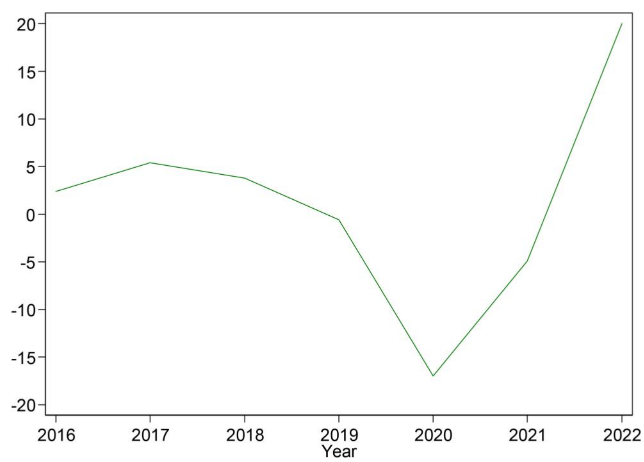

Figure 7. Real GDP growth from 2016 to 2022 for Fiji.
Source: Author's calculation, Stata 13.

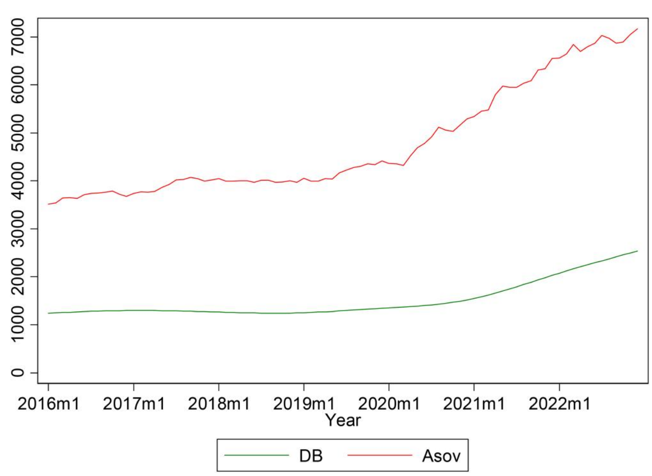

Figure 8. Estimated asset and distress barrier for Fiji from Jan-16 to Dec-22.
Source: Author's calculation, Stata 13.

Table 8. Comparative analysis of BSM, naïve, and credit ratings.

Year	$D2D_{BSM}$	$D2D_{Naive}$	*Diff.*	$RNDP\%_{bSM}$	$RNDP\%_{naive}$	*% diff.*	Moody's	S&P global
2016	5.12	4.61	0.51	0.22	0.25	−0.03	B1+	B+
2017	6.49	6.02	0.47	0.30	0.33	−0.03	Ba3 (stable)	B+
2018	8.34	7.91	0.43	0.26	0.27	−0.01	Ba3 (stable)	B+
2019	4.45	4.16	0.29	0.38	0.40	−0.02	Ba3 (stable)	BB-
2020	3.09	3.01	0.08	0.92	0.94	−0.02	Ba3 (negative)	BB-
2021	5.54	5.31	0.23	0.16	0.20	−0.04	B1 (negative)	B+
2022	4.96	4.28	0.68	0.08	0.08	0.00	B1 (stable)	B+

6.1. Sensitivity analysis

Bearing in mind the dynamic economic landscape of Fiji, which has been subject to various unpredictable events in the past, including shocks to sovereign balance sheets and credit risk. Therefore, to anticipate the potential repercussions of these events, this study employs a rigorous sensitivity analysis of sovereign credit risk indicators in the CCA model. First, we select a baseline period as 31st December 31, 2022, against which we try to comprehend the direction and magnitude of the shocks introduced. We observe impacts on three CCA risk indicators: distance to distress, risk-neutral default probability, and implied credit default spreads. Responsiveness to these indicators is observed by increasing and decreasing the base money, default barrier, exchange rate, and LCL volatility on scales of 1 and 5 percent. This allowed us to devise 16 alternative shock scenarios.

Risk indicators for the baseline year is as follows: d2d: 3.66 sd.; RNDP:12.37% and ICDS as 1.76%. Table 9 *documents the impact on the three credit risk indicators while the extensive implications for sovereign balance sheet are contained in Supplementary Appendix 1 (Appendix A1.1-A1.4).*

We note the baseline distance to distress for Fiji as 3.66 standard deviations for the year ending 2022. Subsequent shocks, as in the third, fourth, and sixth columns of a 1 and 5 percent increase/decrease, highlight negligible effects on the distance to distress. The average value falls between 0.01 and 0.06. Conversely, when the same risk indicator is shocked by LCL volatility, it has a significant impact. For instance, as in the fifth column, the distance to distress falls by 0.19 standard deviations or 5.17 percent when LCL volatility increases by 5 percent. Additional simulations also confirm that, apart from other anticipated shocks introduced to distance to distress, the greatest impact by far is derived from volatility in local currency liabilities.

Further, for RNDP, it is evident from Table 9 that the most significant impacts are from the default barrier, exchange rate, and LCL volatility (0.50–13.19 percent), while the least significant impact stems

Table 9. Sensitivity of distance to distress, risk-neutral default probability and implied credit default spread under sixteen alternative scenarios.

	Baseline	Scenario 1: 1% increase in $BM_\$$	Scenario 2: 1% increase in DB_f	Scenario 3: 1% increase in $\sigma_{LCL_\$}$	Scenario 4: 1% increase in ER_t
D2D	3.66	3.67	3.65	3.63	3.65
Change in D2D		0.01	−0.02	−0.03	−0.02
RNDP	12.37%	12.15%	12.87%	14.42%	12.87%
Change in RNDP		−0.22%	0.50%	2.08%	0.50%
CDS	1.76%	1.73%	1.83%	2.09%	1.83%
Change in CDS		−0.03%	0.07%	0.33%	0.07%
	Baseline	Scenario 5: 1% decrease in $BM_\$$	Scenario 6: 1% decrease in DB_f	Scenario 7: 1% decrease in $\sigma_{LCL_\$}$	Scenario 8: 1% decrease in ER_t
D2D	3.66	3.66	3.68	3.71	3.68
Change in D2D		0.00	0.02	0.05	0.02
RNDP	12.37%	12.58%	11.88%	10.56%	11.88%
Change in RNDP		0.21%	−0.49%	1.81%	−0.49%
CDS	1.76%	1.79%	1.69%	1.48%	1.69%
Change in CDS		0.03%	−0.07%	−0.28%	−0.07%
	Baseline	Scenario 9: 5% increase in $BM_\$$	Scenario 10: 5% increase in DB_f	Scenario 11: 5% increase in $\sigma_{LCL_\$}$	Scenario 12: 5% increase in ER_t
D2D	3.66	3.69	3.62	3.47	3.62
Change in D2D		0.03	−0.04	−0.19	−0.04
RNDP	12.37%	11.34%	15.00%	25.56%	15.00%
Change in RNDP		−1.03%	2.63%	13.19%	2.63%
CDS	1.76%	1.61%	2.12%	3.96%	2.12%
Change in CDS		−0.13%	0.36%	2.20%	0.36%
	Baseline	Scenario 13: 5% decrease in *BM$*	Scenario 14: 5% decrease in *DBf*	Scenario 15: 5% decrease *σLCL$*	Scenario 16: 5% decrease in *ERt*
D2D	3.66	3.64	3.72	3.87	3.72
Change in D2D		−0.02	0.06	0.21	0.06
RNDP	12.37%	13.50%	10.03%	5.35%	10.03%
Change in RNDP		1.13%	−2.34%	−7.02%	−2.34%
CDS	1.76%	1.92%	1.43%	0.69%	1.43%
Change in CDS		0.16%	−0.33%	−1.07%	−0.33%

Source: Author's own compilation.
Note: D2D: Distance to distress; RNDP: Risk-neutral default probability; CDS: Implied credit default spread; $BM_\$$*: Base money;* DB_f*: Distress barrier;* $\sigma_{LCL_\$}$*: Volatility of local currency liabilities;* ER_t*: Spot exchange rate.*

from the base money (0.22–1.03 percent). Generally, when the base money expands, we anticipate a contraction in risk-neutral default probabilities owing to a stronger monetary base. Conversely, upticks in the default barrier, exchange rate, and LCL volatility suggest the heightening of sovereign credit risk due to the onus imposed on the country balances, such as the balance of payments. Hence, it is confirmed that the simulations in Table 9 perfectly align with the expected trends discussed above.

Credit default spreads, on the other hand, are also largely influenced by LCL volatility, while under most scenarios, they are insensitive to alternative shocks. For instance, a 5 percent increase in LCL volatility implies a 2.20% increase in CDS spreads. Increases in LCL volatility, exchange rate, and default barrier fundamentally offload an increasing impact on CDS; however, increases in base money exert opposite effects. Since higher credit default spreads are undesirable and suggest a higher perceived risk of default and remain costly for investors, the results thus parallel the expected outcomes.

Upon thorough examination of Table 9, it becomes apparent that the three risk indicators studied for Fiji are predominantly influenced by LCL volatility, while the minutest impact is observed from the changes introduced to base money. Therefore, leveraging the constituents of LCL–that is, local currency debt (LCD) and base money (BM)–the Fijian government should apprehend the importance of fiscal discipline. Fluctuations in local currency debt and the monetary base should be managed prudently, even under stressful situations, to positively shape Fijis credit risk. Overall, we find that the simulations performed in Table 9 are consistent with sovereign credit risk relationships, as established in prior studies (Baskurt & Çelik, 2023; Brière et al., 2016).

If we relate these above generic simulations to the real economy in Fiji, we can derive actionable policy implications. For instance, we can relate the above sensitivity analysis in Table 9 (Scenarios 9–12) to climate related shocks and other systematic events in the Fijian setting such as the natural disasters and the COVID-19 pandemic. These events directly influence the credit risk through balance sheet deterioration and heightened uncertainty through a single channel. For a climate-vulnerable economy such as Fiji, severe natural disasters typically necessitate emergency spending and reconstruction outlays, often financed through additional borrowing and/or monetary expansion. Scenario 10 in Table 9 captures this mechanism accurately where post-disaster restoration financing needs is indicated by an increase in the distress barrier by 5 percent. As a result, we observe an increase in the present value of the distress barrier from USD 2,028.74b to USD 2,130.17b (Supplementary Appendix A1.3), while the D2D metric declines to 3.62 from 3.66, indicating increase in sovereign credit risk. Similarly, scenario 11 stresses the role of heightened uncertainty following such shocks, where a 5 percent increase in the volatility of the LCL leads to a marked rise in implied sovereign asset volatility from 14.10 percent to 14.80 percent and a sharp decline in distance to distress to 3.47. Often followed by such large external shocks and disasters are unprecedented pressure on the exchange rate. In scenario 12 we witness that a relative depreciation reduces the implied value of sovereign assets from USD 6,767.85b to USD 6,542.17b. In contrast, scenario 9 illustrates that monetary expansion in response to shocks can temporarily support asset values but does not offset the adverse effects of higher liabilities and volatility. These balance-sheet dynamics are consistent with the experience during the COVID-19 shock, which combined revenue losses, increased fiscal support, elevated uncertainty, and exchange-rate pressures This underscores the relevance of the sensitivity analysis as a reduced-form representation of climate and pandemic generated sovereign stress. This discussion can also be viewed from the perspective of a 1 percent increase in the parameter and the corresponding response on the balance sheet items from Table 9 (Scenarios 1–4). In addition to the increase scenarios, policymakers and researchers can also evaluate the decreases in key input variables as in Table 9 (Scenarios 5–8 & 13–16). These decreases could mirror the impacts of different policy events such as, tighter monetary policy, debt restructuring, reduced fiscal uncertainty, or currency appreciation on the sovereign credit risk metrics.

7. Robustness tests

7.1. Distress barrier specification under limited maturity disclosure

The specification of the distress barrier is central in the estimation of credit risk for sovereigns as defined in the Merton's framework. In many corporate and sovereign applications, the barrier is often defined as short-term debt plus a fraction of the long-term debt. However, the balance sheet in many small developing countries differ materially where detailed maturity decompositions are not consistently disclosed at high frequency. Fiji is a similar case, where publicly sovereign liabilities are not clearly disclosed into short-and-long term components across the full time period. As a result, constructing hybrid barriers such as short-term debt plus half of long-term debt would require arbitrary assumptions regarding maturity composition. To avoid introducing unverifiable structural assumptions, this study adopts a conservative and transparent specification whereby the distress barrier is defined as the total stock of short-term sovereign debt denominated in foreign currency terms. To assess the sensitivity of the results to potential misspecification of the distress barrier, a proportional scaling exercise is introduced. Specifically, the baseline distress barrier was adjusted downward and upward by 20 percent to generate lower- and upper-bound stress thresholds. We re-estimate the CCA model under these scaling exercises and report the results in Table 10. The results indicate that while absolute levels of D2D and RNDP vary across scaled barriers, the temporal pattern of risk dynamics remains stable. In particular, the pronounced deterioration in the risk indicators observed during the 2020 period still persists under all alternative barrier levels.

7.2. Data frequency alignment and interpolation risk

The CCA approach requires estimation of credit risk metrics with high frequency data preferably on a scale of daily or monthly. However, typical of small Island economies such as Fiji, we find it difficult to employ the CCA estimation without performing the interpolation exercise. As a result, we interpolated the market value of local currency debt, domestic interest rates, and foreign debt from quarterly to a monthly basis. This exercise was achieved with the cubic spline method. All other variables employed in the study were sourced at the preferred monthly frequency.

Given the potential concern that the cubic spline interpolation exercise may have smoothened short-term fluctuations and influenced the volatility estimates, several robustness checks were conducted to assess the sensitivity of the D2D and the RNDP to alternative harmonization strategies. Firstly, we reconstruct the quarterly variables using two different interpolation approaches: linear interpolation and the last observation carried forward (LOCF, hereafter) approaches. The CCA model was hence re-estimated using the data series generated from this interpolation exercises. We also estimate the CCA model with a 'no interpolation' sub-sample approach. This is achieved by re-estimating the CCA model with the observed data only, and no interpolation of the missing datapoints. The results in Table 11 although

Table 10. Sensitivity of sovereign risk indicators to distress barrier scaling.

	0.80*ST debt		1.0*ST debt (baseline)		1.20*ST debt	
Year	D2D	RNDP	D2D	RNDP	D2D	RNDP
2016	5.44	0.18	5.12	0.22	4.11	0.25
2017	6.70	0.20	6.49	0.30	5.22	0.38
2018	8.44	0.11	8.34	0.26	7.68	0.32
2019	5.63	0.36	4.45	0.38	3.16	0.40
2020	4.48	0.81	3.09	0.92	2.44	0.95
2021	6.04	0.12	5.54	0.16	4.38	0.22
2022	5.89	0.02	4.96	0.08	4.11	0.13

Table 11. Sensitivity of sovereign risk indicators to interpolation and frequency specifications.

	Yearly average distance to distress across interpolation methods							
	Cubic spline (baseline)		Linear		LOCF		Sub-sample	
Year	D2D	RNDP	D2D	RNDP	D2D	RNDP	D2D	RNDP
2016	5.12	0.22	5.18	0.25	4.25	0.10	2.88	0.19
2017	6.49	0.30	6.44	0.29	5.43	0.48	1.91	0.26
2018	8.34	0.26	8.27	0.21	13.24	0.39	9.58	0.33
2019	4.45	0.38	4.51	0.35	5.36	0.44	8.58	0.54
2020	3.09	0.92	3.02	0.89	4.23	0.88	2.82	0.90
2021	5.54	0.16	5.60	0.15	5.66	0.11	2.85	0.13
2022	4.96	0.08	5.01	0.11	4.31	0.03	4.21	0.08

indicate minor quantitative differences, the qualitative dynamics remain unchanged. In particular, the pronounced decline in D2D and the surge in RNDP during 2020 persist under both scenarios with and without the interpolation schemes, indicating that the crisis-period deterioration in sovereign risk is not an artifact of spline smoothing. Hence, this robustness exercise highlights that the principal results of the study are not driven by data interpolation related limitations.

7.3. Operationalization for policy and early-warning use

While the CCA model provides a measure of sovereign risk relevant to the Fijian economy, it becomes more important to translate these risk measures into actionable policy insights. Given the absence of universally transferable distress thresholds, this study defines risk categories using Fiji-specific quantile-based ranges. We divide the monthly D2D values from 2016 to 2022 into quantiles, with the lowest quantile identified as high risk and the highest as the high risk quantile. With this approach we avoid reliance on arbitrary cross-county benchmarks.

As reported in Table 12, the average D2D declined gradually from 2016 to 2019 and compressed more sharply in 2020, reflecting heightened balance sheet stress, before improving in 2021 and 2022. The proportion of high-risk months increased substantially during this period, suggesting increased vulnerability under adverse macroeconomic conditions. To assess vulnerability under adverse conditions, we conduct various stress tests including exchange rate depreciation, interest rate shocks, and increases in debt. D2D was therefore recalculated under each of the scenarios in Table 13, allowing comparisons to the baseline findings. We find that the stress scenarios significantly compress D2D during already vulnerable periods, particularly 2019–2020 period. This indicates elevated sensitivity to exchange rate and rollover shocks, reinforcing the importance of reserve adequacy and debt structure management.

Specifically, to assess forward-looking vulnerability, we devise three stress scenarios as below.

1. 10 percent exchange rate depreciation of the FJD vs USD,
2. 1 percentage point increase in domestic interest rates and,
3. 15 percent increase in short term debt.

Additionally, to enhance policy relevance, we show how the D2D measure moves alongside debt composition, volatility in LCL, and with the foreign reserves coverage ratio. This integrated dashboard

Table 12. Summary of D2D and risk distribution.

			Percentage of months by risk		
Year	Avg. D2D	Risk band (avg.)	High	Moderate	Low
2016	5.12	Moderate	33.3	50	16.7
2017	6.49	Moderate	8.3	66.7	25
2018	8.34	Low	–	25	75
2019	4.45	Moderate	25	50	25
2020	3.09	Moderate	25	75	–
2021	5.54	Moderate	25	41.6	33.3
2022	4.96	High	58.3	25	16.6
Quantile-Based Risk Bands					
		D2D range	Risk classification		
Lower quantile		D2D < 3.540	High		
Middle quantile		3.540–7.042	Moderate		
Upper quantile		D2D > 7.042	Low		

Table 13. Risk metrics measured with the stress scenarios.

Year	Baseline D2D	Stress 1: ER	Stress 2: DIR	Stress 3: ST debt
2016	5.12	5.04	5.09	4.96
2017	6.49	6.41	6.46	6.33
2018	8.34	8.26	8.31	8.18
2019	4.45	4.37	4.42	4.29
2020	3.09	3.01	3.06	2.93
2021	5.54	5.46	5.51	5.38
2022	4.96	4.88	4.93	4.8

Table 14. Sovereign risk dashboard.

Year	Avg. D2D	LCL volatility[1]	FX debt % total debt[2]	Short-term debt % total external debt[3]	Reserve/ ST debt[4]
2016	5.12	0.40	28.0	21.84	2.97
2017	6.49	0.29	29.4	25.03	2.68
2018	8.34	0.16	27.9	23.20	2.50
2019	4.45	0.35	26.1	20.43	2.78
2020	3.09	0.38	25.6	15.76	3.35
2021	5.54	0.37	31.6	14.71	4.13
2022	4.96	0.46	36.8	17.02	3.06

[1]This estimate is obtained from the CCA analysis performed in the study, averaged annually.
[2]This represents foreign currency debt % of total debt and is obtained from the Economic and Fiscal update supplements published by the Ministry of Finance, Fiji.
[3]This represents short-term debt as a percentage of total external debt and is obtained from the world development indicators.
[4]This ratio represents the share of reserve to short term debt and is retrieved from the world development indicators.

approach enables identification of conditions under which declining D2D coincides with weaker reserve buffers or elevated rollover risk, thereby strengthening its function as an early-warning indicator.

The sovereign risk dashboard in Table 14 for Fiji over 2016–2022 illustrates the interplay between CCA-derived D2D and key balance sheet indicators. In the pre-COVID period (2016–2018), D2D increased from 5.12 to 8.34, reflecting improving fiscal stability supported by moderate foreign currency debt, manageable short-term obligations, low volatility of the LCL, and strong coverage in the foreign reserves. The onset of the COVID-19 pandemic in 2020 however precipitated a sharp decline in D2D to 3.09, accompanied by elevated liability volatility, signalling heightened sovereign vulnerability, although the reserves-to-short-term debt ratio improved, indicating adequate liquidity buffers. In the subsequent recovery period (2021–2022), D2D partially rebounded to 5.54 before slightly declining to 4.96, while liability volatility rose and foreign currency debt shares increased to over 36 percent, highlighting renewed exposure to external shocks. Throughout the period, short-term debt remained relatively low and reserves continued to provide substantial coverage, underscoring the importance of liquidity management. The dashboard establishes that periods of declining D2D coincide with heightened FX exposure, increased liability volatility, and shifts in debt composition. This provides emphasises on the need for vigilant fiscal and monetary policy to mitigate sovereign risk during economic shocks.

8. Comparative analysis with prior studies in Fiji

While CCA has previously been applied to assess sovereign credit risk in Fiji, most notably by Jain et al. (2020), the present study introduces several important methodological and empirical extensions. Jain et al. (2020) employ a standard Black–Scholes–based CCA framework using relatively low-frequency quarterly data, covering the period 2014–2017. Their analysis, while informative, does not capture periods of significant economic distress, such as the COVID-19 pandemic, and therefore provides limited insights into sovereign risk under extreme macroeconomic shocks. In contrast, the current study applies CCA using high-frequency monthly data for the period January 2016 to December 2022, enabling a more granular assessment of sovereign balance-sheet dynamics over a longer and more recent period that includes major shocks such as COVID-19. This higher-frequency implementation allows for the identification of rapid shifts in credit risk associated with discrete macroeconomic shocks. As a result, the estimated distance to distress in this study exhibits substantially higher volatility than that reported in Jain et al. (2020), with a pronounced collapse in 2020 during the pandemic that would be largely smoothed out under lower-frequency estimation. See Table 15 below for a comparative outlook on the calculated D2D risk metric. The large discrepancy in the RNDP estimates arise as Jain et al. (2020) primarily used quarterly data for calculating the risk which is a major drawback. This anomaly gives rise to inaccurate estimates and is addressed using the highest frequency data in a small island country setting with monthly data in the present study.

Moreover, while Jain et al. (2020) primarily focuses on baseline indicators such as D2D and RNDP, the present analysis extends the framework through detailed sensitivity tests. In particular, we observe impacts on three CCA risk indicators: D2D, RNDP, and implied CDS. Responsiveness to these indicators is observed by increasing and decreasing the base money, default barrier, exchange rate, and LCL volatility on scales of 1 and 5 percent. This allowed us to devise 16 alternative shock scenarios. These extensions

Table 15. Comparative outlook on the D2D metric estimated with quarterly and monthly data.

	Jain et al. (2020)- quarterly		This study- monthly	
Year	DD	RNDP	DD	RNDP
2014	2.0230	22.15%	—	—
2015	2.0759	18.99%	—	—
2016	2.5457	5.4%	5.1283	21.85%
2017	2.2642	11.7%	6.4925	30.28%
2018	—	—	8.3487	26.26%
2019	—	—	4.4543	38.27%
2020	—	—	3.0935	92.21%
2021	—	—	5.5499	16.43%
2022	—	—	4.9632	8.23%

Source: Jain et al. (2020) and authors estimates.

Table 16. Key methodological innovations to that of Jain et al. (2020).

Dimension	This study	Jain et al. (2020)	Why it matters
Study period	2016–2022 (includes COVID–19)	2014–2017	Captures extreme macro-shocks
Data frequency	Monthly	Quarterly	Captures real fluctuations
Risk indicators	D2D, RNDP, CDS, sovereign asset and LCL volatility measures	D2D, IPD	More extensive analysis
Sensitivity analysis	Yes	No	Comprehend impact on risk measures under alternate situations
Major events/ stress points	COVID-19 shocks	None	Captures non-linear risk spikes
Climate contingencies	Yes	No	Incorporates future climate change uncertainties
Sovereign risk dashboard	Yes	No	Allows identifying patters between risk metrics and real country-level macro data.
Policy relevance	High	Medium	Actionable for monetary and fiscal management

reveal that liability volatility plays a dominant role in driving short-term movements in sovereign credit risk, an insight not explored in earlier applications.

Empirically, the two studies also yield different interpretations of Fiji's sovereign risk during periods of stress. Whereas Jain et al. (2020) fails to study the COVID-19 period, our high-frequency estimates indicate an abrupt and severe spike in the RNDP during the COVID-19 period, reaching levels close to 90 percent. Overall, the comparative analysis demonstrates that the proposed extensions do not merely replicate existing findings but provide sharper, event-sensitive risk indicators that enhance the monitoring and policy relevance of sovereign CCA for Fiji, especially under conditions of economic distress. Table 16 below summarises the key differences between the approach adopted by Jain et al. (2020) and this study.

9. Conclusion

This study estimates the credit risk stemming from Fiji's risk-adjusted balance sheet for the period 2016M1 to 2022M12. Deviating from traditional macroeconomic vulnerability indicators and accounting-based ratios, this study uses contingent claims analysis owing to its computational ability to leverage both non-linear changes in asset values and market prices by adopting a forward-looking approach. The major outputs produced upon the adoption of this approach are sovereign credit risk indicators, such as distance to distress, risk-neutral default probability, credit default spreads, and sensitivity analysis.

The overall results affirm that the CCA model can be considered an appropriate tool for determining the credit risk of small developing countries such as Fiji, where market sentiments tend to underplay compared to that of major developing and developed countries. In particular, this study found that the COVID-19 phase, which significantly impacted the Fijian economy, was accurately depicted in the risk metrics. Distance to distress during this period declined notably at three standard deviations, with risk-neutral default probability reaching an approximate high of 90 percent. These results further underscore the effectiveness of the correlation between the Fijian economy and various risk indicators derived from the analysis. We find that during the period from to 2018–2020, movements in GDP movements responded favorably to the distance to distress. Conversely, in 2016, 2017, and 2020, Fiji exhibited strong economic growth, which resulted in a distinct improvement in distance to distress. We also find convincing evidence of Fiji's asset-to-distress barrier ratio being fairly stable over the past seven years, with an average separation of approximately 2.8 times. Thus, in light of the above findings, we report that volatility in local currency liabilities is a major driver of credit risk in Fiji. This is consistent with studies in developing countries such as Baskurt and Çelik (2023). The sensitivity analysis performed in Section 5.0 substantiates the same, since the strongest response on D2D, RNDP, and CDS was observed from LCL volatility upon adjustments at 1 and 5 percent in BM, ER, and DB. Thus, LCL volatility plays a crucial role in shaping'sji the macroeconomic narratives. Thus, to keep the country's credit risk on a favorable front, the Fijian government might consider managing the volatility stemming from its assets, rather than just hedging against falls in sovereign asset values.

From a policy standpoint, contingent claims analysis is significantly more advantageous than traditional stress-testing techniques. This is because CCA allows the balance sheet for each country to be tailored differently, and in this way, it grasps a granular comprehension of various risks, thereby enhancing policy formulation. Policymakers can also conduct numerous scenarios, and a sensitivity analysis assesses the potential impacts of their different policy options while avoiding far-reaching negative implications.

Despite the valuable insights for Fiji, we recommend a few ideas for further refinement of CCA for developing-country studies. First, the stringent assumptions established in Black and Scholes (1973) of European options, and no coupon bond could be relaxed with a more realistic looking assumptions for sovereigns. Second, an economy-wide balance sheet inclusive of major sectors, such as the household and financial services sectors, could be considered. In practice, this recommendation may seem untimely for small economies considering the scarcity of their data. Finally, the accuracy of LCL volatility can be adjusted with a calibration technique to obtain a more transparent image of real-life outcomes.

10. Limitations and directions for future research

10.1. Solver dependence and implied volatility estimation

Despite the robust estimation procedure, nonlinear solver dependence remains an inherent limitation of the CCA model with unobservable state variables. This is because sovereign asset values and its corresponding volatility are implied values rather than being directly observed, and the estimation procedure relies on numerical optimization techniques that may be sensitive to functional curvature and parameter initialization. Although the convergence precision of the estimation remains robust together with economically feasible parameter bounds to mitigate instability, the results remain conditional on the theoretical aspects of the CCA model. Overall, we acknowledge that since it is not feasible to obtain direct sovereign asset values, the implied structural estimation implemented in this study remains the most theoretically coherent approach for sovereign balance sheet modelling. Future studies may consider extending the focus of the estimation techniques to Bayesian inference, or state-space filtering to reduce algorithmic dependence and enhance robustness.

10.2. Currency denomination and balance sheet mismatch risk

Another important limitation of the current study stems from currency denomination and balance sheet mismatch risk. In small open economies like Fiji, a non-negligible share of sovereign liabilities is denominated in foreign currency, while a substantially large portion of sovereign assets are denominated in local currency. Exchange rate fluctuations therefore alter the domestic currency value of foreign liabilities, potentially amplifying measured sovereign risk in structural models. In the CCA model, this distortion may report a very reduced D2D measure while inflating the RNDP, particularly during episodes of currency depreciation against hard reserve currencies such as the USD. This eventually raises questions concerning whether the risk parameters reflect credit risk deterioration or exchange rate induced valuation effects. This limitation warrants a full decomposition of risk into currency denomination volatility and the volatility of liability components. However, this activity is not feasible for small economies like Fiji where data pertaining to this exercise is not publicly available. Thus, we highlight that exchange rate movements affect debt sustainability through their impact on the domestic value of external obligations, reserve adequacy, and fiscal solvency. As a result, the CCA measures of risk reported in this study should be interpreted as capturing joint sovereign credit and currency mismatch risk rather than isolating credit risk in a narrow sense.

10.3. External validation

A key limitation of this study concerns the absence of liquid market-based indicators for external validation such as CDS and EMBI measures. Unlike developed and emerging market economies, Fiji does not have an active sovereign CDS market. In small and thinly traded sovereign markets, even when external bond yields are available, prices may reflect liability structure and investor concentration rather than continuous market-based assessments of sovereign risk. In the literature on sovereign risk, structural validation of CCA models are primarily drawn from CDS spreads and/or EMBI spreads data. This is because these instruments carry the forward-looking market sentiments (Gray et al., 2007; Gray & Malone, 2008). Unfortunately, however such validation is not possible in the case of Fiji due to the unavailability of data. To address this gap, we adopt a literature triangulation approach. The behaviour of Fiji's D2D and RNDP during periods of distress most notably COVID-19 shock, closely mirrors stylized findings from prior sovereign CCA applications in emerging and frontier economies. Prior research demonstrates that risk indicators for sovereigns also deteriorate sharply during periods of external shocks, reserve losses, and fiscal expansions (Gray et al., 2007; Gray & Malone, 2008). Thus, the pronounced deterioration in Fiji's risk indicators are consistent with the theoretical transmission mechanism as validated by studies mentioned above. While the literature triangulation approach provides indirect support for construct validity, future studies in this domain could strengthen empirical verification should Fiji develop deeper sovereign debt markets or become covered by international spread indices.

Notes

1. The GFC originated in the United States in early 2007 and lasted until 2009. This was triggered primarily by the collapse of the housing market in the US and led to a cascade of events, such as a sharp decline in economic activity, consumer and business confidence, and job losses worldwide.
2. The COVID-19 virus, short for coronavirus disease, first emerged in Wuhan, China in 2019, quickly escalated through its contagious nature across the globe, and appeared as the loftiest health crisis in the 21st century.
3. The Greek restructuring was followed by the country's need to address the unsustainable accumulation of debt. This event involved international and private bondholder negotiations with the Greek government. However, despite the negotiations and the need to avoid spillover effects on Eurozone countries, Greece continued to face adverse repercussions on its economy.
4. The Argentine debt crisis was triggered by its fixed exchange rate regime, years of fiscal mismanagement, and unsustainable borrowing practices.
5. The Russian default in 1918 followed the socialist ideology of the government of Bolshevik, World War 1, and political instability.
6. Option Pricing Theory (OPT) provides a systemic approach widely adopted in finance to estimate the fair values of financial options and aid investors in their portfolio management.
7. Credit Default Spreads (CDS) is a widely used terminology in advanced country credit risk assessment. It is a financial derivative contract issued by the sovereign to its investors for protection against the risk of default.
8. Emerging Market Bond Index (EMBI) serves as a financial index that provides information on the performance of sovereign bonds issued by emerging market economies.
9. The calibration constant is an adjustment tool that allows CCA inputs and outputs to accurately suit the market dynamics. See, for example, Aktug (2014) and Souto et al. (2007) for models that incorporate calibration techniques.
10. Credit contagion refers to the spread of financial distress within the financial system from one entity to the other. In most cases, this is exacerbated by the interconnectedness of market dynamics.
11. The risk-adjusted balance sheet for a sovereign is constructed by adjusting for liquidity, the market, and credit risk. Drawing this type of balance sheet becomes particularly instrumental when evaluating items such as contingent liabilities (e.g. guarantees), the market values of which are difficult to transpire.
12. Special drawing rights are issued by the International Monetary Fund (IMF) to supplement the countries' official reserves in times of economic crisis or when the countries' official reserves are running low for international payments.

13. Computation of implied values is a common practice in the financial world. These are simple estimates derived from observable market data using mathematical models, such as the Black and Scholes Model (1973).
14. Subtracting guarantees to too-important-to-fail entities from the asset side means that these guarantees are treated as implicit sovereign liabilities rather than as resources available to service sovereign debt. Although such guarantees do not appear as explicit debt in standard accounting balance sheets, they represent contingent obligations that are likely to be honored during periods of financial stress. Economically, these guarantees reduce the sovereign's effective net asset position because, if they are called, they require fiscal or foreign-currency resources that would otherwise be available to meet sovereign debt obligations. Therefore, in constructing an economic (contingent-claims) balance sheet consistent with the Merton framework, guarantees to systemically important entities are netted out from assets to reflect their impact on sovereign risk.
15. Soft reserve currencies are issued by the respective country's central banks and are considered less stable currencies, thereby lowering their global acceptance for trade and financial purposes.
16. Hard reserve currencies on the other hand, are widely accepted for international trade and are issued by an economically strong country such as the US dollar, Swiss Franc and British Pound sterling. These currencies are considered safe havens during economic slumps.
17. See Hull et al. (2005) and Jones et al. (1984) for further details.
18. GBM describes the stochastic movement in asset prices, which are identified by continuous-time random movements. These can be understood in the form of drifts and/or volatility to explain the projected movement in asset prices over time.
19. See Supplementary Appendix 2 for Visual Basic (VB) codes for the iterative procedure.

Author contributions

CRediT: **Rajneel Narayan**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing; **Rup Singh**: Conceptualization, Supervision, Validation, Writing – review & editing.

Declaration on the use of generative artificial intelligence (AI)

ChatGPT4 assisted with grammar and language enhancement during the preparation of this manuscript. Following its use, the authors thoroughly reviewed and revised the content. Full responsibility for the article, including any errors, rests with the authors.

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About the authors

Mr. Rajneel Narayan is a Teaching Assistant in Finance at the School of Accounting, Finance, and Economics, The University of the South Pacific, Fiji. He holds a Master of Commerce in Economics from the University of the South Pacific, where his thesis focused on sovereign credit risk, public debt sustainability, and fiscal dynamics in Fiji and Pacific Island countries. He also holds a Postgraduate Diploma in Economics and a Bachelor of Commerce in Economics and Accounting, both with First Class Honours. Former auditor. Rajneel's research interests lie in applied econometrics, health economics, efficiency evaluation, macro-financial analysis, sovereign risk assessment, capital mobility, and public debt sustainability, with a particular emphasis on small island developing states. His work has been published in leading journals such as Applied Economics and New Zealand Economic Papers.

Dr. Rup Singh Acting Head of School and Senior Lecturer in Economics, School of Accounting, Finance and Economics, The University of South Pacific (Suva) Fiji. Former Central Banker. Research interests: Economic Growth, Monetary Policy, and Applied Econometrics.

ORCID

Rajneel Narayan http://orcid.org/0009-0007-8414-9804
Rup Singh http://orcid.org/0000-0002-2225-3792

Data availability statement

The data is available upon request from the corresponding author.

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