Towards An Early Warning Model of Sovereign Debt and Financial Sector Crises with an Application to the Case of Jamaica

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This paper examines the relationship between sovereign debt dynamics and the stability of financial institutions using a system dynamics framework. The model, which builds upon the seminal work of Saeed and Parayno (1993), incorporates three heterogeneous banks, a central government and a rating agency. Further, the banks and the central government are assumed to be boundedly rational and backward looking interacting via both the local and international capital markets. The model is calibrated to conform to time-series data of Jamaica's debt-deficit dynamics and banking system performance between FY 1997/8 and FY 2003/4. It is then used to perform a set of counterfactual exercises based on the impact of exogenous hypothetical shocks to the Jamaican economy four years prior to the onset of the recent global financial crisis. Accordingly, the paper proposes an 'early warning system' for the vulnerability of banking institutions to a default on public debt. Scenario analyses, conducted using the framework, suggest that significant shocks to net international reserves and exports in 2004 would catalyze a significant fall-out of the banking sector in the near to medium term, with the country being more vulnerable to shocks to net international reserves. We close with some implications for prudential regulation.

JEL classification numbers: F37; G15; G21
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1.0 INTRODUCTION AND SUMMARY

1.1 Non-technical Summary

Over the last three decades there has been a large number of systemic banking crises of varying sizes, duration and levels of intensity, as documented by the studies of Lindgren, Garcia, and Saal (1996), Pesola (2001), and Kamil and Rai (2009), among others. The persistence of banking sector problems and the large social and economic costs associated with their occurrence have brought to the fore the need for tools and skill sets which can better help policy makers identify and mitigate such risks. Furthermore, over the same period there have also been many sovereign debt crises arising from economies with high levels of public debt. Increasingly this too has received considerable consideration especially in cases where the domestic financial sector and real economic activities have been negatively impacted (see, for example, World Economic Outlook, September 2003). More recently, Professor Rogoff, co-author of a new history on financial crises, was cited as stating, "There's no question that the most significant vulnerability to stability as we emerge from [the current] recession is the soaring government debt" (Bloomberg Business News, 2009). The same article also cited estimates from the International Monetary Fund (IMF) which suggest that G-20 debt will reach 82.1 per cent of Gross Domestic Product (GDP) in 2010, almost 20.0 percentage points more than two years ago and the equivalent of approximately US$37.0 trillion.

Reflecting this growing concern, policy makers have focused their attention on developing frameworks which can assess the vulnerability of both developed and emerging economies to debt default so as to allow policy makers to put in place mitigation strategies which can dampen the deleterious impact this can have on both economic activity and financial stability. These considerations are especially relevant to small open economies which are particularly sensitive to exogenous shocks which are inherent in an increasingly interconnected world. Indeed, the high level of indebtedness of many small open economies has raised many questions for policymakers and the general public. For example, at what level does public debt become too high to be sustainable? What policy actions are needed to ensure that debt reduction strategies employed by fiscal authorities are sustainable? And perhaps most importantly, what rules and legislation can policy makers put in place to cushion the economy and the financial sector against the risks that high sovereign debt levels present?

In Jamaica, the public sector debt burden has been in excess of 100.0 per cent of Gross Domestic Product (GDP) since FY2000/1 and has increased steadily in recent years, as reflected in a sizeable deterioration in the debt to GDP ratio to 121.2 per cent at the end of FY 2009/10. Similarly, over the same period, the ratio of interest payments to tax receipts has increased steadily peaking at 65.0 percent at end FY 2009/10, while the Central Government has consistently run fiscal deficits between FY 1997/8 and FY 2009/10, which have fluctuated between a low of 1.0 per cent to a high of 7.3 per cent of GDP. At the same time, the exposure of the banking sector to Government of Jamaica (GOJ) debt has remained large over the period and the trends in these exposures serve to highlight the vulnerability of the banking sector to sovereign credit risk. Notwithstanding the high levels of domestic and external debt, significant vulnerabilities to external shocks resided with the structure of the domestic debt stock. At end-2009, approximately 40.0 per cent of domestic debt was maturing in less than 24 months with 55.0 per cent of the domestic debt representing floating-rate instruments. This presented

significant levels of roll-over risk for GOJ which made them increasingly vulnerable to sudden shifts in market sentiment.

This vulnerability was exposed in the aftermath of the September 2008 financial sector meltdown in the United States, where both the non-bank financial sector and the Jamaican Government faced external funding shortfalls. Specifically, the non-bank financial sector faced liquidity short-falls arising from margin calls which resulted from the sharp rise in yields on GOJ global bonds while the GOJ was unable to access global capital markets to meet its financing needs. In response, the central bank intervened in the foreign exchange market in an attempt to manage the sharp depreciation in the domestic currency and provided liquidity to the non-bank entities in order to ensure that all external obligations would be met.[1] The central bank also intervened in the domestic inter-bank market and acted as counterparty to borrowers and lenders to address the problem of asymmetric information which had caused temporary disruption in inter-bank activity.[2] Finally, the central bank tightened monetary policy by increasing its key policy rate to 21 ½ per cent on 1st December 2008. As the central bank attempted to rein in the rapid depreciation of the currency by tightening monetary policy, addressing the price-stability issue on the one hand, it had the unintended consequence of exacerbating the debt-deficit dynamics of the Central Government, on the other. The precarious position of the GOJ during 2009 manifested itself in both a widening of credit spreads viz-a-viz the EMBI (emerging market bond index) as well as successive downgrades of the debt by rating agencies including S&P and Moody's and Fitch.[3] After a series of consultations with market participants as well as multi-lateral lending agencies the GOJ decided to restructure its entire domestic debt stock in January 2010, extending the maturity and lowering the coupon rates on JMD$700.0 billion debt (65.0 per cent of GDP) with a par for par exchange with domestic bond holders. This initiative was dubbed the Jamaica Debt Exchange ("JDX").

It is against this background, both global and local, that this paper intends to make its contribution to the literature on Early Warning Systems (EWS) in the specific area of twin crises of sovereign debt and banking sector distress. The nature of the phenomena to be studied, falls within the ambit of events which are low frequency but have a high (financial and social) impact.

In sum, the research proposes and estimates a simple model of the debt dynamics which projects, on a scenario basis, the likely evolution of the debt-dynamics over the medium-term as well as the vulnerability of the banking sector to sovereign debt default. Specifically, a system dynamics framework is used to evaluate the impact of large but plausible shifts in macro-economic factors, including the stock of net international reserves (NIR) and exports on the solvency of the banking sector through a set of counter-factual exercises.

[1] Between end-September 2008 and end-January 2009 the Net International Reserves (NIR) declined by US$478.0 million or 21.5 per cent. In the following 12-month period, between end-January 2010 and end-January 2009, the NIR then declined by a further 11.2 per cent to US$1566.01 million.

[2] For example, for the trading week ending 24 November and 12 December 2008, the daily quoted 'high' inter-bank rates were 23.4 per cent and 36.2 per cent, respectively compared to tranquil rates of 8.9 per cent in the month prior to the collapse of Lehman Brothers.

[3] On 02 November 2009, S&P lowered its long-term foreign and domestic sovereign credit rating on Jamaica to 'CCC' from 'CCC+' and maintained a negative outlook. On 18 and 24 November 2009, respectively, ratings Agencies Moody's and Fitch also downgraded Jamaica's local and foreign currency government bond ratings.

The remainder of the paper is presented as follows: Section 2 gives an overview of the model, the principal equations of the model. Section 3 discusses the data employed in the calibration of the system dynamics debt model as well as the data used in the estimation of the probability of default. Univariate stress tests are performed in section 4, and the paper concludes in section 5 with a discussion of the major policy implications.

2.0 SYSTEM DYNAMICS MODEL[4]

2.1 Overview of Model

The SD model below follows and builds upon the work of (Saeed & Parayno, 1993) in modelling the dynamics of indebtedness. This model however contributes to the literature by explicitly including the role of credit rating agencies and incorporating the dynamics of the evolution of default probabilities (PD) to impact the debt-deficit dynamics in a multi-period setting. Further, the incorporation of the probability of the default allows for the assessment of the impact of large but plausible changes in the macro-economic (and global) environment to be traced to the evaluation of the stability of the financial system.

The model consists of three actors: the government, the banking sector and a rating agency. Both the government and the banking sector are assumed to be bounded rational and backward looking while the 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 domestic banking sectors are backward looking and use heuristics to guide decisions regarding debt financing and portfolio allocation, respectively. In the model both the central government and 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 with it holds at any given time. More precisely, a bank will default if, and only if, two conditions hold,

(i) If the sovereign is deemed to have defaulted: PD > PD*

and

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

where the Credit Loss per Exposure (CLPE) is captured by:

$$CLPE = EAD \times LGD \times PD \quad (1)$$

and 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). Care must be taken in the interpretation of the term bank solvency used in this paper. Within this framework, the impact on the solvency of the banking sector is examined by assessing whether or not the sector has a sufficient stock of capital to absorb the credit-loss exposure arising out of an exogenous shock. The banking sector is therefore said to be solvent, if after accounting for the loss in credit arising

[4] See Appendix B for the Stock and Flow Diagrams associated with the behaviour of the three agents.

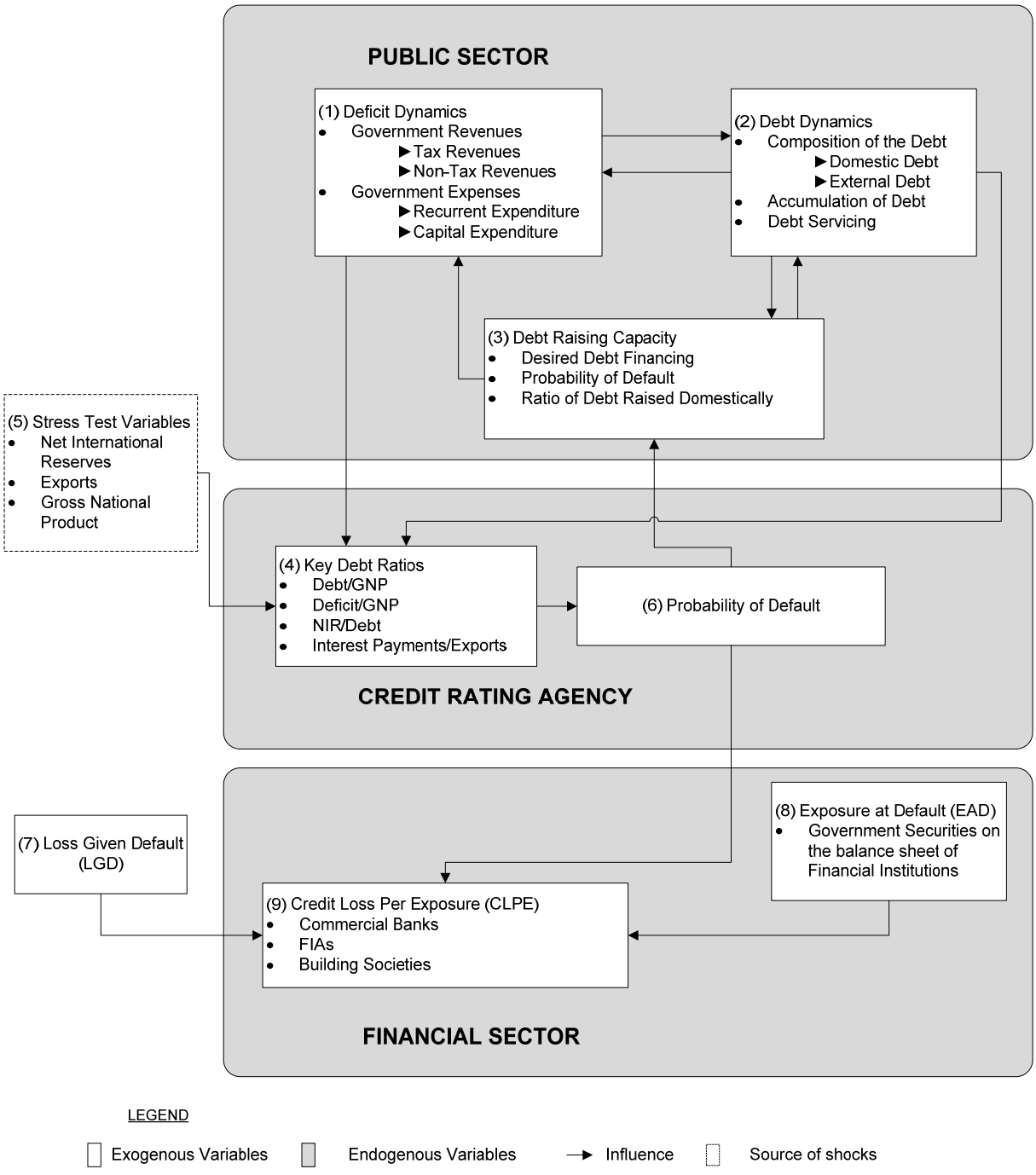
out of the risk exposure to public debt instruments, the stock of capital of the sector remains non-negative.

Thus, the approach taken in the evaluation of the impact of Jamaica's debt burden on the banking sector is consistent with the view that financial stability entails not only the ability of financial markets to allocate resources efficiently but also its ability to manage financial risks and absorb shocks.[5]

Both banks and the government interact via the domestic and international capital markets. The net result is the presence of persistent cycles of debt-deficit cycles on the part of government and local myopia on the part of the banking sector which results in the over-exposure the sector to sovereign credit risk on the ill-conceived assumption that each firm can liquidate their positions in the event of a crisis. This, however, does not hold in the event of a sovereign debt crisis since everyone cannot liquidate their positions simultaneously without having to absorb large haircuts on their positions.

[5] A limitation of the foregoing framework, however, is the evaluation of second-round effects between the real economy and the financial sector and its consequent impact on financial stability is outside the remit of the paper.

Figure 3. Model Overview



The central government makes decisions about the composition of the debt, the acquisition of financing capital, debt repayments as well as taxation. Modules (1) and (3), Deficit Dynamics and Debt Raising Capacity, both capture the Central Government's financing dynamics, whereas Module (2), Debt Dynamics, captures the debt accumulation process. The Central Government financing module (Module 1) includes variables which capture the rate at which the Government raises taxes and the factors which drive the evolution of recurrent expenditures. These three modules together capture endogenously the evolution of debt and deficits over time (see Figure 3).

The credit rating agency is assumed to analyze information from the central government performance (modules 1 and 2) along with other macro-economic variables (modules 5 and 6) and make assessments about the credit worthiness of the sovereign (PD). The Probability of Default (PD), module (6), accounts for the credit rating agencies assessment of the likelihood of default on public debt.

The banking sector makes decisions about the evolution of the banking sectors' balance sheet in relation to their holdings of government securities and all other assets. The banking sector is divided into three sectors: commercial banks, merchant banks and building societies (module 8).

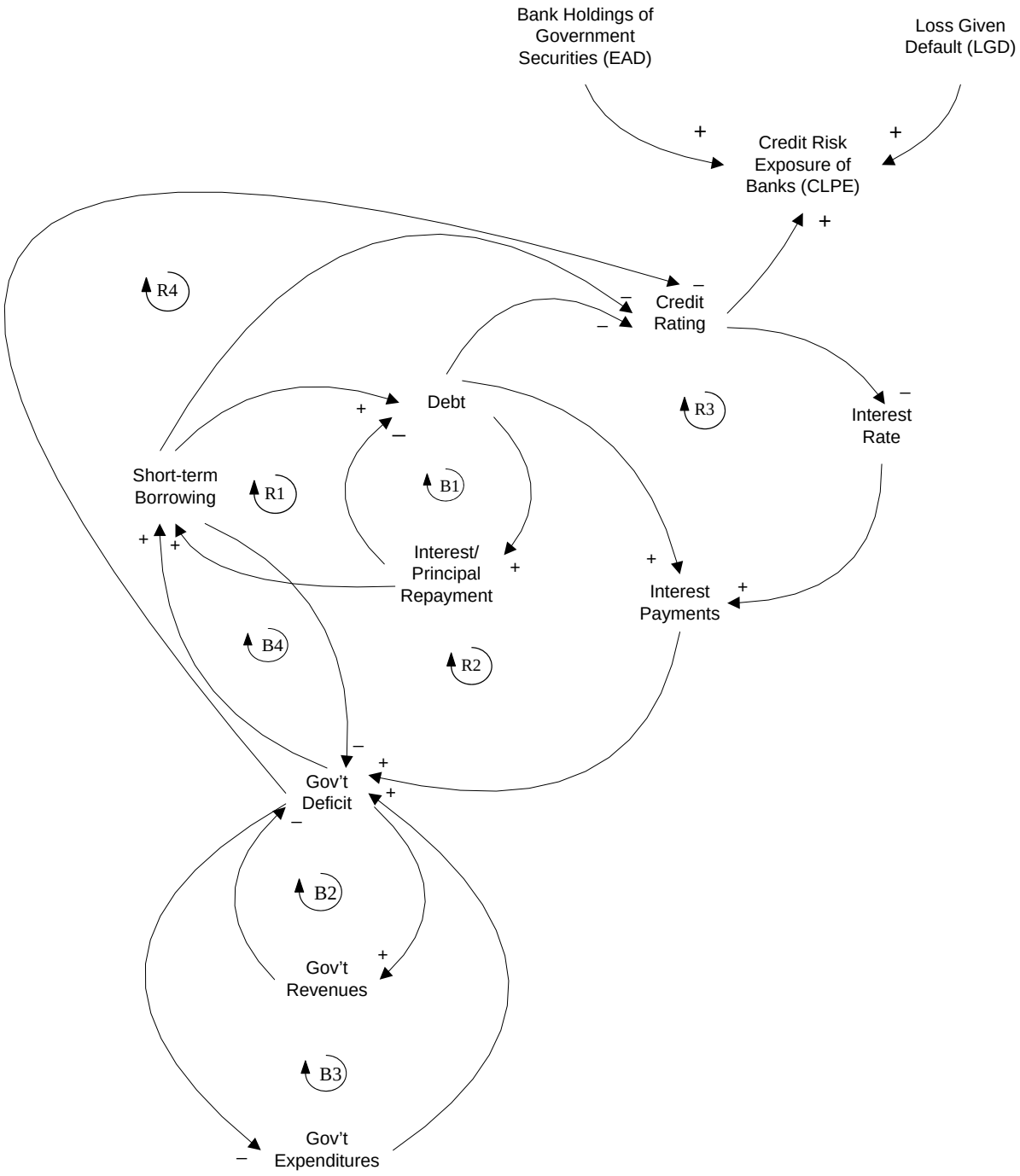
Finally, the economy is exposed to shocks from varying sources. These shocks include, but are not limited to, contingent liabilities of the government which materialize, sudden declines in gross national product and the country's net international reserves or export activities. Shocks in the framework are assumed to be exogenous and cannot be predicted by any agent. The shocks contemplated in this paper are the net international reserves (NIR) and exports (EXP).

2.2 Major Causal Loops: Model Dynamics

The process of persistent debt-deficit cycles is embodied in the positive reinforcing feedback loops shown in Figure 4. Debt increases through the acquisition of debt financing capital and the accrual of interest. As debt increases, debt service, consisting of principal and interest payments, rises while the consequent build-up of government expenditures draws down government money balances. If total expenditure is higher than total revenue, a budget deficit is generated which is covered by borrowing in both domestic and external capital markets. This, however, serves to increase the total stock of debt, closing the positive feedback loop, generating in this way an upward spiral or a 'snowball effect'. This dynamic is further exacerbated by the debt downgrades emanating from the credit rating agencies assessments of the deterioration in the debt-deficit dynamics.

Debt downgrades have two distinct channels through which they affect the debt-deficit dynamics. First, downgrades serve to increase the interest rate on new debt raised on the capital markets which serves to increase the debt stock as well as debt servicing costs which lead to further deterioration in budget deficit dynamics. Second, downgrades serve to encourage potential investors in the capital markets to lend short-term, rather than long-term, which while ameliorating the deterioration in the government money balance in the short-run, serves to increase the government's susceptibility to positive shocks in interest rates and roll-over risk in future periods.

Figure 4. Causal Loop Diagram



The debt growth process is constrained by several negative feedback loops, which are designed to equate government revenues and expenses. The payment of outstanding interest and capital amount decreases the debt, limiting the amount of subsequent payments, while acquisition of more financing capital increases government money balance, which decreases the need for more funds. Additionally, increasing government spending decreases government money balance to a level where it creates a pressure to limit government spending.

The sovereign credit risk exposure of banks increases with downgrade of the credit worthiness of the sovereign, the loss given default proportion and the size of the holdings of sovereign debt held by financial institutions in their investment portfolios.

Agent Behavioral Assumptions

2.3 The Central Government

The Debt Accumulation Process

The assessment of the domestic and external debt dynamics rests on the integration of the flow of net indebtedness over a multi-period horizon, taking into account the maturity of the debt structure, as well as the currency composition of the net flows. The debt dynamics are captured in equation (1) below

$$\frac{d}{dt}D_j = DAR_j + INT_j - AMORT_j - IREP_j \qquad j \in e, i \qquad (2)$$

where the stock of debt (denoted D_j) at any given point in time increases through the debt raising acquisition rate (DAR_j) and the accrual of interest payments due (INT_j) but decreases through the amortization of debt ($AMORT_j$) and payment of interest on debt outstanding ($IREP_j$) and notations e and i represent the external and domestic debt components , respectively.

The fraction of the total desired debt/deficit financing (DDF) that is met in the external capital markets is denoted as ρ, with the remaining fraction met within the domestic capital market. The fraction, ρ, decreases when the probability of default increases beyond a certain threshold value (i.e., $\rho'(PD) < 0$). Thus, the amount of debt financing that may be raised in the external capital markets at any given time is captured by equation (2)

$$DAR_e = \rho(PD) \times DDF \qquad (3)$$

and proportion of the debt financing t to be raised domestically would be given by:

$$DAR_i = [1 - \rho(PD)] \times DDF \quad (4)$$

Interest payments, ($IREP_j$) and interest accrued (INT_j) are calculated as a function of the current market interest rate (IR) and the average market interest rate (AIR), respectively, as well as the stock of existing debt:

$$INT_j = D_j \times IR_j, \quad j \in e, i \quad (5)$$

and

$$IREP_j = D_j \times AIR_j \quad j \in e, i \ (6)$$

Interest rates adjust over a period,IRAT, toward the indicated interest rate, IRR, where:

$$\frac{d}{dt} IR_j = \frac{IIR_j - IR}{IRAT} \quad (7)$$

and the indicated interest rate, IRR, reflecting the market adjusted rate on new debt issues as a function of the risk premium associated with the probability of default as well as the recent performance of the fiscal accounts (see Equation 8).

$$IIR_j = IIR_j \times \delta(\mathrm{PD}) \times \varphi(\mathrm{FP}) \ (8)$$

where the IIR is the initial interest rate and $\delta'(\mathrm{PD}) > 0$, $\varphi'(\mathrm{FP}) > 0$ indicating market rates are increasing functions of deteriorations in the ability of pay (credit risk) as well as well as roll-over risk. Both δ and φ , capture the impact of default risk and the roll-over premia on interest rates observed in the capital markets, respectively. That is, an increase in the interest rate will arise from both an increase in the probability of default and persistent deteriorations in the fiscal accounts which increases the roll-over risk of the government.

The level of amortization, ($\mathrm{AMORT_j}$), in any given period is impacted on by both the average maturity of the debt structure and the relative (un)attractiveness of the country's bond offers based on both the probability of default (an assessment of willingness and ability of pay), (PD), and the current fiscal performance relative to the historical outturn, (FP). Therefore an increase in the risk aversion of investors will arise from both an increase in the probability of default and persistent deteriorations in the fiscal accounts and will result in a decline in the maturity of debt stock. The level of amortization will then be given by equation (9) below:

$$AMORT_i = \frac{D}{ADM_J \times \alpha(PD) \times \tau(FP)} \quad j \in e, i \qquad (9)$$

where $\alpha'(PD)<0$, $\tau'(FP) < 0$, and ADM_j is the average maturity of debt structure.

The Deficit Dynamics

The government money balance (GMB) is calculated as the difference between cash outflows and inflows. Expenditure is composed of debt related expenditures (FIN) and non-debt related expenditure (NONFIN), while revenue is composed of tax revenue (T) and $\mathrm{DAR_j}$ given by:

$$\frac{d}{dt}\left[GMB_j\right] = TAX + DAR_j - FIN - NONFIN, \qquad j \in \{e, i\} \ (10)$$

Tax revenues are assumed to be an endogenous fraction of Gross National Product (GNP) and a tax net factor (λ) which grows as function of the relative performance of the government to

attain its desired government money balance. That is, tax compliance efforts decrease when $\lambda'(\text{GMB}|\text{DGMB}) > 1$, but increase otherwise.

$$\text{TAX} = \text{GNP} \times \text{FGNP}, \text{ where } \text{FGNP} = \text{FGNPI} \times \lambda(\text{GMB}|\text{DGMB}) \quad (11)$$

where FGNP and FGNPI are fractional Gross National Product tax and the initial level of fractional gross national product tax, respectively.

NONFIN, on the other hand, increases when $\phi(\text{GMB}|\text{DGMB}) > 1$, but decreases otherwise.

$$\text{NONFIN} = \text{NONFINI} \times \phi(\text{GMB}|\text{DGMB}) \quad (11)$$

where NONFINI denotes the initial level of non-debt related expenditure.

The Debt Raising Dynamics

The debt raising component of the framework forms the explicit link between the deficit dynamics and the debt dynamics since any shortfall in earnings from taxation and grants relative to expenditure has to be financed via borrowing. The desired debt financing (DDF) is assumed to be driven by the adjustment of current government money balance (GMB) towards the desired balance (DGMB) over a period, DFT. That is, the rate at which the GOJ is able to raise funds in the capital market (both domestic and foreign) is represented by an anchoring and adjustment process (equation (12)). The decision rule structures of GOJ borrowing are therefore, firmly grounded on the theory of bounded rationality developed by Cyert & March (1963) and explored in Georgantas (1990).

$$DDF = \frac{MAX[0,(DGMB-GMB)]}{DFT} \quad (12)$$

The DGMB is defined in terms of the desired coverage period for government funds, or GMBCP, and the projected government expenditure. The projected government expenditure per period, in turn, is the outcome of an exponential smoothing function, DELAYINF, and the period over with past expenditure is average, TAGE:

$$DGMB = DELAYINF(GOVEXP, TAGE) \times GMBCP \quad (13)$$

The behavioral equation (12) has three non-trivial implications. Firstly, it assumes that the government will not lend the surplus to another sovereign when it exceeds its desired government money balance target. Secondly, it will not use surplus funds to pay down on existing debt by calling bonds which it has floated in earlier periods. Thirdly, the government decision to raise finances in the capital market is not based on equation (10), as most standard economic frameworks would assert, but rather a backward looking heuristic which is anchored on what the government was able to spend in earlier periods. This particular decision rule, is central to the persistence of the debt-deficit cycle.

2.4 The Credit Rating Agency

In the model the PD is endogenized by the behaviour of the credit rating agency. The credit rating agency (CRA) is assumed to analyze information from the central government performance in order to make an assessment of the sovereign's ability to pay. A positive feedback loop exists between the performance of the government and the rating given by the CRA. Specifically, the probability of default (from the credit rating) affects the (i) currency composition of the debt (ii) the interest rate charged on new debt issued, (iii) and the maturity structure of the debt. In turn, the debt dynamics impacts the credit rating issued by the CRA. Thus, a feedback loop exists between the probability rating assigned by the CRA and ability of the government to raise capital on the international and domestic capital markets.

The rating agency in making its determination evaluates the evolution the sovereign's debt to GNP, deficit to GNP, the stock of NIR to debt stock, and debt service ratio. The expectations of the agency in relation to these indicators are as follows:-

- Total debt to GNP ratio (EDTGNP) - An increasing debt stock, compared to resource base (whether GDP, GNP or export earnings), increases the likelihood that the debt is unsustainable and, hence, default is more likely to occur.

- Net government deficit to GNP ratio (DEFGNP). This ratio measures the ability of a government to fund its activities from its own resources. If a government finds its growth in expenses outpacing the growth in the revenues, it is more likely to be hard-pressed to meet its debt-service obligations. Thus, the sovereign is more likely to experience debt repayment difficulties as its ratio of net government deficit to GDP rises.

- Reserves to debt stock ratio (RESEDT). Foreign reserves serve as a buffer against sudden adverse shocks and indicate the liquidity capacity of a sovereign borrower. A strong international reserve position shows the ability to respond to foreign currency demands in cases of adverse shocks. When reserves are high, it is likely that shocks to the economy can be addressed through a drawdown of reserves. The higher the ratio of foreign reserves to debt, therefore, the lower the probability of rescheduling.

- Interest payments to exports ratio (INTXGS) or the debt-service ratio. The higher the ratio of debt service to exports of goods and services, the greater will be the likelihood that in the event of a severe decline in export earnings the country will no longer be able to meet debt-service obligations.

The rating agencies assessment of the credit worthiness of the sovereign can be summarized in equation 14.

$$PD(t) = p(EDTGNP, DEFGNP, RESEDT, INTXGS) \qquad (14)$$

The agency also considers the reputation of the sovereign in relation to their history of debt servicing in their evaluation of credit worthiness.

2.5 The Banking Sector

The exposure of the banking sector to sovereign debt default occurs directly through the sector's holding of government securities. For this asset class, the banking sector agents are assumed to use 'pyramiding' rather than portfolio optimization techniques to determine their holdings of government securities.

The banking sector is disaggregated into three categories: commercial banks, FIAs and building societies. It is assumed that due to the large debt overhang and various regulations the decision by the banking sector to invest in government securities is based primarily on trends based on key performance indicators. As such, the future growth rates of Government securities (GS) as well as other assets (OA) on the balance sheets of the banking sector over time are assumed to be executed using trending techniques rather than portfolio optimization. The trend function, g * (t), is based on a behavioral theory of how agents form projections about the future path of key performance indicators. The g * (t) function involves three parameters, each the time constant of a first-order exponential smoothing process. The function is given by:

$$g^*(t) = g(TPPC, THRC, TPT) \qquad (15)$$

where g * (t) is expected fractional growth rate of the input variable, TPPC is the time to perceive the present condition, THRC is the time horizon for the reference condition, and TPT is the time to perceive the trend. The evolution of GS and OA on the balance sheets of banks, and consequently banks' exposure to default risk are captured by extrapolating the perceived present condition (PPC) using the expected growth rate, g * (t) , over a one year forecast horizon (FH).

$$GS^*(t) = PPC(t) \times [1 + TPPC \times g^*(t)] \times \exp(FH \times g^*(t)) \qquad (16)$$

and,

$$OA^*(t) = PPC(t) \times [1 + TPPC \times g^*(t)] \times \exp(FH \times g^*(t)) \qquad (17)$$

In the next section, we ask the question "Can the aforementioned theoretical model explain the e stylized facts observed in the data?"

3.0 CALIBRATION OF THE MODEL

3.1 Data used in the calibration of the System Dynamics Model[6]

[6]The exchange rate has been included in order to allow currency conversion between US dollars (USD) and Jamaica Dollars. The debt incurred from the resuscitation of the financial sector following the 1996 banking sector crisis ("Finsac debt") is also included as an exogenous variable, accounting for the incremental build-up of GOJ debt.

Multiple data sources were used to develop and test the debt dynamics model for Jamaica. The main sources of numerical data to test and calibrate the model were accessed from the Ministry of Finance (MOF). This data included total public debt, domestic debt, and external medium- and long-term public debt. Data on Central Government financing between were sourced from the Fiscal and Economic Programme Monitoring Department of the Bank of Jamaica (BOJ). Aggregate levels of Government securities and total assets for commercial banks, FIAs, and building societies were sourced from the Financial Institution Supervisory Division (BOJ). Data on net international reserves and exports, over the review period, were sourced from the BOJ. Data on gross national product were sourced from the Statistical Institute of Jamaica (STATIN). The simulation period used for calibrating and testing the model dynamics is FY 1997/8 to FY 2003/4. The period of simulation allows for the execution of a behaviour reproduction test of debt dynamics between the period 1997/8 and 2003/4, as well as the utilization of the model as an early warning system for banking sector insolvency for the period covering FY 2004/5 to FY 2009/10.

3.2 Calibration of the SD Model

Before stress-tests are conducted, the SD model is initialized to represent the conditions of Jamaica in 1997. The relationships between the simulation model and historical time-series data are evaluated on three levels in the process of calibration:

- At the highest level, the structure (equations) of the model is evaluated on the basis of their correlation with the dynamic behaviour of the corresponding real-world system.
- At the intermediate level, limited attention is paid to the particular values of the parameters used in the system dynamics model, and instead much emphasis is placed on the behaviour patterns and modes of the data generated by the model, such as, exponential growth and oscillation. The behaviour of the model (output) is compared to the implied behaviour of the system (given the underlying equations of the model) as a means to verify the internal consistency of the model.
- At the lowest level, the time-series output produced by the model are compared with the associated historical time-series data identified in section 2.1. The parameters of the model are solved iteratively using the Monte Carlo technique which provides a relatively robust solution for inter-temporal analytical models of this nature. (See Figure 5).

3.3 Data used in the Calibration of the Credit Rating Agency Decisions

A logit (credit risk) model of GOJ debt default is estimated to capture the credit rating agency's assessment of sovereign default risk. To apply the logit model to the estimation of rescheduling probabilities, annual time series data for thirty-four developing countries were compiled for the period 1986 to 2003. The countries in our sample are Algeria, Argentina, Bolivia, Brazil, Chile, China, Colombia, Costa Rica, Cote D'lvoire, Dominican Republic, Ecuador, Egypt, India, Indonesia, Jamaica, Kenya, South Korea, Malaysia, Mexico, Morocco, Nicaragua, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Sri Lanka, Sudan, Thailand, Tunisia, Turkey, Uruguay and Venezuela. In summary, there were 110 observations of a rescheduling event, which make up 27 per cent of total observations. Out of the thirty-four countries that are selected for this study, twenty-four are middle income countries and the remaining ten are low income

countries as categorized by the World Bank country classification list (See Appendix A: Table 1). The estimation of default probability is conducted by taking the thirty-four countries covered in the 2010 issue of the World Bank's Global Development Finance on CD-ROM, the most comprehensive database on external indebtedness of development countries. Data on the amount of debt rescheduled, interest payments on debt, exports of goods and services, gross national product are captured from this source. Data on fiscal deficits/surpluses are taken from the IMF's International Financial Statistics on CD-ROM.

3.4.The Logit Model

This paper uses a panel logit model to estimate default probabilities (PDs) of 34 emerging market countries between 1986 and 2003 as a function of macro-economic variables. This is then used in the system dynamics model as an estimate of the probability of default. Following the examples in the literature, a binary choice reduced-form (logit) model that expresses the probability of default as a function of various default determinants of ability to pay is estimated. The logit model is a multivariate regression analysis technique, which is used primarily to make predictions in dichotomous situations. Once the logistic function has been estimated from historical data, new data can be substituted into the function to forecast the probability that a country will experience debt payment difficulties.

The underlying logit model of the present study assumes that the probability of rescheduling (P_i) can be estimated as:

$$Prob(d_i = 1) = Prob(\varepsilon_{it} < a + b'x_{it}) = \frac{\exp(\alpha+\beta' x_{it})}{1+\exp(\alpha+\beta' x_{it})} \qquad (18)$$

where the individual P_i's are not observed but information on whether a given country rescheduled its foreign debt payment is observed and the vector of economic indicators is represented by x_{it}. The measured dependent variable, Y_i, equals one if a country rescheduled its foreign debt payments and zero, otherwise.

The binary choice model is derived in the following steps. Consider a random sample of N emerging market countries (or sovereigns), where i = 1,…..,N . Each sovereign i is observed over T periods, t = 1,……,T . Assume that there exists an unobservable (continuous random) variable,y^*_{it}, which indicates whether sovereign i defaults in year t. Assume, further, that this unobservable indicator, y^*_{it} , is a linear function of a vector of k (exogenous) determinants, x_{it} , and a constant a and a random error term,ε_{it}:

$$y^*_{it} = a + b'x_{it} + \varepsilon_{it} \quad (19)$$

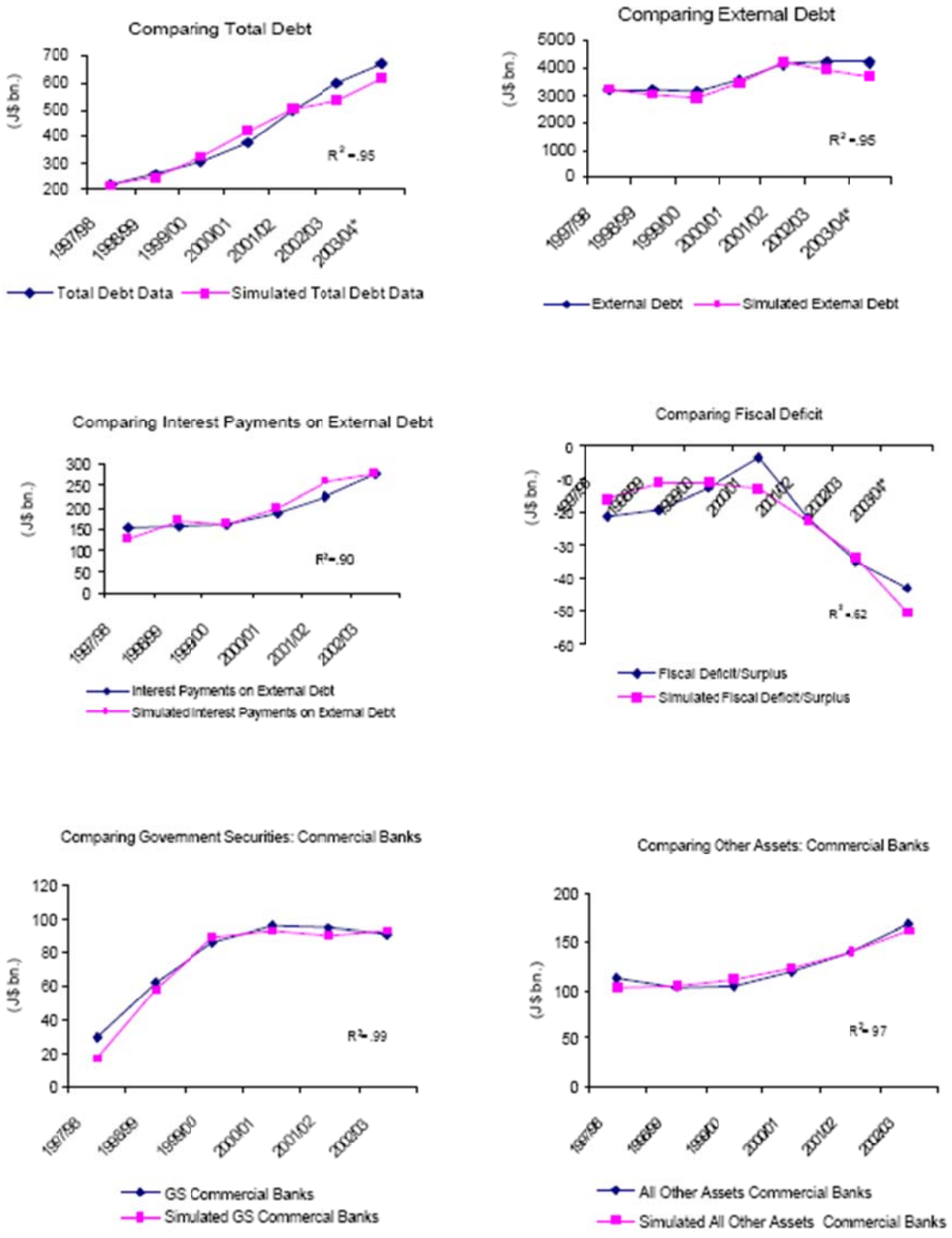
where b is a $k \times 1$vector of parameters.

It is assumed that all ε_{it} are independent and identically distributed (according to a logistic distribution) across countries and over time and have zero mean and unit variance, i.e., $\varepsilon_{it} \sim \Lambda[0,1]$ for all i and t .

The logistic cumulative distribution function (CDF) has the following form:

$$\Lambda(X) = \frac{\exp\left(\frac{\pi}{\sqrt{3}}\frac{X-\mu}{\sigma}\right)}{1+\exp\left(\frac{\pi}{\sqrt{3}}\frac{X-\mu}{\sigma}\right)} \quad (20)$$

Figure 5. Actual and Simulated Debt and Banking Sector Dynamics



Next, it is assumed that a country defaults if the unobservable default indicator is greater than one, i.e. if $y^*_{it} > 0$, and that it does not if $y^*_{it} \leq 0$, where

$$d_{it} = \begin{cases} 1 & y^*_{it} > 0 \\ 0 & y^*_{it} \leq 0 \end{cases}$$

The indicator function above allows for the introduction of the binary dependent variable into the model. Thus, the probability of observing a sovereign default in year t is:

$$Prob(d_{it} = 1) = Prob\left(y^*_{it} > 0\right) = Prob(a + b'x_{it} + \varepsilon_{it} > 0)$$

$$= \text{Prob}(\varepsilon_{it} < a + b'x_{it})$$

Using the equation above and given the symmetric property of the logistic distribution function, the probability of sovereign default is given by equation 20. That is, for each, country i, the vector of (country-specific) explanatory variables in year t, and the explanatory variables in x_{it} determine the probability of default. On the other hand, the probability of no sovereign default is:

$$Prob(d_{it} = 0) = 1 - Prob(\varepsilon_{it} < a + b'x_{it}) = \frac{1}{1 + \exp(\alpha + \beta' x_{it})}$$

The objective is therefore to find the parameter estimators of α and β which make it most likely that the pattern of choices in the sample would have occurred. When using the logit model with individual observations the most suitable estimation is that of maximum likelihood. All parameter estimates are consistent, asymptotically efficient and normal.

Similar to other empirical studies, this study adopts the view that the demand for rescheduling or debt restructuring represents a debt repayment problem for a country. More specifically, this paper considers an emerging market sovereign (i.e. a government) as having defaulted on its debt obligations if its rescheduling ratio in any given year is equal to or in excess of three per cent. Debt rescheduling (TREDT) amounts to a rearrangement that usually involves an extension or stretching out of the original repayment schedule with respect to a particular debt. Thus, a country's government default risk is measured by using country debt rescheduling risk as a proxy. Five indicators of debt servicing capacity are used in the estimation of the probability of default. Also, the lagged dependent variable (L3TREDT) is a dummy variable which takes a value of 1 if the country had defaulted over the past three years and 0, otherwise. As such, this variable can also be interpreted as an indicator of repayment over the recent past. Once a debtor country suffers a debt crisis and reschedules its debt, it will probably find itself in difficulty to service the future debt obligations in the following years. In such situations debtors will also have difficulties to obtain new credits from international creditors. Therefore, a dummy variable that takes the value of 1 if the country defaulted over the preceding 3 years and 0 otherwise is included in the model.

3.5. Probability of Default Estimation Results

The parameter estimates of the logit model are shown in Table 4 of Appendix A. The signs of the parameters are in line with model predictions. The likelihood ratio (LR) statistic and the z-statistics indicate that all the explanatory variables are jointly and also individually statistically significant. All the variables used to estimate the event of a debt rescheduling are found to be at least statistically significant at the 10 percent level. The most statistically significant variable is the lagged dependent variable (L3TREDT). This result confirms the findings of earlier studies which find that state dependence appears to be very important in the case of sovereign defaults. That is, even after controlling for other economic determinants, emerging market countries that defaulted in the recent past are more likely to default in the near future than non-defaulting countries. The 'fit' of the empirical model is most favorable when the model classifies a larger percentage of debt defaults and non-defaults correctly (in sample). The "percent of correct classifications" (82.0 per cent) indicate that the model fits the data very well. When the estimated model parameters were used to calculate the associated default probabilities, all countries for which the model predicts a default probability of 15.0 per cent or higher were classified as defaults and all predicted probabilities that are lower were classified as non-defaults. In 82.0 per cent of all cases the model predicts the outcomes that have been actually observed. Type 1 errors are classifications where countries actually defaulted but the model predicts a default probability of less than 15 per cent ("not predicted defaults"), whereas Type II are cases where countries have a predicted probability above 15 per cent but did not default in reality ("false alarms"). The percentage of Type 1 errors (i.e. actual defaults classified by the model as non-defaults) and the percentage of Type II errors (i.e. actual non-defaults classified by the model) are both very low at 17.2 per cent and 14.9 per cent, respectively. The performance of the logit model for period 2001, 2002 and 2003 are also satisfactory and are documented in Table 6.2 of Appendix A. Column 2 of Table 4 (Appendix A) reports the marginal effects for each explanatory variable.

4.0 STRESS TESTS

Best practice guidelines suggest that stress tests should (1) measure the effect of only large moves in risk factors because day-to-day risk management takes care of small moves (2) the appropriateness of a stress test should be driven by current positions and concentration risk by financial institutions as well as prevailing economic and political factors, and (3) stress test should be accompanied by a clear set of plans of remedial action. For comparative purposes each stress test is executed against a baseline scenario. In the baseline case, the NIR is assumed to remain at an average of US$1 450 million between FY 2004/5 and FY 2009/10. Additionally the external debt interest ratio declines from 7.1 per cent for FY 2004/05 to 4.1 per cent for FY 2009/10. The impact of these scenarios on the probability of default, credit loss per exposure (i.e. the exposure of the financial sector to default in public debt), as well as the solvency of the financial sector are displayed as the 'base case' in each stress test.

Briefly, however, the baseline scenario shows the PD ratio well below the default threshold of 15 per cent, and declining steadily from 5 per cent for FY 2004/5 to 0.7 per cent in FY 2009/10. Consequently, the credit loss per exposure remains marginal for the banking sector.

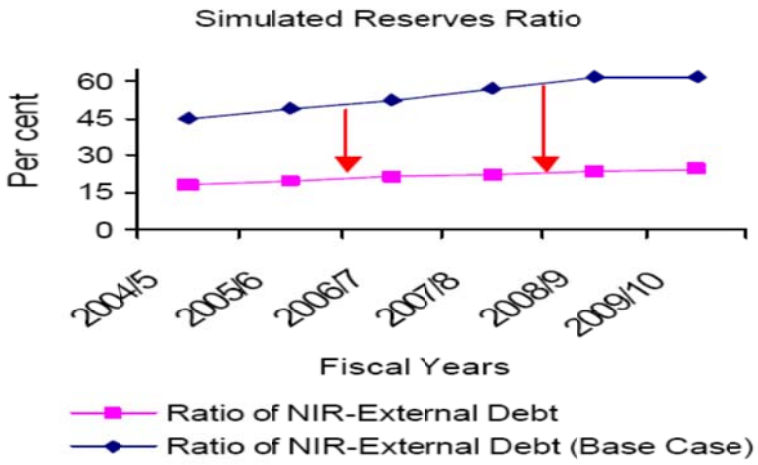
4.1 Stress Test – Net International Reserves

The stress test on the reserves ratio examines the impact of a decline in the NIR to US$ 600 million in FY 2004/5, which is maintained until FY 2009/10. This is equivalent to downward

shift, from the baseline ratio, of the reserves ratio to 19 per cent in 2004/5 and grows marginally to 24 per cent in FY 2009/10. Preliminary tests suggest that such a shock would increase the probability of default by 4 percentage points for FY 2004/5 to 9 per cent. The probability of default would continue to increase until FY 2006/7 when it would have crossed the default threshold of 15 per cent. Under this scenario, the default probability for FY 2009/10 would be 24 per cent. The results of the univariate analysis of the impact of the reserves ratio on the probability of default are summarized graphic ally in Figure 5. As shown, the time-path of the PD indicates a significant increase in the likelihood of a default given the threshold of 15 per cent. Interestingly, under this scenario, the deterioration in the NIR would result in a significant increase in likelihood of default which would take place even where all the other key debt performance indicators were improving. More specifically, external debt ratio would improve by 10 percentage points to 33 per cent, and the external debt interest ratio would deteriorate marginally by 1.5 percentage point to 9 per cent by FY 2009/10. 40 Additionally, the increase in the probability of default would occur in spite of a 22 percentage point decline in the total debt ratio to 134 per cent at the end of FY 2008/9.

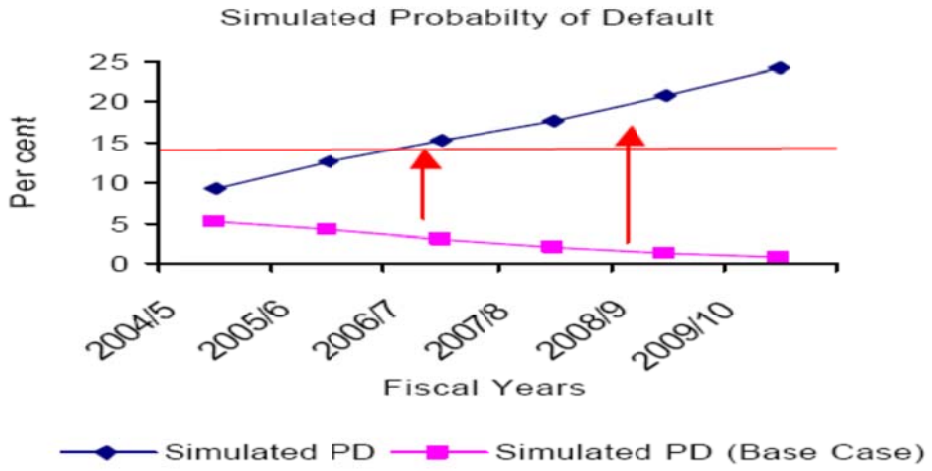
The estimated credit loss per exposure for commercial banks and FIAs is estimated at J$ 19 876 million and J$ 4 685 million, respectively, as at 2006/7 and J$ 59 432 million and J$ 18 628 million, respectively, at the end of FY2009/10. In both cases, the losses in credit arising out of the shock to the NIR would be in excess of the existing stock of capital for these institutions, and insolvency of both commercial banks and FIAs would be estimated at the end of FY 2007/8 (See Figure 6). Under this scenario, building societies would remain solvent and have sufficient capital to cover their exposure to an explicit default in public debt.

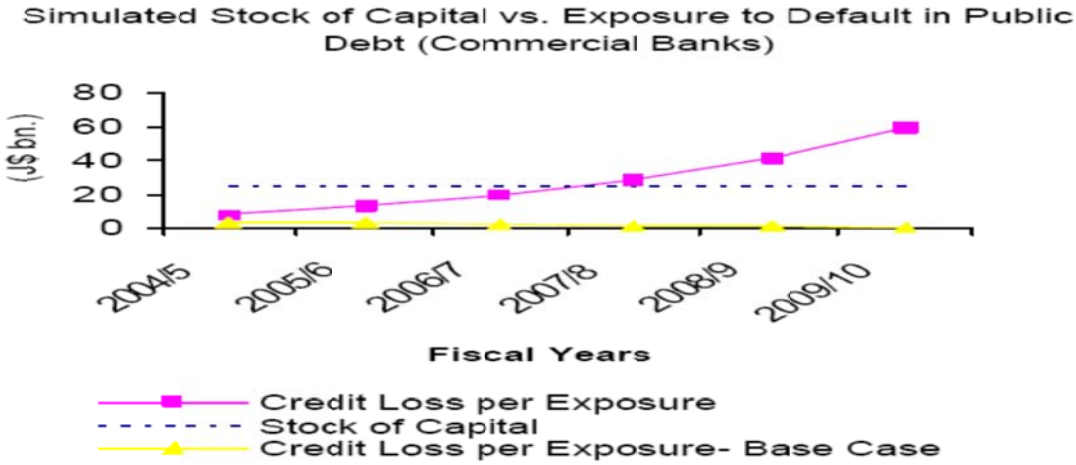
FIGURE 6 STRESS TEST SHOCK TO NIR: UNIVARIATE ANALYSIS[7]

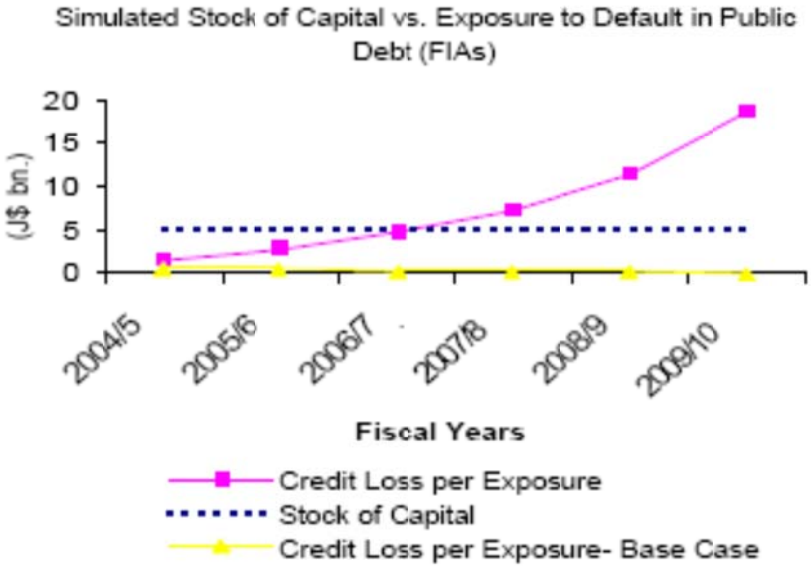


[7] Loss given Default is assumed to be 70 per cent.

4.2


Simulated Probabilty of Default
Per cent
25
20
15
10
5
0
2004/5
2005/6
2006/7
2007/8
2008/9
2009/10
Fiscal Years
Simulated PD
Simulated PD (Base Case)


Simulated Stock of Capital vs. Exposure to Default in Public Debt (Commercial Banks)
(U$ bn.)
80
60
40
20
0
2004/5
2005/6
2006/7
2007/8
2008/9
2009/10
Fiscal Years
Credit Loss per Exposure
Stock of Capital
Credit Loss per Exposure- Base Case

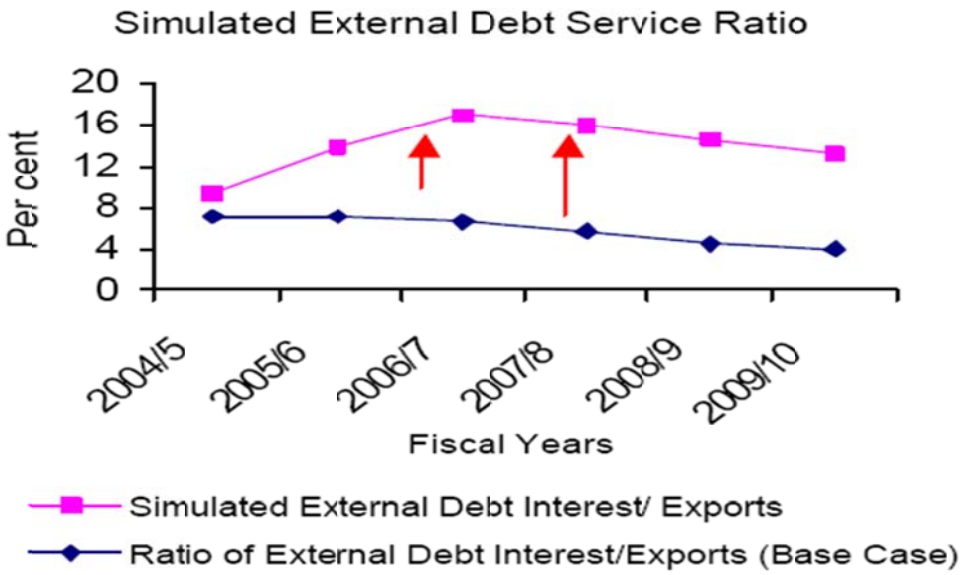

Simulated Stock of Capital vs. Exposure to Default in Public Debt (FIAs)
(U$ bn.)
20
15
10
5
0
2004/5
2005/6
2006/7
2007/8
2008/9
2009/10
Fiscal Years
Credit Loss per Exposure
Stock of Capital
Credit Loss per Exposure- Base Case

Stress Test- Debt Service Ratio

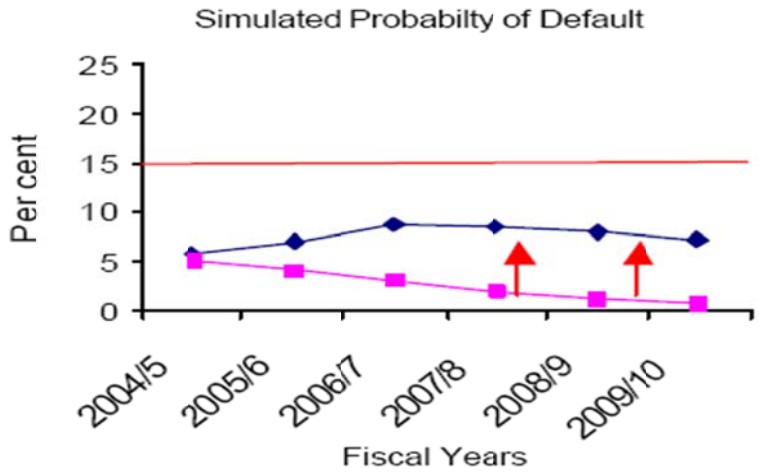
The stress test experiment performed on the external debt service ratio was examined by exploring the impact of a sustained decline in exports over the forecast period FY2004/5 to FY2006/7. The impact of a decline in exports over the period under examination would be a cumulative increase in the debt interest ratio of 8 percentage points to 17 per cent at 2006/7. Preliminary tests suggest that such a shock would increase the probability of default by 3 percentage points. This would be equivalent to an estimated probability of default of 9.0 per cent at the end of FY2006/7.42 Under this scenario, the deterioration in the probability of default would take place where external debt ratio improved to 39.0 per cent, total debt improved to 134.0 per cent and the reserves ratio improved to 51.0 per cent by fiscal 2006/7.[8]

The estimated credit loss per exposure for commercial banks and FIAs and building societies is estimated at $ 11 165 million and $ 2 632 million, respectively, at the end of FY2005/6. As shown graphically in Figure 7, the exposure of the commercial banking sector to a shock in the external debt interest ratio would not be in excess of the existing stock of capital. On the other hand, the FIA sector however would be deemed insolvent at the end of FY 200/10. As in the case for the stress test of NIR on building societies, preliminary results suggest that building societies would remain solvent.

FIGURE 7 STRESS TEST SHOCK TO EXPORTS: UNIVARIATE ANALYSIS



[8] However, it should be noted that the probability of default would remain below the default threshold of 15 per cent under this particular stress-test.



Simulated Stock of Capital vs. Exposure to Default in Public Debt

(Commercial Banks)

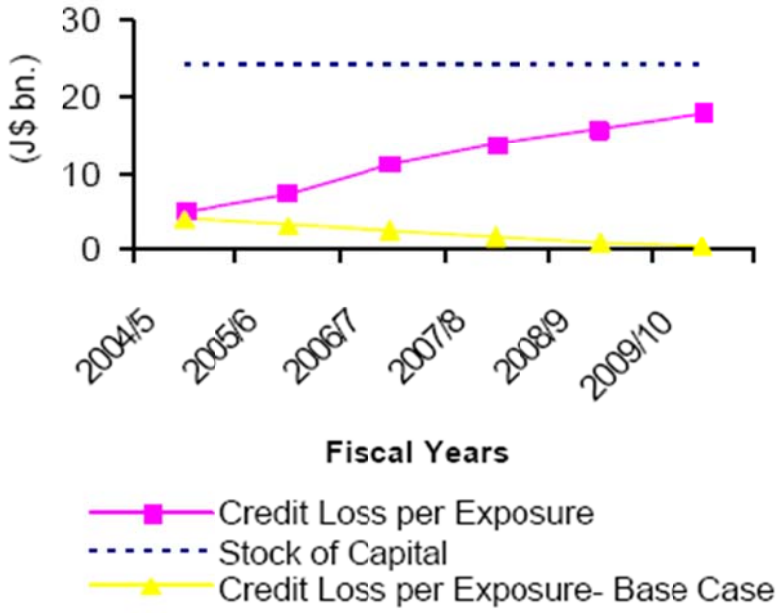
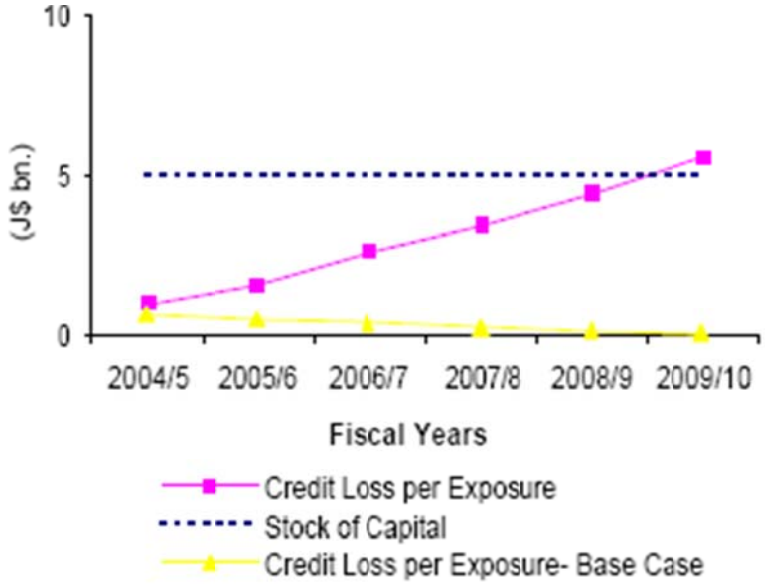


FIGURE 7 (Continued) STRESS TEST SHOCK TO EXPORTS: UNIVARIATE ANALYSIS

Simulated Stock of Capital vs. Exposure to Default in Public Debt (FIAs)



5.0 DISCUSSION AND CONCLUSION

This paper explored, using counterfactual analysis, the potential for banking sector insolvency given various stress tests over the period 2004/5 – 2009/10. The analysis underscores the high level of vulnerability of the banking sector to negative shocks in the net international reserves (NIR) and exports. Specifically, a sharp drawdown in the stock of NIR, against the backdrop of inadequate fiscal adjustments, would serve to increase the vulnerability of Jamaica to domestic shocks (for example those impacting the country's ability to export) or external shocks (such as those which limit the ability of the country to earn and retain foreign reserves).

This exposure is credited to the banking sector's increasing susceptibility to the default of GOJ debt given the large volume of Government securities on their balance sheets. The immediate market-oriented policy inference would involve the gradual easing of monetary policy which would facilitate greater diversification of the asset base of the banking sector. However, in the absence of fiscal discipline and should there be a shock to investor confidence which would precipitate a more restrictive monetary policy stance, this approach would serve only to increase the vulnerability of the financial sector to sovereign credit risk. Additionally, finance theory would predict that greater diversification (i.e. reduction in concentration risk for the banking sector) would result in a lower return on investments, discouraging banks from diversifying out of their own free will regardless of the time path of interest rates.

From this vantage point, central banks or regulatory authorities could impose exposure limits to banks' public debt holdings, for example, along the lines of the large exposure rules which are currently enforced for lending to the private sector in some jurisdictions, that is, consider imposing a limit on the ratio of government securities to assets on the balance sheet of financial institutions. Alternately, central banks/regulatory authorities could require financial institutions to hold additional stocks of capital to buffer against the increased likelihood of default in sovereign debt instruments, by increasing the risk weighting of such instruments. Such a regulation would serve to simultaneously increase the diversification of banking sector portfolios, and catalyze the banking sector's role of financial intermediation. In the case of Jamaica, the latter approach was applied following the successful implementation of the Jamaica Debt Exchange ("JDX") and the signing of a stand-by agreement with the IMF in January 2010.

Several other insights may be gleaned from the stress-testing framework. First, a reduction in the total debt stock is a necessary but insufficient condition of debt sustainability. Second, the finding that the process of debt stock management is longer and more complex when the size of the debt is large. In such instances an orderly and transparent debt restricting programme should be contemplated with holders of these debt instruments.

The analysis further underlines the importance of taking the necessary fiscal and monetary adjustments necessary to encourage a minimization of default probability. Failure to do so implies that the economy may be confronted with severe borrowing restrictions on the one hand, or unsustainably high borrowing cost domestically and otherwise, on the other hand. This result suggests that the typical emerging market government has a strong incentive:

- to keep a good track record as a borrower, i.e. not to default on external debt obligations
- to limit the speed with which it accumulates external liabilities
- to keep a cushion of international reserves to act as a buffer to external and unforeseen
- shocks to the economy
- to make the fiscal adjustments necessary to gain credibility in the market so as to lengthen the maturity structure of its domestic debt and foment the gradual and sustainable decline in interest rates
- to engage in the pro-active identification of contingency sources of financing for the central government in the event of an unanticipated shock in the domestic or international capital markets.

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APPENDIX A.

Table 1

Sample Countries

	COUNTRIES	By Income	By Location	By Indebtedness
1	ALGERIA	Middle	Africa	Severely Indebted
2	ARGENTINA	Middle	America	Severely Indebted
3	BOLIVIA	Middle	America	Severely Indebted
4	BRAZIL	Middle	America	Severely Indebted
5	CHILE	Middle	America	Severely Indebted
6	CHINA	Low	Asia	Low Debt
7	COLOMBIA	Middle	America	Moderately Indebted
8	COSTA RICA	Middle	America	Moderately Indebted
9	COT'S IVORY	Middle	Africa	Severely Indebted
10	DOMINICAN REP.	Middle	America	Moderately Indebted
11	ECUADOR	Middle	America	Severely Indebted
12	EGYPT	Low	Africa	Severely Indebted
13	INDIA	Low	Asia	Moderately Indebted
14	INDONESIA	Low	Asia	Moderately Indebted
15	JAMAICA	Middle	America	Severely Indebted
16	KENYA	Low	Africa	Severely Indebted
17	KOREA, SOUTH	Middle	Asia	Low Debt
18	MALAYSIA	Middle	Asia	Low Debt
19	MEXICO	Middle	America	Severely Indebted
20	MOROCCO	Middle	Africa	Severely Indebted
21	NICARAGUA	Low	America	Low Debt
22	NIGERIA	Low	Africa	Severely Indebted
23	PAKISTAN	Low	Asia	Moderately Indebted
24	PANAMA	Middle	America	Severely Indebted
25	PARAGUAY	Middle	America	Low Debt
26	PERU	Middle	America	Severely Indebted
27	PHILIPPINES	Middle	Asia	Moderately Indebted
28	SRI LANKA	Low	Asia	Low Debt
29	SUDAN	Low	Africa	Severely Indebted
30	THAILAND	Middle	Asia	Low Debt
31	TUNISIA	Middle	Africa	Moderately Indebted
32	TURKEY	Middle	Europe	Moderately Indebted
33	URUGUAY	Middle	America	Moderately Indebted
34	VENEZUELA	Middle	America	Moderately Indebted

Source: THE WORLD BANK, World Debt Tables

- Classification of the sample countries is made according to World Bank Classification Tables given in World Bank Debt Tables.
- According to the Bank, a country will be in the severely indebted countries group if one of the key debt ratios is above critical level. These ratios and their critical levels are present value of debt service to GNP and present value of debt service to exports of goods and services. Their critical levels are 80 per cent and 200 per cent respectively. The critical levels of the same ratios are 48-80 per cent and 132 – 220 percent for moderately indebted countries.

Table 2

Variables and Definitions

Variables	Definitions
EDT Total debt Stock	Sum of public and publicly guaranteed long-term external debt, private non-guaranteed long-term debt, the use of IMF credit, and short-term debt (estimated).
INT Interest Payments	Actual amounts of interest paid in foreign currency, goods, or services in the year specified
XGS Exports	Exports of goods and services in the year specified
RES International Reserves	The sum of a country's monetary authority's holdings of special drawing rights (SDRs), its reserve position in the IMF, its holdings of foreign exchange, and its holdings of gold (valued at year-end London prices)
TREDT Debt Stock Rescheduled	Amount of debt outstanding rescheduled in any given year
L3TREDT Dummy Variable for history of rescheduling	That is, we include a dummy variable that takes the value of 1 if the country defaulted over the preceding 3 years and 0 otherwise.
DEF Deficit	Net government deficit to GNP ratio is a measure of the ability of a government to fund its activities from its own resources.

Table 3

Indicators of Country Rescheduling Risk and Expected Coefficient Signs

Ratio of Deficit to GNP	DEFGNP	+
Ratio of Total Debt Stock to GNP	EDTGNP	+
Ratio of interest payments on external debt to export	INTXGS	+
Dummy Variable for history of rescheduling	L3TREDT	+
Ratio of reserves to total debt	RESEDT	-

Table 4

Dependent Variable: Rescheduling Event (TREDT)

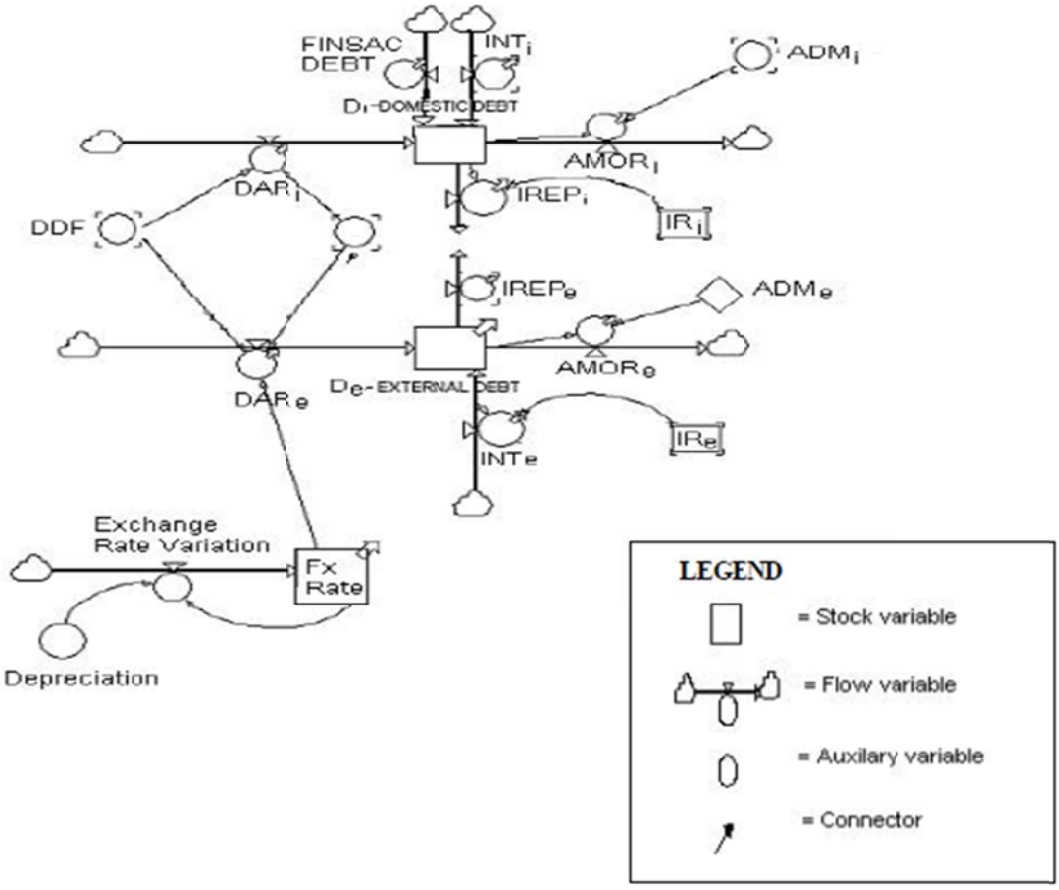
Explanatory Variables	(1) Coefficient (z-statistics)		(2) Marginal Effects [a] $(\partial P / \partial x_i)$
CONSTANT	-3.2198	***	n.a.
	(-4.87)		
DEFGNP	9.950	***	1.23
	(2.70)		
EDTGNP	0.8045	**	0.10
	(2.00)		
INTXGS	5.366	*	0.67
	(1.76)		
L3TREDT	3.3932	***	0.056
	(9.66)		
RESEDT	-2.282	*	-0.28
	(-1.86)		
McFadden R-squared	0.41		
S.E. of Regression	0.33		
Akaike info criterion	0.71		
LR Statistic	196.50		
P-value of LR Stat	0.000		
Observations	399		
Per cent correct classifications	82.7 %		
Per cent Type I errors	17.2 %		
Per cent Type II errors	14.9 %		
Obs with Dep = 0	289		
Obs with Dep = 1	110		
Mean dep. var	0.27		

Notes:
Estimation Method: Maximum Likelihood – Binary Logit. Zstatistic (in parentheses) are derived using robust (QML) (Huber/White) standard errors. Significance at 10%, 5% and 1 % are denoted by *, **, and ***, respectively.

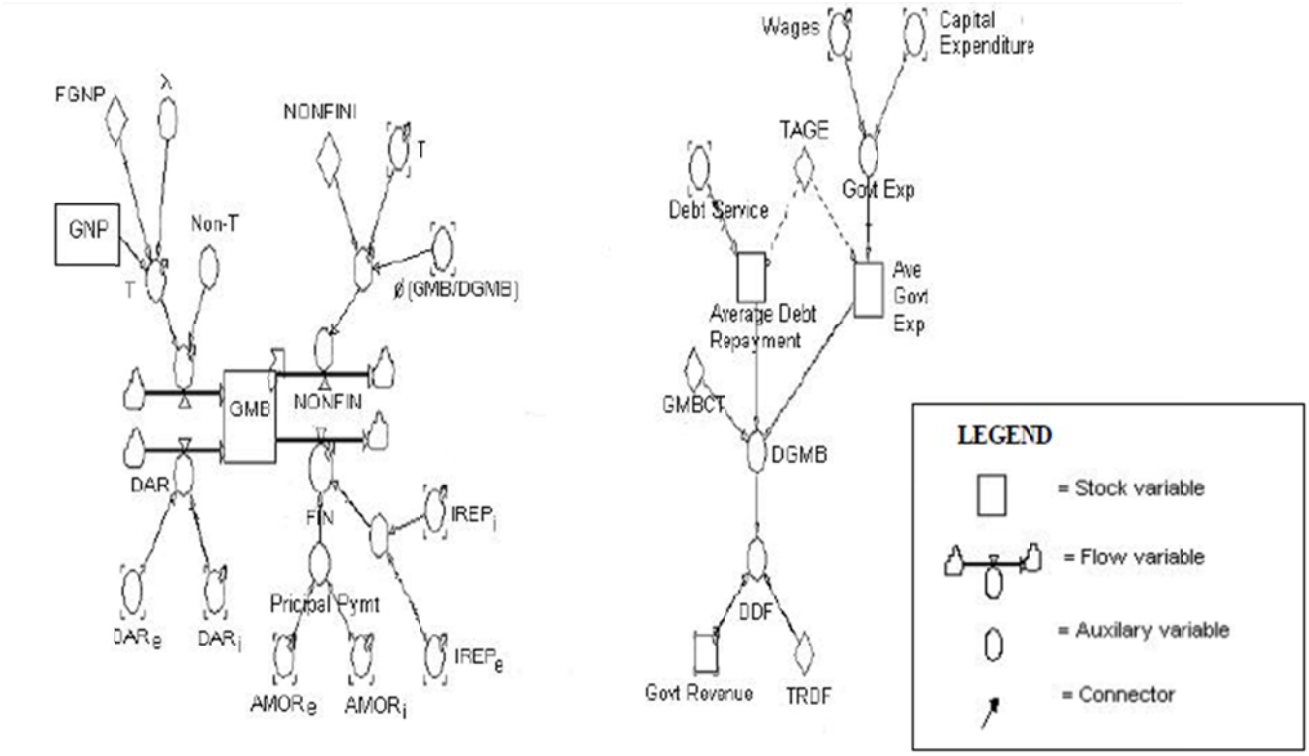
(b) Marginal effects are calculated at the sample means of the explanatory variables except for the dummy L3TREDT (default over the past three years). As suggested by Greene (2000, p. 817), this marginal effect is calculated as the default probability when L3TREDT = 1 minus the default probability when L3TREDT = 0, the other explanatory variables being equal to their sample means.

APPENDIX B.

DEBT DYNAMICS MODULE



DEFICIT DYNAMICS MODULE



CREDIT RATING AGENCY MODULE