CONTINGENT CLAIMS ANALYSIS OF SOVEREIGN DEBT SUSTAINABILITY IN ASIAN EMERGING MARKETS

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ABSTRACT

Contingent claims analysis applied to Indonesia, Malaysia, the Philippines, the Republic of Korea, and Thailand shows no particular vulnerability to sovereign debt distress during recent years. However, the highly volatile "distance to distress" measure suggests that any of these countries may fall victim to a sudden loss in market confidence. For example, the value of Indonesia's sovereign assets dropped to just two standard deviations above its repayment obligations during the 2013 United States Federal Reserve taper tantrum, causing capital outflows and currency depreciation. Generally, we find that contingent claims analysis and market-based risk measures well complement conventional debt sustainability analysis for Asia.

Keywords: contingent claims analysis, public debt sustainability

JEL codes: E60, F34, G13, H63

I. INTRODUCTION

This paper applies contingent claims analysis (CCA) to assess public debt sustainability of five Asian economies: Indonesia, Malaysia, the Philippines, the Republic of Korea, and Thailand.[1] It forms part of an ADB research project exploring risk-adjusted public debt sustainability analysis (DSA) for Asian economies. Related project papers provided standard DSA and fan-chart debt ratio projections for Asian countries (Ferrarini and Ramayandi 2015) and reviewed risk-based fiscal analysis methods in the Asian context (Kopits, Ferrarini, and Ramayandi 2016). These papers confirmed the validity of standard public DSA as an assessment tool. To complement DSA's focus on macroeconomic and fiscal flows analysis with information about market sentiment and valuations, they suggested that analysts apply risk-based fiscal analytical methods.

Value at risk (VaR) and contingent claims analysis (CCA) are risk-based methods that have long been applied to the analysis of private sector risk and have recently been adapted to the assessment of sovereign fiscal sustainability.[2] VaR estimates the worse potential outcome of stochastic shocks on fiscal sustainability at a given confidence level. CCA derives the implied value of sovereign assets—thus "contingent claims"—from the market value of liabilities, to establish a sovereign's sustainability against a certain threshold of debt repayment obligations.[3] Of the two, VaR analysis derives a fiscal sustainability indicator from a full evaluation of the assets and liabilities on a sovereign's intertemporal consolidated balance sheet. Particularly, the identification and valuation of sovereign assets involves high informational and computational costs. CCA's focus on the market valuation of sovereign liabilities rather than assets, which are less observable and more difficult to value, circumvents the heavy data requirements of VaR. This makes CCA more readily applicable to the context of developing Asia and of emerging economies more broadly (Kopits, Ferrarini, and Ramayandi 2016).[4]

On this premise, this paper sets up the basic CCA framework for the five Asian emerging economies following mainly Gray, Merton, and Bodie (2007) and Gray and Malone (2008). We estimate the sovereign consolidated balance sheet and compute a risk-based fiscal sustainability indicator, which we then subject to scenario analysis to assess the implications of specific shocks to countries' macroeconomic and policy environment. We then use bootstrapped projections of exchange rates and the CCA framework to assess public debt sustainability in the countries studied.

Throughout the paper, emphasis is placed on providing a simple exposition of the basic intuitions underlying CCA. Details and specific aspects of analysis are relegated to appendices. Appendix 1 reports the detailed results of sensitivity analysis. Appendix 2 shows the findings on the People's Republic of China (PRC) and explains why data limitations prompted the authors to exclude this country from the sample of countries discussed in the main text. Appendix 3 provides guidance

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[1] Our analysis also includes the PRC. Results are shown in Appendix 2. However, due to data limitations on the one hand, and the low share of external debt out of the total government debt, CCA does not seem practicable in the case of the PRC.

[2] For example, Barnhill and Kopits (2003) adapted the VaR method to calculate the effect of macroeconomic volatility of Ecuador's public sector intertemporal balance sheet. Da Costa, Caputo Silva, and Baghdassarian (2004) conducted VaR simulations for Brazil, and Adrogue (2005) applied the technique to compare public debt sustainability and fat-tail default risk facing Central American economies.

[3] See Kopits, Ferrarini, and Ramayandi (2016) for a comparison of VaR and CCA methods.

[4] Of course, the benefit of data parsimony comes at a cost, namely that the opportunity to estimate the probability of exact line items causing significant shocks a sovereign's asset valuation is foregone, and so is the feasibility to disentangle the sources of risk reflected in the synthetic CCA risk indicators.

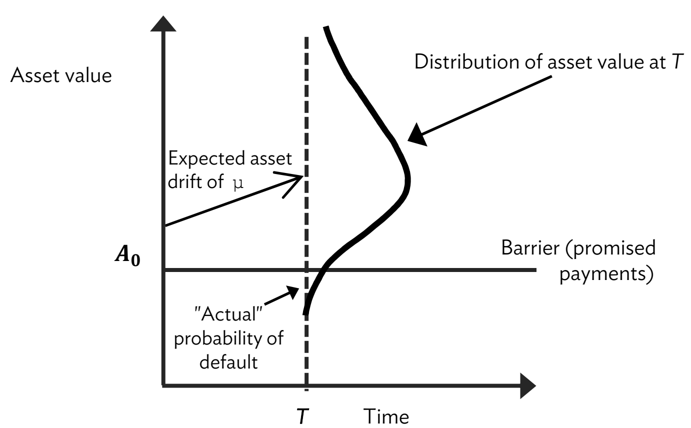
through the steps of implementation of CCA, from data collection to estimation, and to the interpretation of result. For a more thorough discussion of CCA and macrofinancial risk analysis, the reader is referred to Gray and Malone (2008) and related publications listed in the references section.

II. CONTINGENT CLAIMS ANALYSIS AND THE SOVEREIGN BALANCE SHEET

A contingent claim, such as an option, is a financial asset the payoff of which depends on the value of another financial asset. Merton (1974, 1977) models contingent claims as a generalization of the Black and Scholes (1973) and Merton (1973) option-pricing theory for the assessment of firms' credit risk.

Central to CCA is the concept of risk-adjusted balance sheet of firms, which derives the value of senior (debt) and junior (equity) liabilities from assets that are assumed to follow a stochastic process. Figure 1 illustrates the basic intuition underlying CCA. It shows that the default barrier is breached when the value of assets falls below the value of promised payments on debt (Gray and Malone 2012). The repayment of debt is thus considered risky, and the value of debt consists of its notional, default-free value, minus the expected loss component from default over some time horizon.

Figure 1: Asset Value and Probability of Default

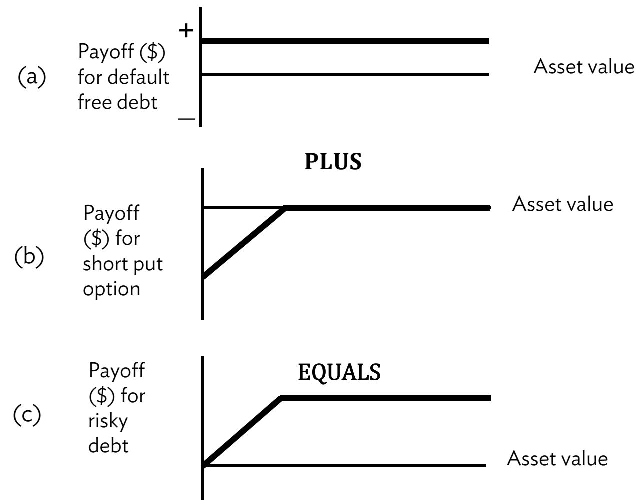


Source: Adapted from Gray and Malone (2008), Figure 5.3.

Merton's (1974) intuition is that the expected loss can be modeled as a put option on the value of the borrower's assets, with strike price equal to the promised payments of debt. The implications are illustrated in Figure 2, where the payoff structure of risky debt equals default-free debt plus the put option to account for the implicit default guarantee. By the same token, Figure 3 shows that a firm's equity can be modeled as a call option on the residual value of its assets, debt being the senior claim. Equity holders receive the difference between the value of assets and debt in case of no default, or will receive nothing in the case of default, when the full value of assets will have to pay off the holders of debt.

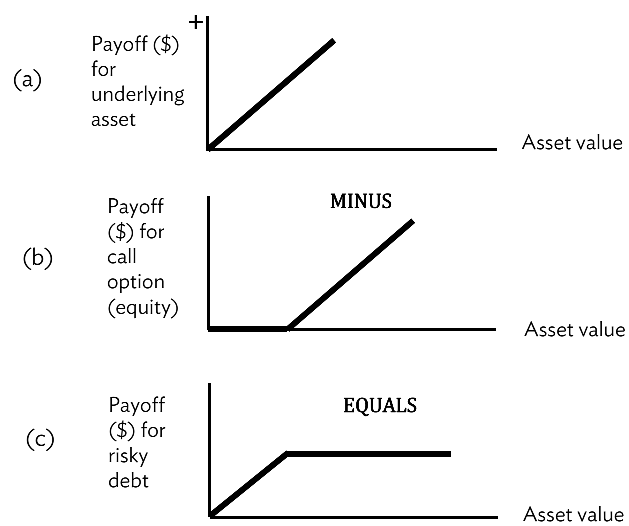
CCA is well established as a tool for assessing private firms' bankruptcy risk (Crosbie and Bohn 2003). Only recently has it been applied to the analysis of sovereign risk, as explored mainly by Dale Gray of the International Monetary Fund and a number of coauthored papers since the mid-2000s. Essentially, the sovereign version of CCA consolidates a country's balances akin to a firm's balance sheet, by distinguishing sovereign—rather than private—assets, debt, and equity.

Figure 2: Payoff Diagrams for Risky Debt = Default-Free Debt Plus Short Put Option



Source: Adapted from Gray and Malone (2008), Figure 5.3.

Figure 3: Payoff Diagrams for Risky Debt = Asset Minus Equity (Call Option)



Source: Adapted from Gray and Malone (2008), Figure 5.2.

Local currency liabilities (domestic debt and money base) replace firm equity and are modeled as the junior claim. This rests on the assumption that countries will find it easier to restructure or issue local currency debt as opposed to restructuring foreign currency debt (IMF 2002).[5] Just like a firm has the option to lower the value of equity by emitting more shares, a sovereign may choose to dilute local

[5] For example, during the Ukraine (1998), Russian Federation (1999), or Argentinian (2001) debt restructuring, haircuts were much larger for domestic than international debt (Sturzenegger and Zettelmeyer 2008). A counterexample is the case of Uruguay (2003).

currency-denominated debt by printing money. No such option exists for sovereign foreign currency debt, which thus constitutes the senior claim akin to a firm's "risky debt" in the CCA corporate framework.

Local currency liabilities constitute a call option on the country's assets, and the sovereign's distress barrier is simply assumed to be the book value of short-term foreign currency debt plus half the value of long-term foreign debt. Sovereign debt is deemed unsustainable as soon as the market value of sovereign assets falls short of the (present value of the flow of future) contractual obligations on debt. The lower or more volatile a sovereign's total assets, the higher its probability of default.

With this framework in place, CCA derives the value and volatility of sovereign assets from the liability side of the risk-adjusted balance sheet, which in turn is derived from the accounting balance sheet of the public sector and the central bank combined. Sovereign assets typically include international reserves; sovereign wealth fund assets; sovereign pension fund assets; other public sector assets (property, state-owned enterprises, etc.); as well as fiscal assets, such as the present value of the future flow of taxes and revenues.

On the other side of the consolidated sovereign balance sheet, liabilities mainly comprise the monetary base (M0); local currency-denominated debt; foreign currency-denominated debt; sovereign pension funds' liabilities; the present value of expenditures on economic and social development, security, government administration, and benefits to other sectors; the present value of target wealth to be left to future generations; as well as financial guarantees to the private sector (too-big-to-fail).

To derive the risk-adjusted consolidated balance sheet, a stylized version of which is shown in Table 1, too-big-to-fail guarantees are subtracted from the present value stream of income (on the assets side). Liabilities are rearranged as domestic liabilities ("equity") and foreign debt ("debt"), both expressed in foreign currency. They are valued as contingent claims on sovereign assets and modeled as options on the total value of the assets.

Table 1: Consolidated Sovereign Balance Sheet

Assets	Liabilities
Foreign reserves, gold, special drawing rights Pension fund assets–liabilities Sovereign wealth fund assets Other public sector assets (state-owned enterprises, real estate) Present value of future income (taxes, fees, seigniorage) minus present value of future expenditures on economic and social development minus present value of target wealth to be left to future generations minus financial guarantees to too-big-to-fail institutions	Domestic liabilities: base money + local currency debt ("equity") Foreign currency debt "debt")

Source: Adapted from Gray and Malone (2008), Figures 8.1 and 8.2.

Specifically, if we consider a basic debt structure with two types of debt in zero-coupon form, domestic liabilities expressed in foreign currency terms DL_f are defined as the sum of the monetary base and local debt expressed in foreign currency:[6]

$$DL_f = \frac{M_0 + B_d}{X} \tag{1}$$

where B_d is the market value of local debt; M_0 is the monetary base in local currency, and *X* is the spot exchange rate.

Domestic liabilities are a call option on the value of sovereign assets A_f , expressed in foreign currency, with a strike price equal to the default barrier B_f. The latter is derived from payments promised in foreign currency until a time horizon *T*.[7] In theory, a sovereign's decision to default on debt depends on the perceived trade-off between short-run benefits and longer-run costs stemming from a loss of reputation for repayment (Eaton and Gersovitz 1981). In practice, governments' actions are revealed during distress episodes and past evidence forms the most reliable guide for identifying default barriers (Rogoff 2011). However, when historical evidence is scarce, CCA requires that the barrier be set at an arbitrary level, for example as the level of a countries' short-term foreign debt plus half their long-term foreign debt (as in Gray, Merton, and Bodie 2007 and Crosbie and Bohn 2003), or as the total short- and long-term foreign debt (as in Bodie and Brière 2014 and Duyvesteyn and Martens 2015). In this paper, we follow this latter method, as our data does not distinguish short-term from long-term debt.

As in Gray, Merton, and Bodie (2007), we assume that the value of sovereign assets A_f and domestic liabilities DL_f follows a lognormal diffusion process with constant volatility and risk-free rate. The value of domestic liabilities can then be computed using the Black and Scholes (1973) formulae, as in Merton (1974, 1977):

$$DL_f = A_f N(d_1) - B_f e^{-r_f T} N(d_2) \tag{2}$$

with *N(.)* the cumulative standard normal distribution, σ_A the volatility of the sovereign assets' returns.

$$d_1 = \frac{\ln(\frac{A_f}{B_f}) + (r_f + \frac{\sigma_A^2}{2})T}{\sigma_A \sqrt{T}} \tag{2a}$$

$$d_2 = d_1 - \sigma_A \sqrt{T} \tag{2b}$$

6 For simpler notation, we omit subscript *t*, denoting time.
7 The choice of time horizon (T) has a bearing on d_1 and d_2, which the below computations will keep fixed at 5 years.

To find the values of the two unknowns A_f and σ_A, equation (3) links the volatilities of sovereign assets and local currency liabilities σ_{DL} (the junior claim). Assuming that the Black and Scholes assumptions hold, the following relationship applies:[8]

$$DL_f \sigma_{DL} = A_f \sigma_A (d_1) \tag{3}$$

With equation (1) determining the value of domestic liabilities, equations (2) and (3) solve to estimate the value of the sovereign's assets A_f and their variance σ_A^2 as a function of the foreign debt default barrier B_f.

Term d_2 of equation (2a) represents the main debt sustainability indicator within the CCA framework, and is referred to as the distance to distress. It measures a country's distance from default as the difference between the implied market value of sovereign assets and the distress barrier, scaled by a one-standard-deviation move in sovereign assets. Put differently, it shows the number of standard deviations between a sovereign's assets value and distress.

With this simple framework in place, distance to distress can be estimated on the basis of a fairly limited amount of data, which we turn to next.

III. DATA AND SUMMARY STATISTICS

Data for Indonesia, Malaysia, the Philippines, the Republic of Korea, and Thailand are obtained from three sources:

(i) Bloomberg, for daily 5-year CDS spreads in the five countries, spot exchange rates of the five currencies versus United States (US) dollar and daily 5-year US government bond interest rate (Bloomberg government bond benchmark index).
(ii) Datastream, for the market value of government debt in local currency units, measured by the market capitalization of the JP Morgan GBI EM Index on a daily frequency, and domestic interest rates (yield to maturity) of the local currency debt index.
(iii) CEIC, for monthly series of monetary base (M0) and the monthly book value of foreign debt. Exceptions are the Republic of Korea and Malaysia, for which quarterly CEIC data have to be linearly interpolated in order to derive monthly frequencies.

We compute the volatility of the local currency liabilities as the annualized standard deviation of their daily returns over the past rolling 3 months. This keeps the indicator fairly stable while keeping it reactive to new information.[9] To calculate a daily frequency series of local currency liabilities, we linearly interpolate the monthly frequency series of the monetary base and add it to the market capitalization of local debt, the latter being available on a daily basis from the JP Morgan government debt indices.

[8] Black and Scholes (1973) assume that markets are efficient, no dividend is paid during an option's life, options are exercised at maturity, the absence of trading costs and taxes, constant volatility and interest rate, and that returns are lognormally distributed.
[9] Robustness checks with a rolling 1-month standard deviation yield stable results.

Table 2 lists the mean and standard deviation of the indicators used for the analysis. The two lines at the bottom of the table indicate the length of the country monthly time series in our sample, which is longest for Thailand (from October 2004) and shortest for the Republic of Korea (from December 2011). Compared to the value of local currency liabilities (the sum of the monetary base, M0, and the market value of local debt, Bd) the value of foreign debt (Bf) is less than 5% in the Republic of Korea and Thailand. Foreign debt is higher in Indonesia, at about 80% of total domestic currency debt, and at 40% in Malaysia. It is highest in the Philippines, exceeding local currency liabilities by a factor of more than three on average from January 2011 to August 2015.

Markets deemed all the five countries to be at a low risk of default over the sample period; CDS spreads are low on average, ranging between 21 basis points for the Republic of Korea to 45 basis points for Thailand. Also domestic interest rates are relatively low, at less than 4% in the Republic of Korea, Malaysia, and Thailand, and somewhat higher in the Philippines and Indonesia.

Exchange rate average returns vary greatly across countries, from −0.4% in Indonesia to 0.1% in Thailand and the Republic of Korea. Volatilities range from 5.4% on Philippine foreign exchange returns, up to 7.7% in relation to Malaysia's ringgit.

Table 2: Descriptive Statistics of the Main Variables of Interest

		Indonesia	Republic of Korea	Malaysia	Philippines	Thailand
M0	Avg	30.12	47.90	16.48	12.33	25.63
$ billion	St dev	4.48	9.49	3.27	1.70	7.90
Bd	Avg	49.63	338.58	64.26	2.89	38.69
$ billion	St dev	10.06	42.22	8.98	0.53	10.68
Bf	Avg	62.33	7.35	35.16	54.17	2.84
$ billion	St dev	5.41	0.61	14.32	3.17	1.75
Bf/(M0+Bd)	Avg %	78.16	1.90	43.55	356.01	4.42
CDS 5-year spread	Avg	176.95	78.82	114.23	123.40	101.06
basis points	St dev	38.95	32.90	45.13	36.85	56.89
Interest rate	Avg	8.00	3.09	3.75	5.03	3.95
%	St dev	1.35	0.45	0.28	0.66	0.84
FX spot rate	Avg	10,275.80	1,092.35	3.27	43.36	33.81
value of $1	St dev	1,520.81	39.06	0.21	1.40	3.20
FX return	Avg	−0.4%	0.1%	−0.2%	−0.1%	0.1%
	Volatility	7.2%	7.0%	7.7%	5.4%	6.0%
First month		30-Jun-09	31-Dec-11	31-Mar-08	31-Jan-11	31-Oct-04
Last month		31-Aug-15	30-Jun-15	30-Jun-15	31-Aug-15	31-Jul-15

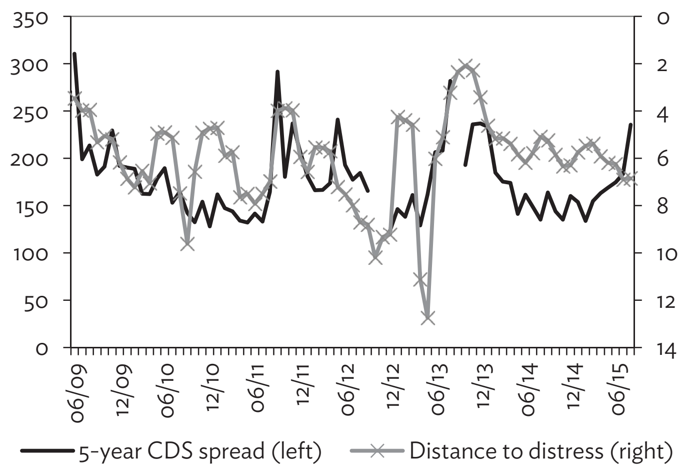
Bd = value of local debt, Bf = value of foreign debt, CDS = credit default swap, FX = foreign exchange, M0 = monetary base.
Source: Authors' estimates.

IV. DISTANCE TO DISTRESS, SENSITIVITY, AND SCENARIO ANALYSIS

Based on the above data, we compute distance to distress according to the CCA framework laid out in section II. Results are plotted in Figure 4, together with 5-year CDS spreads for the five countries. For example, consider the first panel on Indonesia. The country's CDS spreads are seen hovering about the 150 basis points line—measured on the left axis— and occasionally jump up to nearly twice that level, such as in June 2009, when the global financial crisis hit Indonesia, and in June 2013, when capital outflows intensified against the backdrop of uncertainty in the Federal Reserve's (Fed) timing of interest rate hikes.

Figure 4: Distance to Distress and 5-Year CDS Spreads

(a) Indonesia



(b) Republic of Korea

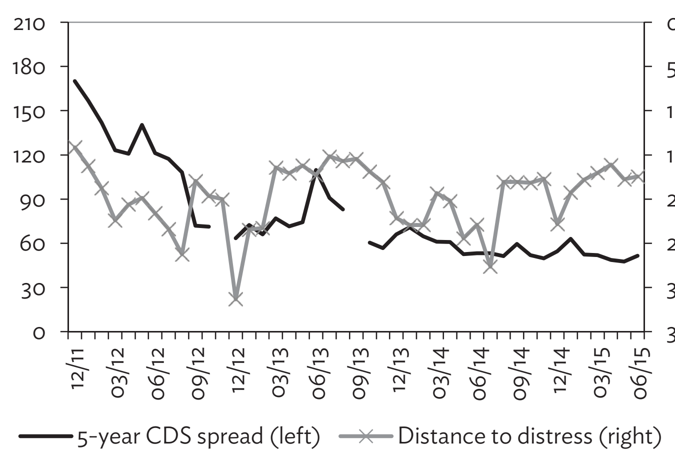


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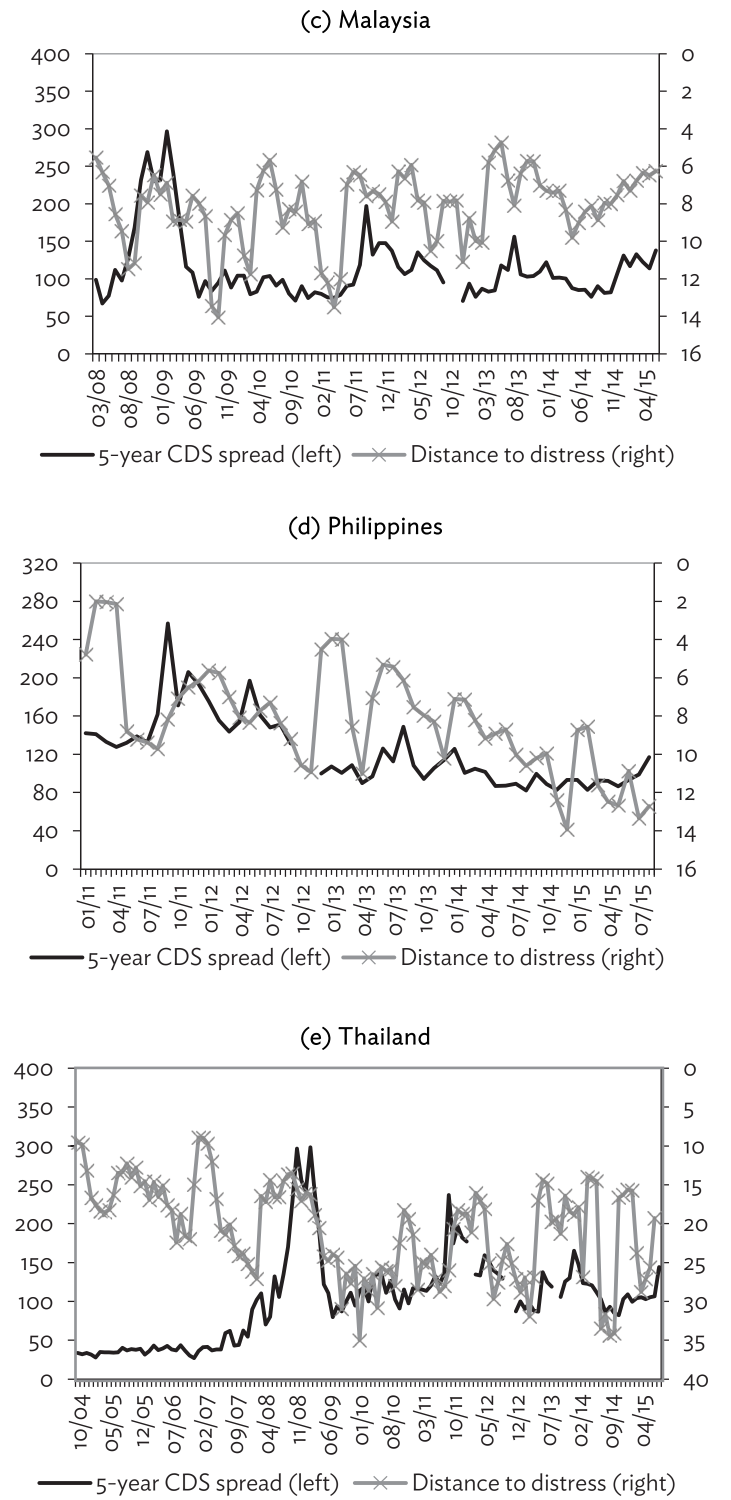
Table 4 continued



CDS = credit default swap.
Note: Data gaps in the 5-year CDS spreads were filled with data points available within the month other than end-of-month data.
Source: Authors' estimates.

Distance to distress—measured on the right-hand side of the Indonesia chart— indicates the number of standard deviations the total value of Indonesia's sovereign assets exceeded the country's distress barrier. Over the 6 years shown on the chart, this distance measured about six standard deviations on average. This means that the likelihood of asset value breaching the distress barrier was very low. Only once over the entire period, in October 2013, did the distance to distress fall to two standard deviations only, signaling the market's diminished confidence in the country. This corresponds to the period of taper tantrum by the US Fed, causing heavy capital outflows from Indonesia and other emerging markets, combined with sharp exchange rate depreciations.

Figure 4 suggests that Indonesia and the other countries have been staying at a safe distance from distress. In the Republic of Korea and Thailand, this measure ranged between 15 and 30 standard deviations, and in Malaysia and the Philippines, it fluctuated at about half that level. In no instance during the period of observation would the distance to distress reading have raised red flags or signaled impending distress. However, the entire period of observation is marked by sudden swings of market confidence in all five countries, causing frequent spikes of both the distance to distress and CDS series. Market turbulence was particularly high during the 2008/2009 global financial crisis, as is most visible on the Malaysia and Thailand charts.

Figure 4 also exhibits some correlations between the distance to distress and the CDS credit spreads. Previous conclusions are confirmed by correlation analysis summarized in Table 3. In levels, correlation between the two series is negative, because higher CDS spreads correlate to lower distance to distress. Except for Thailand, correlation is negative also in differences. That is, distance to distress tends to fall and CDS spreads increase when credit conditions deteriorate. Both in levels and in changes, correlation coefficients are highest for Indonesia and the Philippines, but their magnitude is still only moderate in general. The moderate correlation with CDS spreads is an indication that the debt sustainability information inferred from the CCA is only partly explained by the market perception of risks on sovereign debt reflected in the CDS spreads.

Table 3: Correlation of 5-Year CDS Spreads with Distance to Distress

	Indonesia	Republic of Korea	Malaysia	Philippines	Thailand
Level	−0.43	−0.12	−0.18	−0.36	0.15
1-month change	−0.20	0.23	−0.02	−0.26	−0.07
3-month change	−0.34	0.10	−0.04	−0.36	−0.12
First month	31-Jan-06	31-Dec-11	31-Oct-04	31-Jan-11	31-Aug-02
Last month	31-Aug-15	30-Jun-15	30-Jun-15	31-Aug-15	31-Jul-15

CDS = credit default swap.
Notes: First row: correlation between the two series in level. Second row: correlation between the monthly changes of the variables. Third row: correlation between the 3-month changes in the variables.
Source: Authors' estimates.

A. Sensitivity Analysis

We next assess the sensitivity of the distance to distress measures to the introduction of three alternative shocks: (1) a 1% increase in M0, (2) a 1% increase in the value of risky debt, and (3) a 1% increase in the domestic liabilities volatility. Table 4 summarizes these shocks' impact on the distance to distress measure, while the broader impacts on sovereign balance sheets are contained in Appendix 1.

Table 4: Sensitivity of the Distance to Distress to Three Alternative Scenarios

	Baseline	Scenario 1: 1% increase in M0	Scenario 2: 1% increase in foreign debt	Scenario 3: 1% increase in LCL volatility
Indonesia				
Distance to distress	6.84	6.85	6.82	6.23
Change in distance to distress		0.01	−0.02	−0.61
Republic of Korea				
Distance to distress	17.45	17.45	17.41	16.00
Change in distance to distress		0.01	−0.04	−1.44
Malaysia				
Distance to distress	6.26	6.27	6.25	5.75
Change in distance to distress		0.00	−0.02	−0.52
Philippines				
Distance to distress	12.71	12.72	12.69	10.21
Change in distance to distress		0.01	−0.02	−2.50
Thailand				
Distance to distress	19.30	19.32	19.25	17.32
Change in distance to distress		0.02	−0.05	−1.98

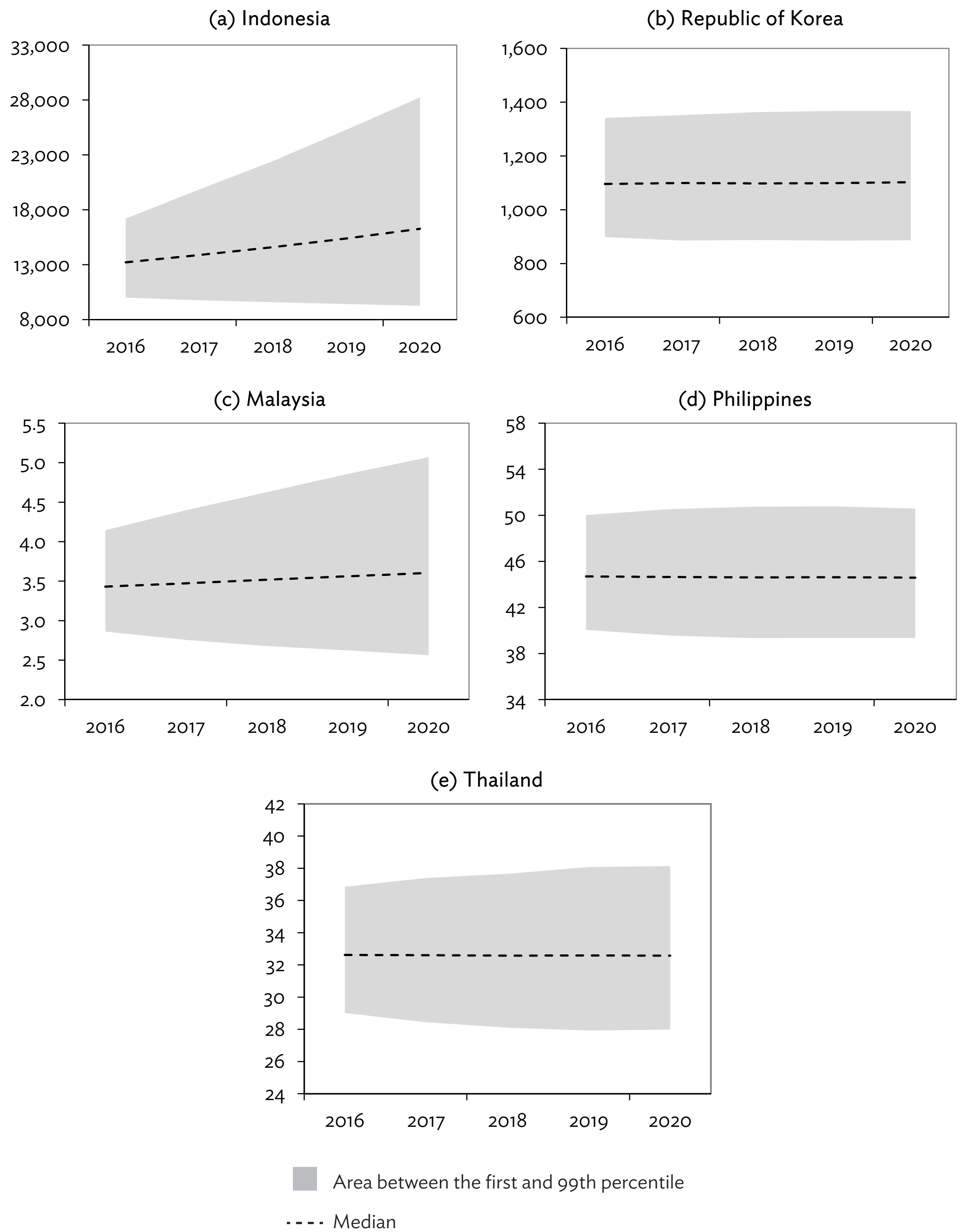
LCL = local currency liability.
Source: Authors' estimates.

The first column Table 4 reports the baseline distance to distress, which at 17.45 standard deviations is highest for the Republic of Korea and lowest for Malaysia at 6.26. When shocked, distance to distress is largely insensitive to a 1% increase in base money or foreign debt, shown in the second and third columns. By contrast, the distance to distress is significantly shortened by a 1% increase in volatility of domestic liabilities, shown in the fourth column. For example, the measure falls by 0.52 standard deviation or 8.3% from the baseline for Malaysia and by 2.50 standard deviation or 19.7% for the Philippines. Additional simulations confirm that distance to distress reacts strongly to changes in returns' volatility and not to the other shocks envisaged. For example, raising foreign debt by as much as 10% causes Malaysia's distance to distress to drop by just about a third of its reaction to a 1% rise in asset volatility.

B. Scenario Analysis: Implications of Exchange Rate Uncertainty

Sensitivity analysis in the previous section is based on daily frequency data. Here, for an impact analysis of exchange rate uncertainty, we focus on annual aggregates and apply the CCA analysis to assess annual movements of the distance to distress, given the probability distribution of the future exchange rate for each of the five economies.

Figure 5: Exchange Rate Fan Charts



Source: Authors' estimates.

We first bootstrap the exchange rate projection five years ahead in order to get a probability distribution that is historically consistent.[10] This yields exchange rate fan charts for the five countries, shown in Figure 5. Assuming a fixed value of domestic local currency liabilities, the exchange rate distribution translates to a distribution of domestic liabilities in foreign currency terms, according to equation (1). It also translates to the distribution of sovereign asset values, which we can then use in equation (2a) and (2b) to derive the distribution of the distance to distress for each of the five countries, assuming that foreign debt, the foreign interest rate and the volatility of sovereign assets returns are constant.

Figure 6 shows the resulting distance to distress country charts. The heightened exchange rate uncertainty, that is mostly visible in Indonesia and Malaysia, tends to have a moderate impact on the cross-sectional dispersion of the distance to distress. This is because, in our simulations, higher uncertainty about countries' exchange rates translates into greater cross sectional dispersion of the foreign currency value of the sovereign assets but is assumed to have no impact on the time-series volatility of the exchange rate, the variable the distance to distress is the most sensitive to. As a result, none of the countries is pushed into breaching the threshold of no distress.

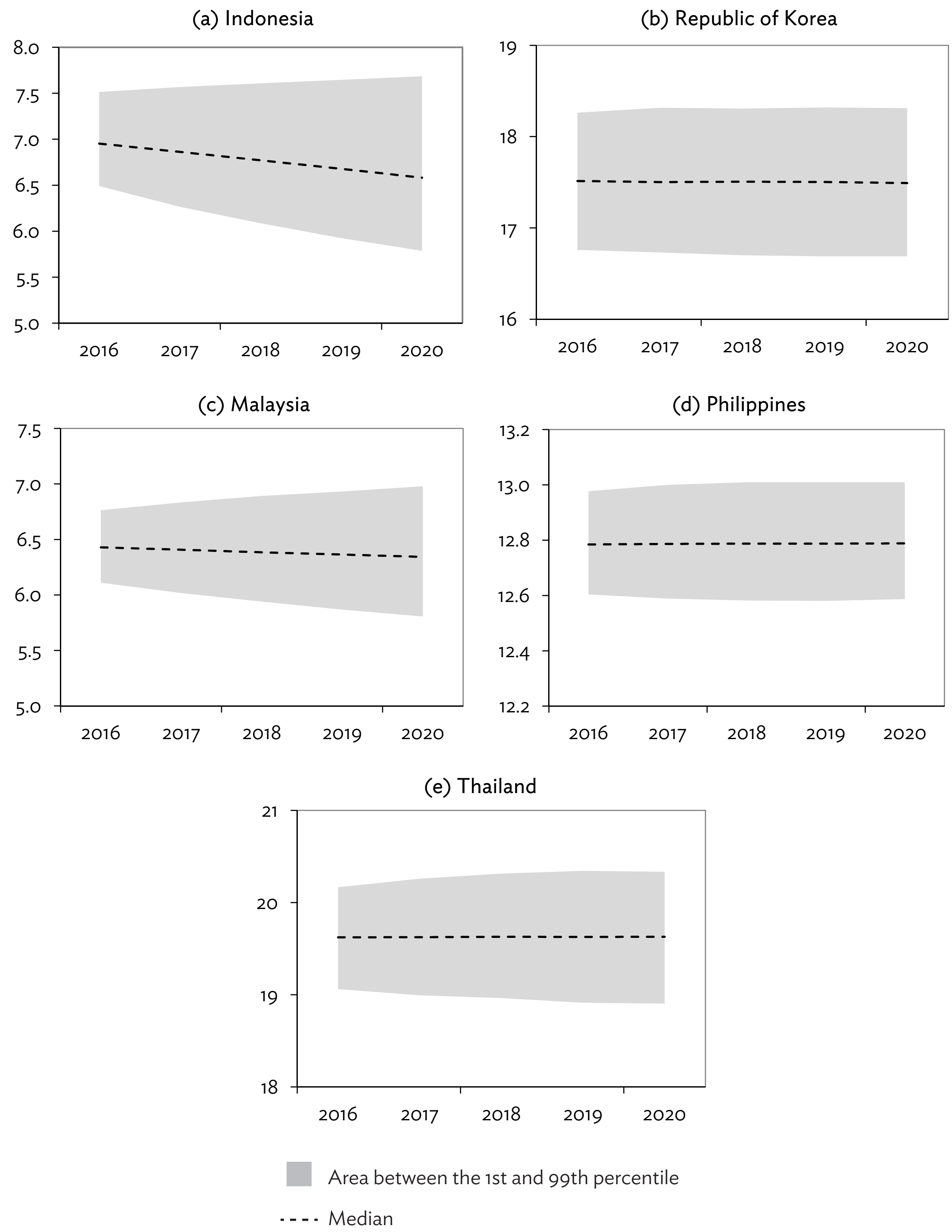
Among the five countries analyzed, Indonesia appears most vulnerable to exchange rate shocks. Even in this case, the distance to distress is seen dropping only slightly. Far from breaching the threshold, distance to distress falls to no less than about 6.5 standard deviations by the end of the projection period.

However, it should be noted that changes in the value of foreign exchange rates likely affect also the volatility of the foreign currency value of sovereign asset returns. In other words, by way of the central CCA assumptions, the projected distribution of future exchange rate values should imply variations in asset returns volatility as well. Departing from the analysis hitherto as regards the computation of the volatility of asset returns, and in the light of a lack of daily forecast figures, we now measure the volatility as the standard deviation of changes to yearly asset returns, based on the projected value of the sovereign assets distribution.

Experimenting with this hypothesis, Figure 7 presents the outcome of simulation for Indonesia. Changes in the asset returns volatility due to exchange rate variations are now seen affecting Indonesia's distance to distress. Over the time span of simulation, this distance shortens from about 7 to 3 standard deviations. Although the effect of exchange rate uncertainty is now more pronounced, the country remains at a considerable length from breaching the threshold. The scenario analysis now shows how exchange rate fluctuations can act as a main factor of vulnerability affecting a country's distance to distress.

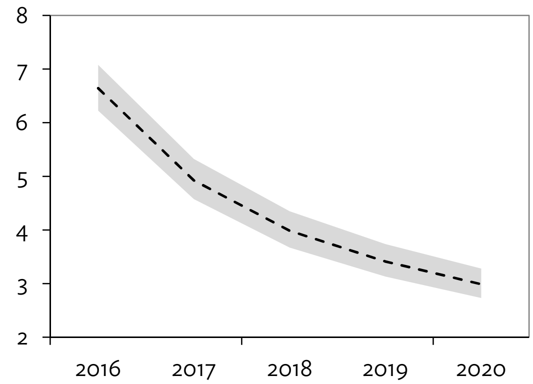
[10] The annual forecast distribution is generated by annualizing a 10,000 random draw of quarterly exchange rate projections obtained from an AR(1) estimate for each economy.

Figure 6: Distance to Distress Distribution Due to Exchange Rate Variation



Source: Authors' estimates.

Figure 7: Distance to Distress Distribution, Indonesia



Source: Authors' estimates.

V. CONCLUSION

We apply contingent claims analysis to Indonesia, Malaysia, the Philippines, the Republic of Korea, and Thailand. We find that none of them would appear to be particularly vulnerable to sovereign debt distress, not in normal times and not when facing the less favorable macroeconomic scenarios considered. However, CDS spreads and distance to distress are highly volatile throughout the period of observation and none of the countries considered is immune to sudden drops in market perception of risk as reflected in higher CDS spreads and eroding assets value. Indonesia, for example, saw its sovereign assets value drop close to just above two standard deviations of its repayment obligations amidst capital outflows, exchange rate depreciation, and heightened uncertainty caused by the 2013 US Fed taper tantrum.

The CCA distance to distress measure correlates with country CDS spreads. Sensitivity and scenario analysis offer useful tools to help identify some of the drivers responsible for movements in the CCA measure, as well as in CDS spreads by extension. However, a large portion of sovereign CDS volatility remains unexplained within the context of the CCA analytical framework and somewhat undermines its usefulness to explain significant swings in market perception of risk.

Notwithstanding such caveats, CCA does help pinpoint the sustainability of a sovereign's capacity to pay as inferred to by implied asset value and volatility. Given its data parsimony and computational simplicity, it represents a feasible addition to the practitioner's tool box, complementing macroeconomic and fiscal flow analysis of standard DSA with an instrument to gather and reflect market sentiment and conduct basic scenario analysis.

Further research would assess the feasibility to extend Asian countries' CCA to other sectors of the economy. Gray and Malone (2008) discuss various types of linkages between the sovereign balance sheet equations and the corporate, financial, household balance sheets, complemented by the foreign sector. In principle, these sector CCA balance sheets can be integrated into one economywide balance sheet with risk exposures across sectors, modeled as implicit put and call options. In practice, the construction of an economywide CCA balance sheet is limited by scarce data availability in the studied countries.

APPENDIX 1: SENSITIVITY ANALYSIS OF THE SOVEREIGN BALANCE SHEET AND DEBT SUSTAINABILITY INDICATORS

Table A1.1: Indonesia

Contingent claim sovereign balance sheet ($ billion)	Baseline	Scenario 1: 1% increase in M0	Scenario 2: 1% increase in foreign debt	Scenario 3: 1% increase in LCL volatility
Implied value of sovereign assets	134.95	135.25	135.43	134.95
Value of risky foreign currency debt	47.88	47.88	48.35	47.88
Distress barrier	51.73	51.73	52.25	51.73
PV of distress barrier	47.88	47.88	48.35	47.88
PV of expected loss	0.00	0.00	0.00	0.00
Value of local currency liabilities	87.08	87.38	87.08	87.08
Implied volatility of assets	6.70%	6.71%	6.68%	7.34%
Credit risk indicators				
Distance to distress	6.84	6.85	6.82	6.23
Sensitivity - change in distance to distress		0.01	−0.02	−0.61

LCL = local currency liability, M0 = monetary base, PV = present value.
Notes: The baseline case corresponds to the estimation made in August 2015. The three alternative scenarios correspond to a 1% change in M0; the value of foreign debt (e.g., from 100 to 101); and LCL volatility (e.g., from 6% to 7%), respectively.
Source: Authors' estimates.

Table A1.2: Republic of Korea

Contingent claim sovereign balance sheet ($ billion)	Baseline	Scenario 1: 1% increase in M0	Scenario 2: 1% increase in foreign debt	Scenario 3: 1% increase in LCL volatility
Implied value of sovereign assets	464.84	465.46	464.90	464.84
Value of risky foreign currency debt	5.87	5.87	5.92	5.87
Distress barrier	6.37	6.37	6.43	6.37
PV of distress barrier	5.87	5.87	5.92	5.87
PV of expected loss	0.00	0.00	0.00	0.00
Value of local currency liabilities	458.98	459.60	458.98	458.98
Implied volatility of assets	11.13%	11.13%	11.13%	12.12%
Credit risk indicators				
Distance to distress	17.45	17.45	17.41	16.00
Sensitivity - change in distance to distress		0.01	−0.04	−1.44

LCL = local currency liability, M0 = monetary base, PV = present value.
Notes: The baseline case corresponds to the estimation made in June 2015. The three alternative scenarios correspond to a 1% change in M0; the value of foreign debt (e.g., from 100 to 101); and LCL volatility (e.g., from 6% to 7%), respectively.
Source: Authors' estimates.

Table A1.3: Malaysia

Contingent claim sovereign balance sheet ($ billion)	Baseline	Scenario 1: 1% increase in M0	Scenario 2: 1% increase in foreign debt	Scenario 3: 1% increase in LCL volatility
Implied value of sovereign assets	138.46	138.65	138.94	138.46
Value of risky foreign currency debt	48.39	48.39	48.88	48.39
Distress barrier	52.55	52.55	53.08	52.55
PV of distress barrier	48.39	48.39	48.88	48.39
PV of expected loss	0.00	0.00	0.00	0.00
Value of local currency liabilities	90.06	90.26	90.06	90.06
Implied volatility of assets	7.41%	7.41%	7.38%	8.06%
Credit risk indicators				
Distance to distress	6.26	6.27	6.25	5.75
Sensitivity - change in distance to distress		0.00	−0.02	−0.52

LCL = local currency liability, M0 = monetary base, PV = present value.
Notes: The baseline case corresponds to the estimation made in June 2015. The three alternative scenarios correspond to a 1% change in M0; the value of foreign debt (e.g., from 100 to 101); and LCL volatility (e.g., from 6% to 7%), respectively.
Source: Authors' estimates.

Table A1.4: Philippines

Contingent claim sovereign balance sheet ($ billion)	Baseline	Scenario 1: 1% increase in M0	Scenario 2: 1% increase in foreign debt	Scenario 3: 1% increase in LCL volatility
Implied value of sovereign assets	63.70	63.85	64.16	63.70
Value of risky foreign currency debt	46.47	46.47	46.93	46.47
Distress barrier	50.21	50.21	50.71	50.21
PV of distress barrier	46.47	46.47	46.93	46.47
PV of expected loss	0.00	0.00	0.00	0.00
Value of local currency liabilities	17.24	17.38	17.24	17.24
Implied volatility of assets	1.11%	1.12%	1.10%	1.38%
Credit risk indicators				
Distance to distress	12.71	12.72	12.69	10.21
Sensitivity - change in distance to distress		0.01	−0.02	−2.50

LCL = local currency liability, M0 = monetary base, PV = present value.
Notes: The baseline case corresponds to the estimation made in August 2015. The three alternative scenarios correspond to a 1% change in M0; the value of foreign debt (e.g., from 100 to 101); and LCL volatility (e.g., from 6% to 7%), respectively.
Source: Authors' estimates.

Table A1.5: Thailand

Contingent claim sovereign balance sheet ($ billion)	Baseline	Scenario 1: 1% increase in M0	Scenario 2: 1% increase in foreign debt	Scenario 3: 1% increase in LCL volatility
Implied value of sovereign assets	88.18	88.51	88.20	88.18
Value of risky foreign currency debt	2.08	2.08	2.11	2.08
Distress barrier	2.25	2.25	2.27	2.25
PV of distress barrier	2.08	2.08	2.11	2.08
PV of expected loss	0.00	0.00	0.00	0.00
Value of local currency liabilities	86.10	86.42	86.10	86.10
Implied volatility of assets	8.63%	8.64%	8.63%	9.61%
Credit risk indicators				
Distance to distress	19.30	19.32	19.25	17.32
Sensitivity - change in distance to distress		0.02	−0.05	−1.98

LCL = local currency liability, M0 = monetary base, PV = present value.
Notes: The baseline case corresponds to the estimation made in July 2015. The three alternative scenarios correspond to a 1% change in M0; the value of foreign debt (e.g., from 100 to 101); and LCL volatility (e.g., from 6% to 7%), respectively.
Source: Authors' estimates.

APPENDIX 2: CONTINGENT CLAIMS ANALYSIS FOR THE PEOPLE'S REPUBLIC OF CHINA

Data issues largely undermine the reliability of distance to distress estimates for the People's Republic of China (PRC), which are therefore relegated to this appendix. For example, monthly data on the book value of PRC foreign debt is unavailable. Among the databases accessed for this study, only annual data on PRC foreign debt could be retrieved from the CEIC database, and even that series has many missing values. We decided to use instead the market value of foreign debt obtained from the JP Morgan debt indices. We derived the series by aggregating the market value of the JP Morgan EMBI global and the Euro EMBIG index, which is foreign debt issued by the Chinese government in US dollars and euro (we converted the latter into US dollars).

Table B1 summarizes the data underlying the PRC analysis and Table B2 plots the results. The PRC's distance to distress is extremely volatile, more so than its CDS spread pattern would suggest. This is because the market value of foreign currency debt derived from JP Morgan debt indices is more volatile than CEIC book values, which we had to drop due to data limitations. The high volatility of the distance to distress may also be partly caused by the limited volatility of US dollar-denominated local currency liabilities, because of the renminbi's peg to the US dollar.[1]

Table A2.1: PRC Summary Statistics

M0	Avg	742.82
$ billion	St dev	199.82
Bd	Avg	333.51
$ billion	St dev	58.79
Bf	Avg	14.16
$ billion	St dev	10.33
Bf/(M0+Bd)	Avg %	1.32
CDS 5-year spread	Avg	94.82
basis points	St dev	36.67
Interest rate	Avg	3.56
%	St dev	0.48
FX spot rate	Avg	6.49
value of $1	St dev	0.31
FX return	Avg	0.1%
	Volatility	2.2%
First month		31-Jan-08
Last month		31-Aug-15

Bd = the value of local debt, Bf = the value of foreign debt, CDS = credit default swap, FX = foreign exchange, M0 = monetary base, PRC = People's Republic of China.
Source: Authors' estimates.

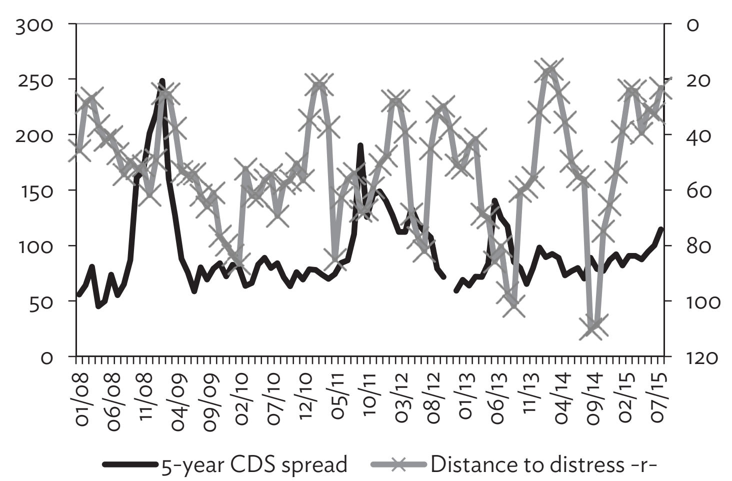
[1] The volatility of local currency liabilities averages about 4% for the PRC, which is considerably lower than that of other countries in the sample, such as about 12% in the case of Indonesia.

Table A2.2: Sensitivity Analysis of the Sovereign Balance Sheet and Debt Sustainability Indicators, People's Republic of China

Contingent claim sovereign balance sheet ($ billion)	Baseline	Scenario 1: 1% increase in M0	Scenario 2: 1% increase in foreign debt	Scenario 3: 1% increase in LCL volatility
Implied value of sovereign assets	1,393.04	1,402.30	1,393.45	1,393.04
Value of risky foreign currency debt	41.04	41.04	41.45	41.04
Distress barrier	44.35	44.35	44.79	44.35
PV of distress barrier	41.04	41.04	41.45	41.04
PV of expected loss	0.00	0.00	0.00	0.00
Value of local currency liabilities	1,352.00	1,361.26	1,352.00	1,352.00
Implied volatility of assets	6.77%	6.77%	6.77%	7.74%
Credit risk indicators				
Distance to distress	23.20	23.23	23.14	20.27
Sensitivity - change in distance to distress		0.04	-0.06	-2.93

LCL = local currency liability, M0 = monetary base, PV = present value.
Notes: The baseline case corresponds to the estimation made in August 2015. The three alternative scenarios correspond to a 1% change in M0; the value of foreign debt (e.g., from 100 to 101); and LCL volatility (e.g., from 6% to 7%), respectively.
Source: Authors' estimates.

Figure A2: Distance to Distress and 5-Year CDS Spreads, People's Republic of China



CDS = credit default swap.
Source: Authors' estimates.

APPENDIX 3: GUIDE TO CONTINGENT CLAIMS ANALYSIS DATA AND ESTIMATIONS

The Microsoft Excel files underlying this paper are available upon request. They contain the data and CCA results for each of the five countries analyzed, plus the PRC. They provide guidance on to how to estimate the main items in the sovereign balance sheet, calculate the historical evolution of the debt sustainability indicators derived from contingent claims analysis, and perform scenario analysis. Each file contains four spreadsheets, providing the following information:

A. Data and Local Currency Liability Volatility

This spreadsheet contains all the data necessary for CCA analysis. It also computes the volatility of local currency liabilities.

1. The data series start in column K. The series are clustered by source and are mostly raw data, with two exceptions:
   (i) For M0, sourced from CEIC, both the monthly raw data and the daily interpolated data are provided. The linear interpolation was conducted in Eviews.
   (ii) For the market value of foreign currency debt, sourced from JP Morgan–Datastream, the market values of debt in US dollars and in euro have been aggregated (euro debt was converted in US dollars and added to the US dollar debt.)

2. The calculation of volatility of local currency liabilities (LCL) is located on the left side of the spreadsheet. The results are shown in the two columns colored in blue. Please note that:
   (i) The first column computes daily rolling 1-month LCL volatility.
   (ii) The second column computes daily rolling 3-month LCL volatility, which was used for the estimations.
   (iii) To annualize the daily volatility measure, the standard deviation of returns is multiplied by the square root of 252, which is the average number of trading days in 1 year.

B. Contingent Claims Analysis Estimation

This spreadsheet contains all the intermediate steps toward estimating the sovereign balance sheet items and the final debt sustainability indicators. Follow these four steps to run the calculations:

1. Columns B to I (in blue) are to be filled first with the necessary data (from spreadsheet A)
2. Columns AA to AB (in blue) should be filled with initial values to help the convergence of the iteration process. To do so, copy and paste (paste special in values) the “initial values” in columns Y and Z of the spreadsheet, which provide initial estimations of the total value of the sovereign balance sheet and its volatility
3. Indicate the “start line” and “end line” of your calculation. Note that this will depend on the data availability for the various countries.
4. Push the “start” button in grey. It may take several minutes for the iterations to converge, to yield the final estimates of the total value of the sovereign balance sheet, its volatility and the debt sustainability indicators. Graphs are provided at the right-hand side of the spreadsheet.

C. Sensitivity Analysis

This spreadsheet checks the results for their sensitivity to various scenarios. Starting from the baseline scenario corresponding to the last historical data available (line 15), three alternative scenarios are analyzed, each corresponding to a 1% increase in:

1. M0
2. the value of foreign debt, Bf
3. the volatility of the local currency liabilities, Bd

This spreadsheet allows for any kind of scenario analysis, simply by changing the input parameters (columns B to H) and rerunning the estimation.

The structure of this spreadsheet is identical to that of spreadsheet B (CCA estimation). Hitting the grey button will compute debt sustainability indicators based on the new hypotheses specified, following the same steps as in section (B). Before that, remember to copy and paste the "initial values" (columns Y and Z) into columns AA and AB.

D. Output

This spreadsheet summarizes the main results in the form of:

1. a table summarizing the main items in the sovereign balance sheet estimation and the results of the sensitivity analysis, and
2. a graph comparing the historical evolutions of the distance to default to the CDS spread.

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Contingent Claims Analysis of Sovereign Debt Sustainability in Asian Emerging Markets

Contingent claims analysis applied to Indonesia, Malaysia, the Philippines, the Republic of Korea, and Thailand shows no particular vulnerability to sovereign debt distress during recent years. However, the highly volatile “distance to distress” measure suggests that any of these countries may fall victim to a sudden loss in market confidence. For example, the value of Indonesia’s sovereign assets dropped to just two standard deviations above its repayment obligations during the 2013 Fed taper tantrum, causing capital outflows and currency depreciation. Generally, we find that contingent claims analysis and market-based risk measures well complement conventional debt sustainability analysis for Asia.

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