MODELLING SOVEREIGN DEBT INDUCED BANKING CRISES: THEORY, APPLICATION AND POLICY CONUNDRUMS†

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Abstract

The paper examines the relationship between sovereign debt dynamics and the stability of financial institutions using a system dynamics framework. It also explores the effectiveness of various policy options aimed at restoring stability after severe macrofinancial shocks. The model incorporates three main agents: banks, a central government and a rating agency. The framework identifies the transmission mechanisms linking sovereign debt and financial sector crises when the above three agents interact over time. Although the calibrated model is informed by Jamaican data and the debt situation which has prevailed there since the global financial crisis, the model provides a framework for the consideration of sovereign debt crises in other countries. The model does well in developing a causality driven approach to explain the reasons behind increasingly unsustainable debt-deficit dynamics and how these imbalances can spill-over into the banking sector leading to increased financial fragility.

Keywords: Financial Stability, Sovereign Debt Restructuring, Bank Failure, Early Warning Model.

"A crisis is a terrible thing to waste."

Paul Romer, November 2004

1.0 INTRODUCTION

The current sovereign debt crisis in Europe which was precipitated by the sub-prime crisis in the United States of 2008 has highlighted several linkages between the vulnerability of both sovereign and the banking sector to macro-financial risks coupled with vulnerabilities which were hitherto considered as unrelated. It is in this broad context that the former head of the IMF, Mr. Dominique Strauss-Kahn, noted that "… a wider definition of sovereign risk where core fiscal variables and the macroeconomic context are complemented with elements reflecting broader balance sheet development, debt portfolio structure, investor base, cross broker linkages, and financial assets of a country would be warranted" (Strauss-Kahn, 2011). He further noted that these concerns, having to do with the intersection of sovereign risks and the robustness of the financial sector, if left unattended, could not only undermine economic recovery but also compromise global financial stability.

The aforementioned considerations are especially relevant to small open economies which are particularly sensitive to exogenous shocks which are inherent in an increasingly interconnected world. Additionally as pointed out by Goodhart et. al (2006), small open economies are particularly susceptible to sudden 'stops' in capital market activity and sudden 'capital' flight. That is, when domestic agents need foreign currency liquidity, the central bank's ability to help may be strictly limited by the extent of its foreign currency reserves. This is particularly true of those economies whose borrowing (and financial system) is largely denominated in foreign currencies.

It is against this broad background that this paper intends to make its contribution to the financial stability literature in the specific area of 'twin crises' of sovereign debt and banking sector distress. The theoretical framework can be used to understand many types of crises and risk transfers between the banking sector and the government sector that cannot be easily analyzed with other techniques. The framework can, for example, help identify situations where sudden

deterioration in macro-financial risk factors become magnified reinforcing feedback loops then trigger severe crises in other sectors of the economy. The building blocks of this synthesis are focused on solvency rather than illiquidity, stocks (and concentration risk) in the balance sheet for banks and governments rather than merely focusing on flows, and the process of transitioning into the crisis (White, 2010).

Jamaica presents an interesting case study, since it has had levels of debt in excess of 100.0 per cent of its Gross National Product (GNP) for the last decade, a financial sector with relatively high concentrations in sovereign debt securities and an economy which has been prone to external shocks. Between 2000 and 2010 in particular, the economy has experienced fiscal shocks (e.g. contingent liabilities of the government materializing), macro-financial shocks, rating-downgrades and a debt-restructuring.

The organization of the paper is as follows. The next section, Section 2, presents a brief survey of the theoretical bank stability/fragility literature and highlights some of the existing gaps in the literature. Section 3 presents the system dynamics framework and Section 4 and discusses the model's ability to capture crisis dynamics in Jamaica during the recent global financial crisis as the case study. Section 5 evaluates the effectiveness of various policy alternatives aimed at restoring macro-financial stability. The paper concludes, in Section 6, with a discussion of the merits of adopting this approach to understanding systemic risk issues.

2.0 LITERATURE REVIEW

A plethora of models concerning banking crises, primarily game-theoretic in a nature have been developed over the last two decades. These game-theoretic models of financial instability can be broadly categorized as either illiquidity or insolvency models of financial instability. Theoretical models of financial instability that are driven by illiquidity typically depend on some type of 'domino effect.' That is, in the framework there is usually demandability on the part of one agent (e.g. depositors) or the 'transferability of claims' among agents (e.g. banks). When these rights are exercised, due to the illiquidity of some assets, then this may lead to failures among banks and losses to depositors. See for example the substantive works of Diamond and Dybvig (1983), Allen and Gale (1998), Freixas et al. (2000) and Dasgupta (2004). The main disadvantage of this genre of the bank crisis literature is that crisis outcomes are binary: (i) either all depositors

liquidate their holdings and default becomes inevitable, or (ii) nobody liquidates their position and the bank(s) remain solvent. Thus these frameworks show how a crisis could occur but are unable to assist in a forward looking assessment of future crises since there is no accumulation of risk that precipitates the crisis. The second class of theoretical studies considers crises emanating from a rapid fall in the market value of bank assets due to either marking or credit related risks (see for example, Kiyotaki and Moore (1997), Allen and Gale (2000), Acharya and Yorulmazer (2002), Suarez and Sussman (2007) and Morris and Shin (2000)). Several mechanisms have been suggested by this literature for promulgating asset based liquidity crunches including the dissipation of asset values in secondary markets arising from difficulties in a subset of banks which may lead to contagion and co-ordination failure between banks due to highly correlated portfolio choices ex-ante. A chief drawback of this portion of the literature, from a bank surveillance perspective, would be that almost all of these models have not been calibrated or tested with real data (Goodhart et. al, 2008). Also these theoretical frameworks of bank crises, have implicitly or explicitly assumed that the government issues risk-free assets, and in so doing have not addressed frontally the exposure of banks to sovereign debt instruments in a context where debt dynamics become increasingly unsustainable.

System dynamics has provided a theoretically grounded analytical synthesis between finance and economics that can address these short-comings in the bank crisis literature. The work of Parayno & Saeed (1993) in modeling the dynamics of indebtedness incorporates the macro-economic model of the economy, market-clearing mechanisms and government decision making behaviour is one such contribution. The time-frame is long spanning several decades and the focus is on developmental issues in a context of highly indebted countries with Indonesia as a case study. Similarly, Yamaguchi (2011) presents a system dynamics model of the macro-economy which synthesizes money creation, the banking system, the government, producers and households. The model is used to evaluate implications of the fractional reserve system on economic growth, unemployment and inflation and highlights the significant challenges that growing debt poses to the attainment of macrofinancial stability. The government agent developed in this paper builds upon the work of Parayno et. al (1993) by making the evolution of default probabilities explicit and endogenous and evaluates the transmission of risk between the banking and government sector. Further, the model presented in this paper attempts to contribute to the understanding of how sovereign debt crises can emerge and the development of ex ante

mechanisms to improve crisis management (e.g., adequate self-insurance (risk weighting government securities, special legislation – implementation of a systemic risk fund, bank regulatory reform and so on).

3.0 MODEL OVERVIEW AND CONCEPTUALIZATION

The overview of the model is shown diagrammatically in Figure 1.[1] The banks and the central government are assumed to be boundedly rational interacting via both the local and international capital markets. Further, the credit rating agency is assumed to be perfectly rational and forward-looking. As a result, while the rating agency has access to perfect information and has perfect foresight the central government and the banking sector are instead backward looking, subject to information asymmetries and the use of heuristics to guide decisions regarding debt financing and portfolio allocation decisions, respectively. The rating agency assesses the credit worthiness of the debt instruments offered by the central government and in so doing influences the quantity, pricing terms and currency composition of the funding that the government agent is able to acquire over time. At the same time, the credit rating agency's assessment also influences the credit risk exposure of the banking sector that makes decisions concerning how much sovereign debt instruments and capital to hold on its balance sheet.

In the model both the central government and agents within the banking sector can default. The government will default when the probability of default (PD) issued by the credit rating agency exceeds a critical threshold PD*. The banking sector will default when its credit risk exposure, which is itself contingent on default of the sovereign, exceeds the stock of capital which it holds at any given time. More precisely, a bank will default if, and only if, two conditions hold,

   (i) If the sovereign nation is deemed to have defaulted: $PD > PD*$[2]

and

   (ii) If SCLE > Capital Base (Banking Sector)

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[1] For more details on the model see Lewis (2011b).

[2] The threshold value (P*) is chosen by the credit rating agency in a way that minimizes the likelihood that it declares a country in default when it is fact not deserving of this credit rating and the likelihood that it will not declare a country in default when in fact this is the situation. This approach maintains the reputation of the credit rating agency.
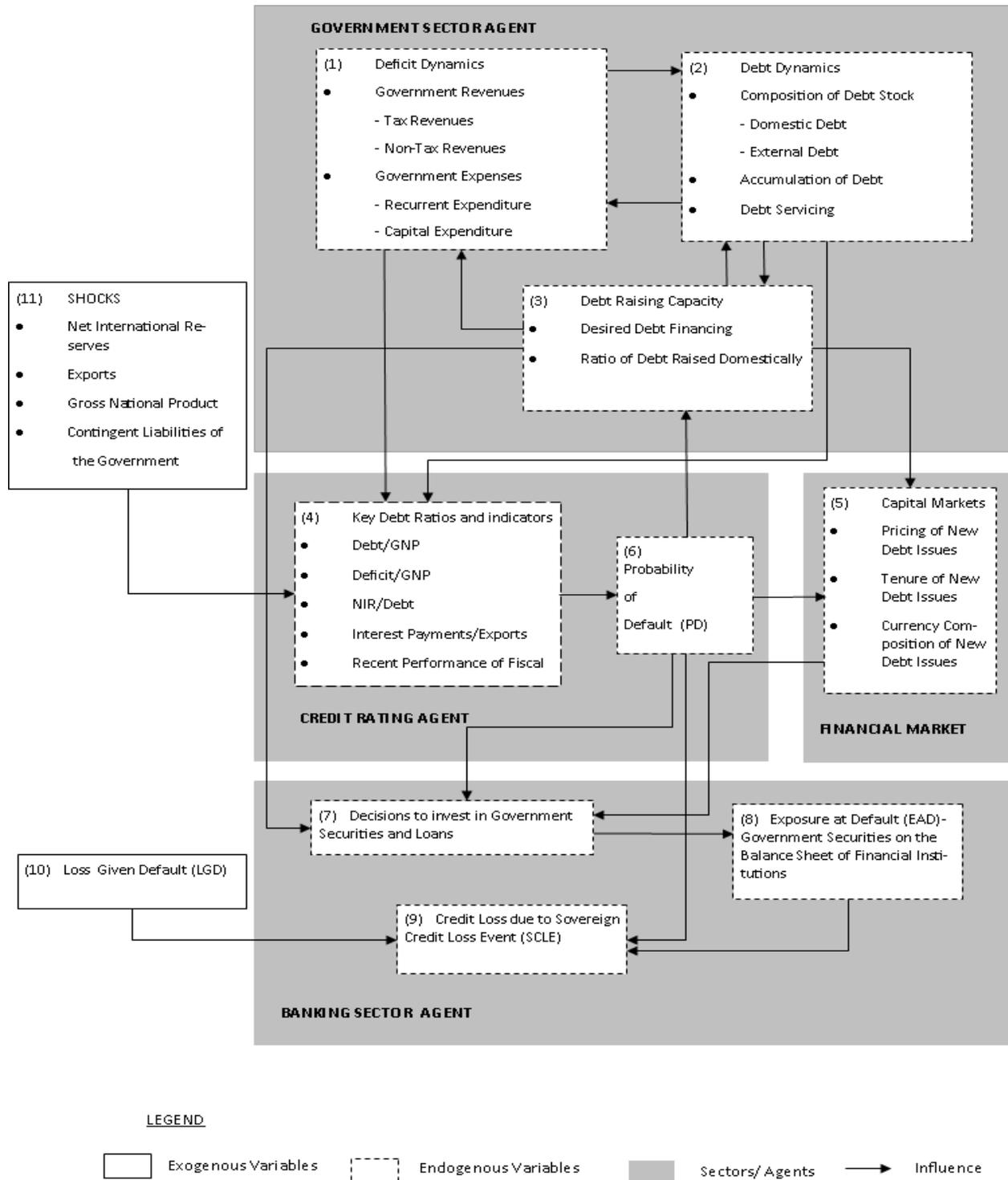
Figure 1: Model Overview

where the Sovereign Credit Loss Event is captured by:

$$SCLE = EAD \times LGD$$

where the EAD is the exposure to the bank to sovereign debt instruments at the point of default and LGD is the loss given default (the reciprocal of the recovery rate).

There are powerful reinforcing loops at work in debt-deficit-downgrade dynamics (see Figure 2). In particular, interest rates are a powerful mechanism through which debt-deficit-downgrade cycles can persists and lead to sovereign debt defaults and banking crises. Firstly, higher deficits lead to higher default risks via credit rating downgrades and are priced by the market in terms of higher interest rates leading to higher deficits (R1). Secondly, persistent fiscal deficits encourage shorter maturity of debt and a higher roll-over risk premium which also increases the interest rates (even without a debt downgrade) on new debt which, in turn, increases the government agent's interest rate payments (R2). Thirdly, higher debt repayments arising from shorter maturity of debt results in higher cash demand for the cash-strapped government agent which leads to higher demand for deficit financing. This has the effect of increasing overall indebtedness of the government agent. This dynamic will imply higher debt repayment obligations (relative to tax receipts) leading to higher demand for deficit financing (R3). For the banking sector agent the reinforcing loop that drives ever larger exposures to the government agent's securities is the demand for debt financing from the government and the pursuit of past returns for the bank which encourages increased risk-taking even in the face of increasing exposure to a an ever more likely default vent (R4). The presence of these sets of feedbacks allows for the endogenous generation of the modes of behaviour that (i) capture economies which have low and declining exposure to sovereign risk and banking sector exposure, (ii) economies which have risk exposures that rise temporarily and then return to a low state and therefore do not pose a threat to the viability of the banking sector, and (iii) those economies which have high and rising exposures to sovereign debt and banking crises episodes.

Figure 2: Conceptual diagram of main adverse feedback loops governing a twin sovereign debt and bank crisis

4.0 SIMULATION RESULTS: THE IMPACT OF MACRO-FINANCIAL SHOCKS ON THE STABILITY OF THE BANKING SYSTEM AND A SOVEREIGN NATION

Stress tests on the framework beginning in period 1 (2007) are used to test the model's ability to detect the occurrence of twin sovereign debt and banking crises dynamics. These shocks are not anticipated by any agent in the framework. The stylized historical macro-economic shocks are as follows:-

    (i) increase of the rate of depreciation in the foreign exchange rate to 18.0 per cent in period 2008 for one year.

    (ii) decline in net international reserves (NIR) of 11.0 per cent and 22.0 per cent in 2007 and 2008, respectively.

    (iii) reduction in the exports of goods and services of 27.0 per cent in 2008 and 1.0 per cent in 2009.

    (iv) increase in the indicated external interest rate, (IRI_e), to 0.12 per cent from 0.055 per cent in 2007.

These exogenous shocks versus the baseline evolution of these variables are shown graphically in Figure 3. The response of the agents is shown graphically in Figure 4 which also captures the evolution of the impact of the global financial crisis on Jamaica between periods 2006 and 2013.
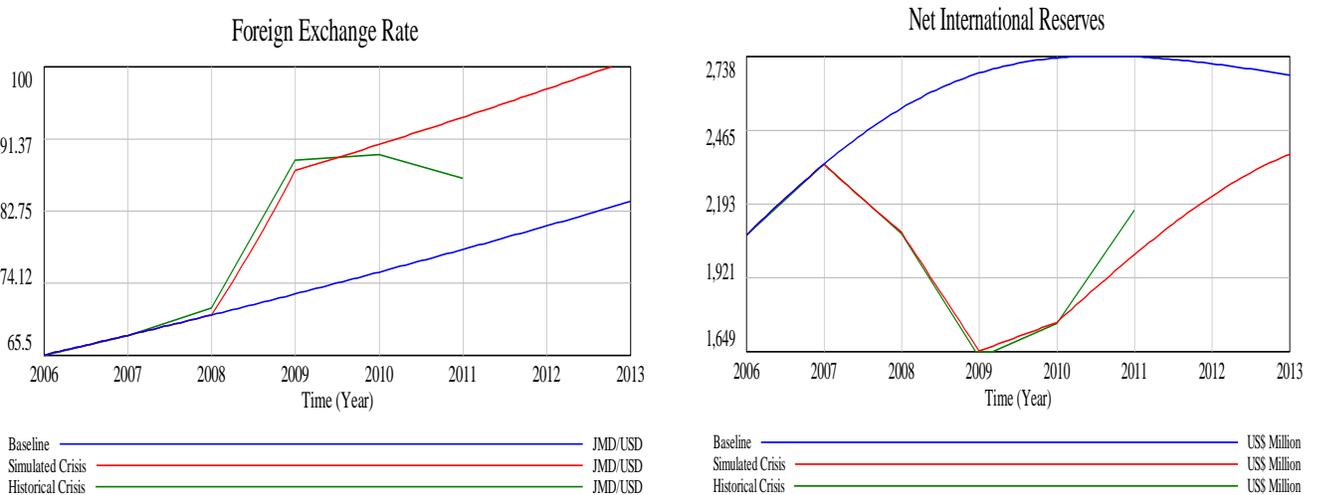

Figure 3. Summary of exogenous shocks to Jamaica resulting from the impact of the global financial crisis

Exports

6,600
5,938
5,276
4,614
3,953

2006 2007 2008 2009 2010 2011 2012 2013
Time (Year)

Baseline ————————————————————— US$ Million
Simulated Crisis ————————————————————— US$ Million
Historical Crisis ————————————————————— US$ Million

Average External Bond Interest Rates

0.4
0.3125
0.225
0.1375
0.05

2006 2007 2008 2009 2010 2011 2012 2013
Time (Year)

Baseline ————————————————————— Per cent/Years
Simulated Crisis ————————————————————— Per cent/Years
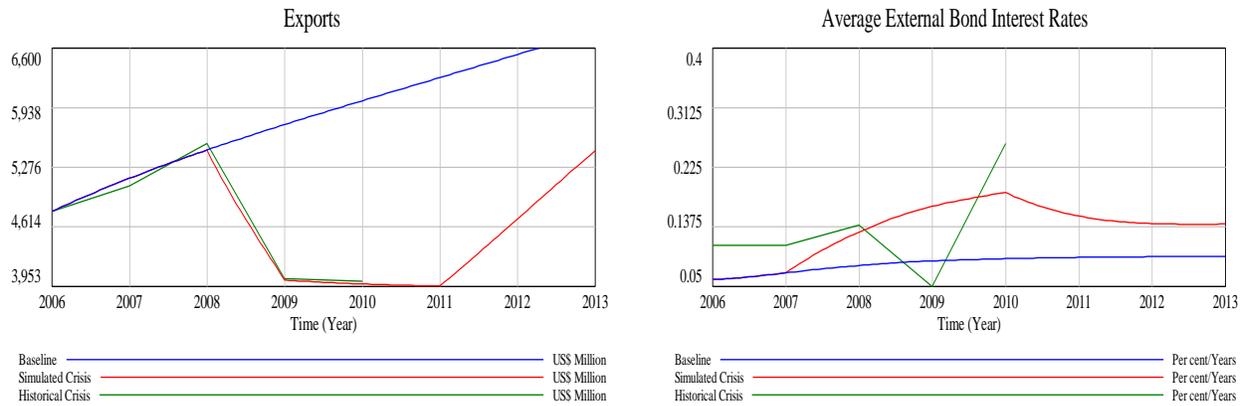Historical Crisis ————————————————————— Per cent/Years

Figure 3 (cont'd). Summary of exogenous shocks to Jamaica resulting from the impact of the global financial crisis

The dynamics generated by the model results in a significantly different outturn than the baseline (see Figure 4). The explanation for this significant departure can be found in the positive feedbacks, which had conferred favourable debt-deficit dynamics under the baseline, transforming into a positive self-reinforcing vicious cycle in the context of unanticipated macro-economic shocks. The simulation shows that by 2010 both the government and the banking sector are in default with the former being downgraded to default status by the CRA and the latter having insufficient capital to cover credit losses arising out the write-down of the

Probability of Sovereign Nation Default (PD t+1)

24
18
12
6
0

2006 2007 2008 2009 2010 2011 2012 2013
Time (Year)

Baseline ————————————————————— Per cent
Simulated Crisis ————————————————————— Per cent
Default Threshold ————————————————————— Per cent

Bank Regulatory Capital - Leverage Ratio

20
15
10
5
0

2006 2007 2008 2009 2010 2011 2012 2013
Time (Year)

Baseline ————————————————————— Per cent
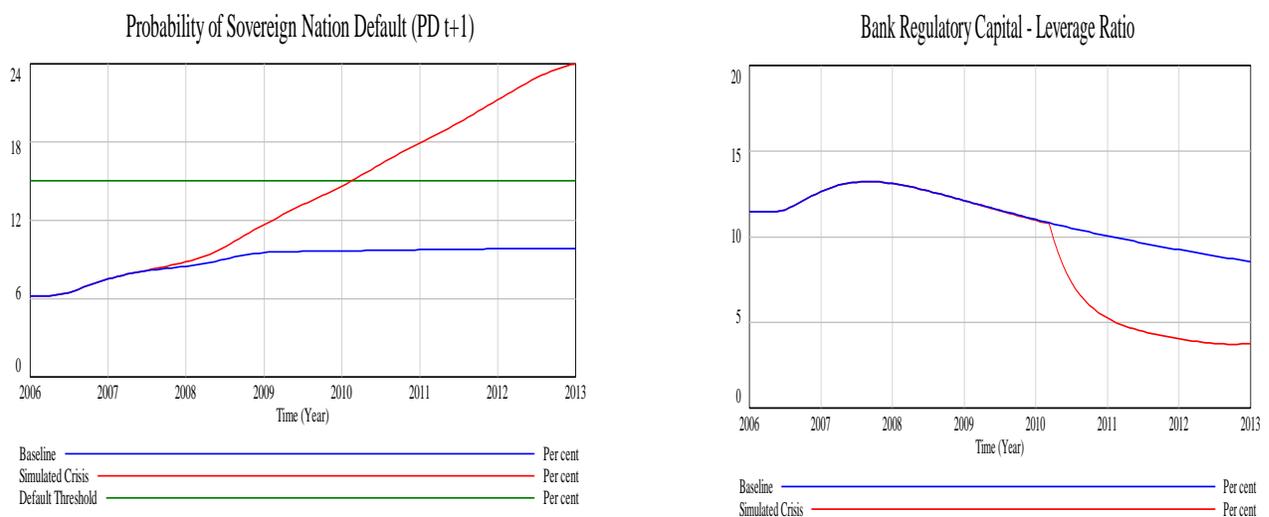Simulated Crisis ————————————————————— Per cent

Figure 4. Simulated Impact of the Global Financial Crisis on Macro-Financial Stability-Jamaica

value of the government securities held in its investment portfolio. This is the fundamental characterization of a twin sovereign debt and banking crisis

5.0 THE EVALUATION OF ALTERNATIVE POLICY OPTIONS TO ASSUAGE THE IMPACT OF THE GLOBAL FINANCIAL CRISIS ON MACRO-FINANCIAL STABILITY

The system dynamics model also allows for the evaluation of alternative policy interventions in the wake of the global financial crisis as well as later on in the evolution of the crisis. The section briefly evaluates the impact of each of these policies on key indicators of macro-financial stability.

The policies are detailed below:-

(i) Policy 1: Bail-out the banking System: This policy consists of recapitalizing those banks which do not have sufficient capital to remain solvent post sovereign debt default.

(ii) Policy 2: Implement dynamic risk weighted assets on holdings of government securities by banks.

(iii) Policy 3: Establish a financial stability fund for systemic risks facing the banking sector. A fund is established to which the banking sector makes contributions from its profits. The banking agent is allowed to access funds from this funding pool in the event of a systemic risk which threatens the viability of the sector.

(iv) Policy 4: An exogenous debt restructuring, in which the entire banking sector is assumed to participate, is implemented by 2010 under the following rules: - (a) the debt restructuring impacts the domestic portion of the debt stock only; (b) voluntary exchange of domestic debt instruments for debt with twice the average maturity; and (c) a 900 basis points (bps) reduction in interest rate on domestic debt instruments; (d) par-for-par exchange of all domestic debt instrument i.e. no hair-cuts.
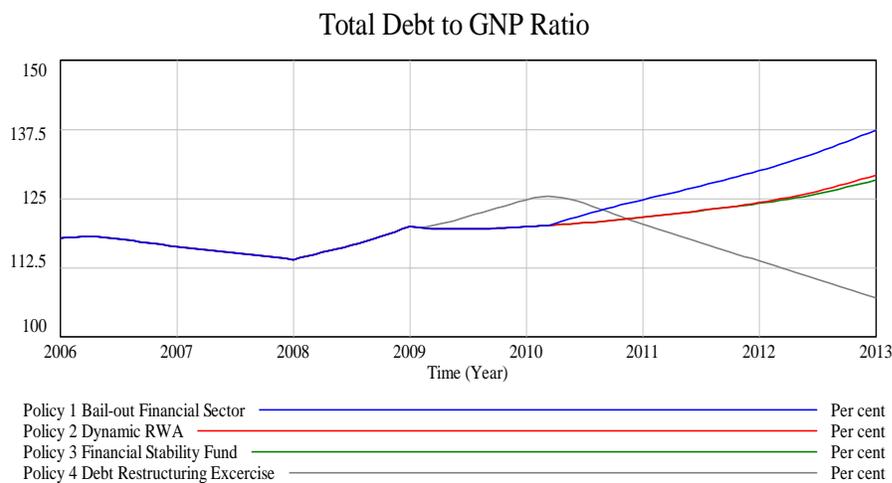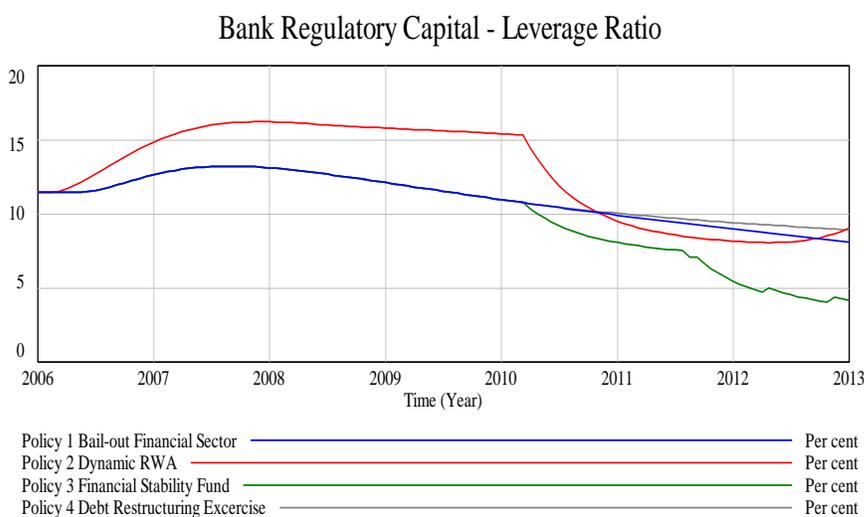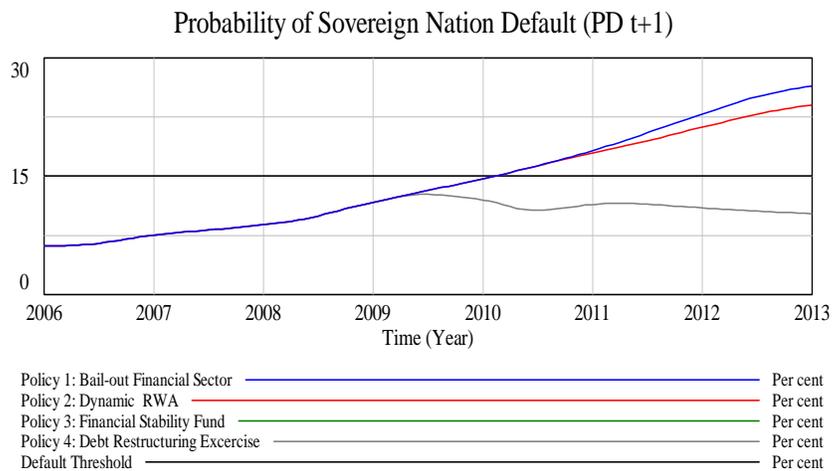
Probability of Sovereign Nation Default (PD t+1)

30

15

0

2006　2007　2008　2009　2010　2011　2012　2013

Time (Year)

Policy 1: Bail-out Financial Sector	Per cent
Policy 2: Dynamic RWA	Per cent
Policy 3: Financial Stability Fund	Per cent
Policy 4: Debt Restructuring Excercise	Per cent
Default Threshold	Per cent

Bank Regulatory Capital - Leverage Ratio

20

15

10

5

0

2006　2007　2008　2009　2010　2011　2012　2013

Time (Year)

Policy 1 Bail-out Financial Sector	Per cent
Policy 2 Dynamic RWA	Per cent
Policy 3 Financial Stability Fund	Per cent
Policy 4 Debt Restructuring Excercise	Per cent

Total Debt to GNP Ratio

150

137.5

125

112.5

100

2006　2007　2008　2009　2010　2011　2012　2013

Time (Year)

Policy 1 Bail-out Financial Sector	Per cent
Policy 2 Dynamic RWA	Per cent
Policy 3 Financial Stability Fund	Per cent
Policy 4 Debt Restructuring Excercise	Per cent

Figure 5: Relative effectiveness of alternative policy options in maintaining macro-financial stability

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The impact, relative effectiveness in maintaining macro-financial stability, is shown in Figure 5 by evaluating its relative impact on the the probability of sovereign default, capitalization of the banking sector, and the debt-to-GNP ratio. Policy 1, which adopts a 'wait-and-see' posture, results in the worst outcome for all the indicators of macro-financial stability with the exception of the capital base of the banking system. The bail-out of the financial sector which occurs after the sovereign has defaulted results in a higher path for the probability of default (PD) and higher debt-to-GNP ratios post policy implementation. Policies 2 and 3, which involve the implementation of dynamic risk-weights for government securities and the establishment of a financial stability fund respectively, help insulate the banking system from the impact of an explicit default by the government agent. These policies operate through different mechanisms. Policy 2 requires the banking agent to 'self-insure' against a default event by requiring them to hold buffer capital for each additional $1 invested in government securities. Consequently, as the crisis unfolds the banking system's holding of capital rises and offsets the inimical impact of the explicit sovereign default event. Policy 3, on the other hand, creates a fund which increases as a proportion of surplus profits during the 'exuberance' investment phase in government securities and channels these contributions into a stabilization fund.[3] It should be highlighted, however, that neither Policy 2 nor Policy 3 result in an improvement in the sovereign default risk in the evolution of the debt-deficit dynamics. The impact of a debt restructuring exercise, Policy 4 proves successful in breaking the self-reinforcing cycle of persistent deterioration in debt-deficit dynamics followed by persistent sovereign downgrades. That is, both the doubling of the age of debt as well as the reduction of the interest rate on outstanding domestic debt, serve to strengthen the balance sheet of the government agent. These result in an improvement in the path of the fiscal deficit and an eventual decline in the debt profile.

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[3] The effectiveness of Policy 3 is however constrained both by the initial endowment of the fund as well as the period of time over which it can be built up via bank contributions prior to a crisis episode.

6.0 CONCLUSION

Policymaking is difficult as policy makers typically have imperfect information about which policies produce which outcomes, and they are often left with little choice but to arrive at appropriate policies via a trial-and-error process. The enormity of this challenge increases exponentially when unanticipated shocks and increased uncertainty enters the policy domain. This paper attempts to model one such policy conundrum, twin sovereign and banking sector stability in the face of unanticipated macro-financial shocks, in a way that is mathematical tractable, rigorous and yet simple enough to be illuminating. However, there are trade-offs in achieving this. The complexity of the modelling exercise has been limited to evaluating a simple three-agent economy with no firms and households. Furthermore, macro-economic shocks and the external sector are introduced as exogenous phenomena.

The framework is capable of capturing the key crisis dynamics underlying a severe sovereign and banking sector fall-out resulting from exogenous scenario-driven 'stress-test' shocks. The stress-tests are derived from plausible, narrative-based, macroeconomic scenarios which are intuitive, realistic and context driven. This makes the results of such stress tests highly intuitive to policy makers, analysts and risk managers. The exercise shows that the modelling methodology is capable of an evaluation of the dynamics of a severe sovereign and banking sector crisis. The model has been calibrated to capture both the impact of the global financial crisis on Jamaica and it endogenously generates the modes of behaviour observed historically. That is, the model is computable and can be calibrated against real data as well as for counterfactual analysis. As such the model, at least in principle, should be able act as an early warning tool for sovereign nations and bank fragility in the context of appropriately defined stress tests.

The various policy formulations experimented with in the paper raise some important questions. One of these questions is: who bears the costs of twin sovereign debt and financial crises? Each of the policies contemplated has separate implications for the economic agents that will have to bear the cost associated with restoring macro-financial stability. This simulation environment, it is hoped, will stimulate meaningful discussions among various stakeholders (banks, governments, households and pensioners) which will hopefully lead to enhancing consensus around the best way forward in terms of banking sector and fiscal policy reform.

Acknowledgements

References

Acharya, V., & Yorulmazer, T. (2002). *Information contagion and inter-bank correlation in a theory of Systemic Risk.* London: London Business School.

Allen, F., & Gale, D. (1998). Optimal Financial Crises. *Journal of Finance 53, no. 4*, 1245-1284.

Allen, F., & Gale, D. (2000). Financial Contagion. *Journal of Political Economy*(108), 1-33.

Dasgupta, B. (2004). Capital Accumulation in the Presence of Informal Credit Contracts: Does the Incentive Mechanism Work Better than Credit Rationing Under Asymmetric Information? *Department of Economics Working Paper Series*. University of Connecticut.

Diamond, D. W., & Dybvig, P. (1983). Bank Runs, Deposit Insurance, and Liquidity. *Journal of Political Economy, 91*.

Freixas, X., Parigi, B. M., & Rochet, C. (2000). Systemic Risk, Interbank Relations and Liquidity Provision by the Central Bank. *Journal of Money, Credit and Banking* (2), 611-638.

Goodhart, C. A., & Tsomocos, D. P. (2006). *Analysis of Financial Stability*. Retrieved October 8, 2010, from www.mnb.hu/Root/Dokumentumtar/ENMNB/.../goodhart.pdf

Goodhart, C., & Dimitrios, T. (2008). *Analysis of Financial Stability*. Retrieved June 22, 2008, from www.mnb.hu/Resource.aspx?ResourceID=mnbfile...goodhart.

Kiyotaki, N., & Moore, J. (1997). Credit Cycles. *The Journal of Political Economy*, 211-248.

Lewis, J. (2011b). The Implications of Jamaica's Debt Burden for Financial Stability: A System Dynamics Approach. *29th International Conference of the System Dynamics Society*, (pp. 1-23). Washington, DC.

Morris, S., & Shin, H. S. (2000). *Rethinking Multiple Equilibria in Macroeconomic Modelling*. Retrieved June 10, 2008, from Home Page of Hyun Song Shin: http://hyunsongshin.org/www/nber.pdf

Strauss-Kahn, D. (2011). Financial Crisis and Sovereign Risk: Implications for Financial Stability - Opening Remarks. *Financial Crisis and Sovereign Risk: Implications for Financial Stability* . Washington DC: International Monetary Fund.

Suarez, J., & Sussman, O. (2007). Financial Distress, Bankruptcy Law and the Business Cycle. *Annals of Finance, 3, no. 1*, 5-35.

White, William R. "Some Alternative Perspectives on Macroeconomic Theory and Some Policy Implications." The Mayekawa Lecture. Institute for Monetary and Economic Studies: Bank of Japan, 2010. 35-58.

Parayno, P., & Saeed, K. (1993). The Dynamics of Indebtedness in the Developing Countries: The Case of the Philippines. Socio-Economic Planning Sciences, 27(4).

Yamaguchi, Kaoru. Workings of a Public Money System of Open Macroeconomies. Presented at 7th Annual AMI Monetary Reform Conference in Chicago, USA. September, 30 2011