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A Computable General Equilibrium (CGE) Model of Banking System Stability: Case of Jamaica

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Abstract

This paper applies a computable general equilibrium (CGE) framework to the evaluation of financial stability of the banking sector in Jamaica. This CGE framework, which follows the work of Goodhart *et al.* (Ann Fin 2, 1-21, 2006b), incorporates heterogeneous banks and capital requirements with incomplete markets, money and default. Further, agents in the model interact in several financial markets, including credit, deposit and interbank markets in an infinite horizon setting. The model is calibrated to conform to time-series data of Jamaica's banking system between 2005 and 2008 and can be readily used to assess financial fragility given its flexibility, computability and the presence of multiple contagion channels.

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[1] The views expressed in this paper are those of the author and do not necessarily reflect the view of the Bank of Jamaica. Author E-Mail Address: Jide.Lewis@boj.org.jm

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I.   INTRODUCTION

A major cause of systemic problems within the financial system is the contagious interaction between individual participants, in particular banks. This interaction can have many channels, for example: via direct counterparty effects; distressed institution sales causing the market value of other agent's assets to decline, credit-crunches in lending promulgating economic recessions and leading to institution failures elsewhere in the economy (Goodhart (2005)).

Most mainstream macroeconomic frameworks are based on an implausible assumption that no economic agent ever defaults (Bardsen et. al (2006)). While this assumption enormously simplifies macroeconomic modelling by allowing for the use of representative agents, it paves the way for macroeconomic analyses and policy prescriptions which are inherently flawed. This flaw which has become even more pronounced against the backdrop of the current global economic and financial crisis. One approach taken over the last decade to tackle the limitations of current frameworks has been to employ the use of stress or scenario tests to evaluate the robustness of the balance sheet and P&Ls of financial institutions to large but probable shocks. However, these approaches capture, at best, only the first rounds effect of the shock and are often unable to detect possible contagion arising from the initial shock.

In order to develop an empirically tractable assessment of the risks of contagion, some key characteristics that macroeconomic frameworks should capture include an endogenous risk of default, explicit roles for money, banks and liquidity as well structural micro-foundations (see Goodhart (2005)). Endogenously generated defaults are important since if all pay-offs were certain then everyone would repay all their debts in full. Hence, everyone would borrow or lend, without credit risk. Indeed, there would be no need for financial intermediaries, such as banks, whose role is predicated on their capacity to evaluate credit risk, on the one hand, and maintain customer's faith in their own credit worthiness, on the other. Additionally, if all banks are assumed within the framework to be identical, then there would never have an incentive to trade with each other. Since

direct interactions between banks in the interbank market, are often viewed as a key channel of financial contagion, the assumption that the banking system can be modelled as consisting of one representative bank, excludes a main potential channel of contagious interaction.

The organization of the paper is as follows. The next section, **Section II**, presents a brief survey of the bank stability/fragility literature. **Section III** presents the CGE framework. **Section IV** will discuss the approaches employed to calibrate the model to the Jamaican data. **Section V** contains the results and the conclusion is given in **Section VI,** with key policy implications.

II.   LITERATURE REVIEW

In the study of financial stability, researchers have employed two broad approaches each with its own sets of advantages and limitations. The first approach involves estimating the likelihood of defaults for individual banks or even systemic financial crises arising from fluctuations in a set of predetermined variables. This approach has the advantage of congruence with the data, which is important from a surveillance perspective, but is subject to the Lucas critique.[2] The other approach, establishes frameworks based on optimizing micro-foundations. However, such models require simplifying assumptions that are extreme and may typically have less congruence with the data. Indeed, these two approaches can be thought of as existing along of continuum rather than as being discretely independent concepts/approaches.

An Overview of Empirical Frameworks

Empirical studies such as Gavin and Hausman (1996) and Sachs, Tornell, and Velasco (1996) show that some key macroeconomic parameters act as key indicators of an impending banking crisis. For example, credit growth, equity price declines as well as the

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[2] For example, regularities may breakdown as the policy regime changes such that the model fits the historical data but is unable to detect future episodes of crisis.

ratio of broad money to foreign exchange reserves have been identified as critical variables in the evaluation banking sector vulnerabilities.

Honohan (1997) uses event study analysis to determine the importance of key factors in the predictions of a banking crisis. The study revealed several bank-specific factors which have preceded banking crises. In particular, he showed that banking crises were associated with a higher loan-to-deposit ratio, a higher foreign borrowing-to-deposit ratio, and higher growth rate of credit. Also, a high level of lending to government and central bank lending to the banking system were associated with crises related to government intervention.

Other papers, Crochektt (1997), Gonzalez-Hermosillo (1999) and International Monetary Fund (1998) show that the amount of non-performing loans increases markedly before and during a crisis, and bank profitability falls. These approaches encourage the evaluation of financial stability issues along continuum of possible contingent states, as apposed to polar or binary evaluations of what constituted a financial crisis. Analyzing financial stability along a continuum implies that crisis prevention policies may be applied before an actual crisis materializes. As such, these approaches have lent themselves to the development of Early Warning Systems (EWS).

The relatively small number of bank failures has, in large measure, constrained researchers to use pooled data, over several years and several countries. However, by omitting critical time-varying factors, this research has failed to capture the underlying dynamics of the failure/survival process. That is, the process by which a bank repositions their portfolios and lending strategies to respond to contemporaneous economic and industry conditions. Also, the conventional EWS design for bank failure, which by virtue of its binary formulation (i.e. fail/ non-fail), is not able to capture the underlying dynamics of the failure/survival process. As such, although these models tend to perform well at classifying banks within sample, they generally perform poorly, at best, out of sample. Furthermore, not all methods or techniques that are used with cross-section data work well with time-series/cross section data (see Glenon et. al. (2003)).

An overview of Theoretical Frameworks

At the theoretical end-of the spectrum, a plethora of models, primarily game-theoretic in a nature were developed in over the last decade. Most of them depend on assumptions of asymmetric information and some type of moral hazard. Allen and Gale (1998), for example, propose a framework where uncertainty is generated by lack of knowledge about when depositors may need to withdraw their money from the bank. This risk is exacerbated by the illiquidity of (some of) the bank's assets. Early redemption of an illiquid asset in the case of run can only be done at a cost. So much so, that the bank may not be able to honour its pledge to redeem all its deposits (plus stated interest) at par. Because of the sequential repayment convention, when the probability of failure to repay rises above some small probability, a run ensues and the bank(s) default. Morris and Shin (2000), on the other hand, suggested an argument stemming from co-ordination failure and switching strategies that offers an explanation for some of the recent currency crises.

Other theoretical approaches, consider defaults as arising from declines in the value of bank assets, e.g. arising from credit or market risk. The uncertainty in these approaches specifically concerns the value of bank assets, and as such captures insolvency rather than illiquidity.[3] Suarez and Sussman (2007), for example, investigate the dynamic implications of financial distress and bankruptcy law. The effect of liquidations on the price of capital goods, due to financial imperfections, generates endogenous cycles. In addition, the amplitude of the cycle in the long run depends on the nature of the bankruptcy law.

Akram *et al.* (2007) evaluate two main approaches to pursue financial stability within a flexible inflation-targeting regime. Their results suggest that the potential gains from an activist or precautionary approach to promoting financial stability are highly shock dependent. They conclude that the preferred target horizon depends on the financial stability indicator and the shock. However, an extension of the target horizon in order to

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[3] Of course, these two - insolvency and illiquidity, go hand in hand, since depositors will flee, and potential lenders will refrain, from a bank perceived as potentially in trouble.

improve financial stability may contribute to relatively higher variation in inflation and output. These findings are significant in so far as most policy recommendations concerning the pros and cons of inflation targeting tend to omit the evaluation of the trade-offs that are involved in pursuing the twin objectives of Central Banks of price stability and financial stability.

Several factors can be put forward as limiting the performance of these theoretical frameworks. However, from a bank surveillance perspective, the chief drawback would be that almost all of these models have not been calibrated or tested with real data (e.g. Allen and Gale (1998)). This paper, which lies more along the theoretical end of the spectrum, presents a model of financial fragility, calibrated against banking sector data in Jamaica. The paper details the performance of a general equilibrium model of the banking system with heterogeneous investors and banks, incomplete markets, and endogenous default.

III.   CGE FRAMEWORK FOR BANKING FRAGILITY

The model was designed following closely the work by Tsomocos (2003a) and Goodhart et. al. (2006b). The model incorporates financial interactions among three heterogeneous banks $b \in B = \{\gamma, \delta, \tau\}$, four private sector agents $h \in H = \{\alpha^{\gamma}, \beta^{\delta}, \theta^{\tau}, \phi\}$, a regulator and a central bank (see **Figure 1**).

The time horizon is infinite $T = \{0,1......\infty\}$, and at each future date there are two possible states of nature $s \in S = \{i, ii\}$. State i is a normal /good state while state ii represents an extreme/crisis event. At time $t \in T$, the probability that state s = i will happen at t+1 is denoted by p. This probability is assumed to be known by all agents and constant over time. Each bank at $t \in T$ maximizes its expected profit taking into consideration the immediate future.[4],[5] Additionally, the bank manager has the alternative of leaving the

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[4] See objective function in next section.
[5] At the end of time t the bank maximizes its expected profits for time t+1, and the expectation is taken over two possible states of nature.

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bank for better contracts elsewhere if he has attained profitability above a certain benchmark. In other words, he has an opportunity cost for working in the bank and, under certain conditions, the manager will maximize the expected profits over a finite horizon. In other words, the manager will be approached by other financial institutions and be offered a better contract if his existing bank's level of profits is higher than a benchmark level, which is defined as $\bar{\pi}$. That is, in period t+i, if $\bar{\pi}_{t+i}$ is greater than or equal to the benchmark level, $\pi_{t+i} > \bar{\pi}$, the manager will leave the bank at the end of the period for a better contract. However if $\bar{\pi}_{t+i}$ is less than the benchmark level, $\pi_{t+i} < \bar{\pi}$, he will remain with the bank. Therefore, the manager's discount factor associated with the period $t+i$ can be described as

$$\beta^{t+i} = \frac{\beta^{t+i}}{(\bar{\pi} - \bar{\pi}_{t+i})} \max[(\bar{\pi} - \bar{\pi}_{t+i}), 0]$$

Arising from the existence of distinct, i.e. heterogeneous banks, each characterized by a unique risk/return preference, it follows that there is more than one market for bank loans and deposits. Agents in the model interact in several financial markets, including a credit, deposit and an interbank market (cf. **Figure 1**). Specifically, at the beginning of each period, bank borrowers are assigned to borrow from a single bank, by information constraints or history. For each bank there exists a credit market in which the bank and its client interact: households α, β and θ borrow from banks γ, δ and τ, respectively. The agent ϕ represents the pool of depositors in the economy. Each bank in its respective deposit market interacts with the agent ϕ, who supplies funds to the banking system.

Multiple credit and deposit markets, which are characterized by limited participation, lead to different loan rates amongst various banks and to endogenous credit spreads between loan and deposit rates. There also exists an interbank market in which banks

may borrow from/lend to each other. It is this market the central bank conducts open market operations (OMOs). [6]

The time structure of the model is shown in **Figure 2**. By the end of period t, deposit markets, credit market, and the interbank market open simultaneously. Each bank decides rationally how much credit to offer and the amount of deposits it demands from the respective markets, forming expectations over the two possible future states of nature. Banks also trade among themselves, to smooth out their individual portfolio positions. Meanwhile, households borrow from, or deposit money with banks, mainly to achieve a preferred time path for consumption. Finally, the central bank conducts open market operations to influence the money supply and thereby determine the official interest rate.

At the beginning of period t+1, one of the possible states $s \in S = \{i, ii\}$ occurs. Where according to which state s happens, the financial contracts signed in the previous period are settled and some level of default may occur. Banks are subject to default and capital requirements' violation penalties are applied where applicable. Given this, bank profits are realized, after which all markets re-open.

IV. THE BANKING FRAGILITY CGE MODEL
Domestic Banking sector

The banking sector comprises of three heterogeneous banks, $b \in B = \{\gamma, \delta, \tau\}$, representing, in the Jamaican case, commercial banks, merchant banks and building societies, respectively. Each sector is distinguished by its unique portfolio deriving from different capital endowments and risk return preferences. The asset side of their balance sheets consists of loans, interbank lending, and investments, while liabilities include deposits, interbank borrowings, other liabilities and capital. Banks borrow from the non-bank private sector by way of deposits and from each other and the central bank via the interbank market. They also extend credit to the private sector and hold a diversified

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[6] It is assumed, however, that a single interest rate clears the interbank market.

Figure 1. Block structure of model showing agent/market interactions

Figure 2. Time structure of model

t+2...

t+1

t

Policy rules
are defined

Nature chooses the state
s є S according to a
distribution f(s)

Markets open
simultaneously:
 - Interbank Market
 - Credit Markets
 - Deposit Markets

Markets re-open

- Settlements of deposits and
credit are carried out.
- Defualt may appear in all markets
- Penalties on violation of CAR and
  default

Given all transactions, bank benefits are calculated
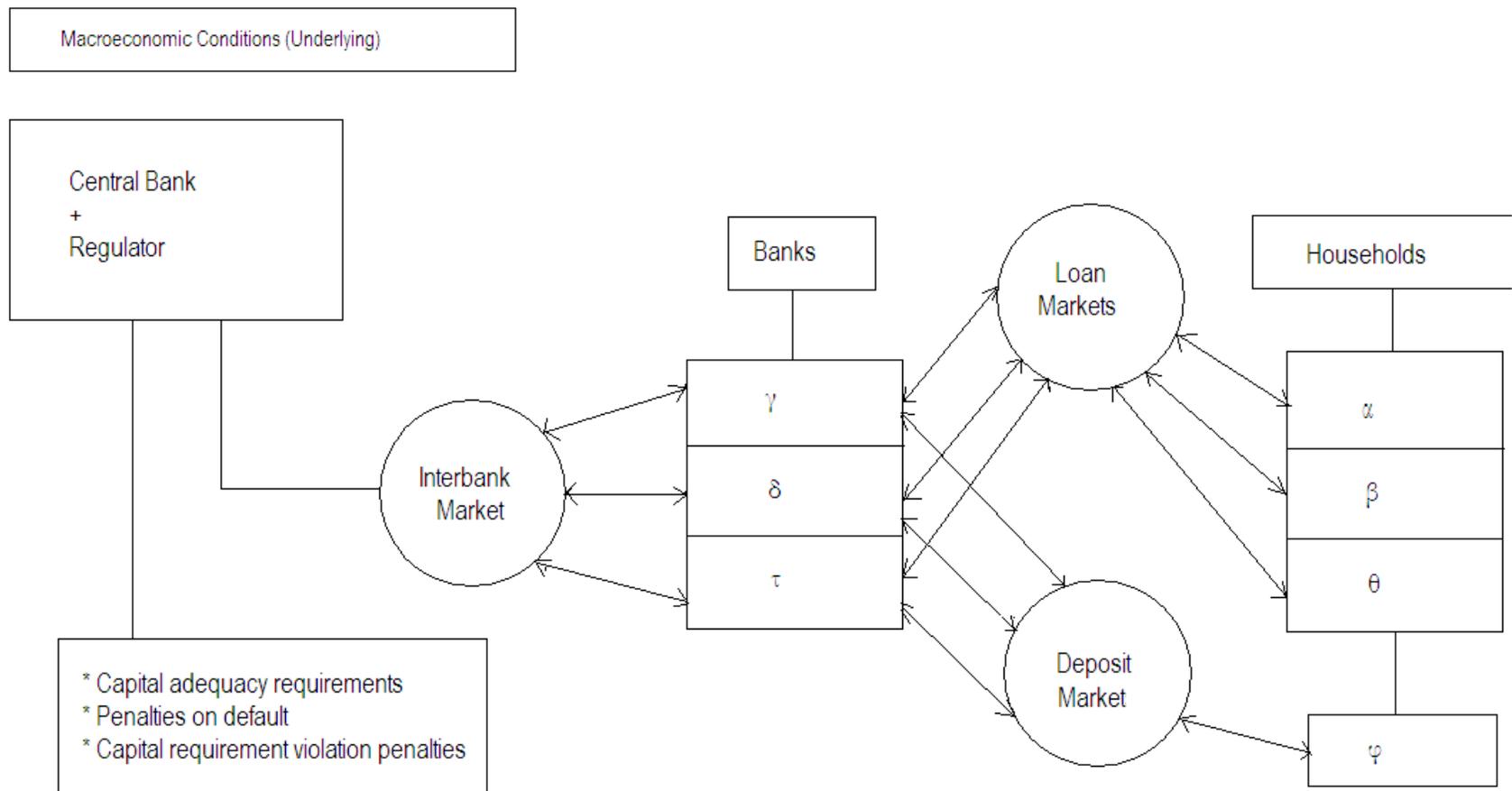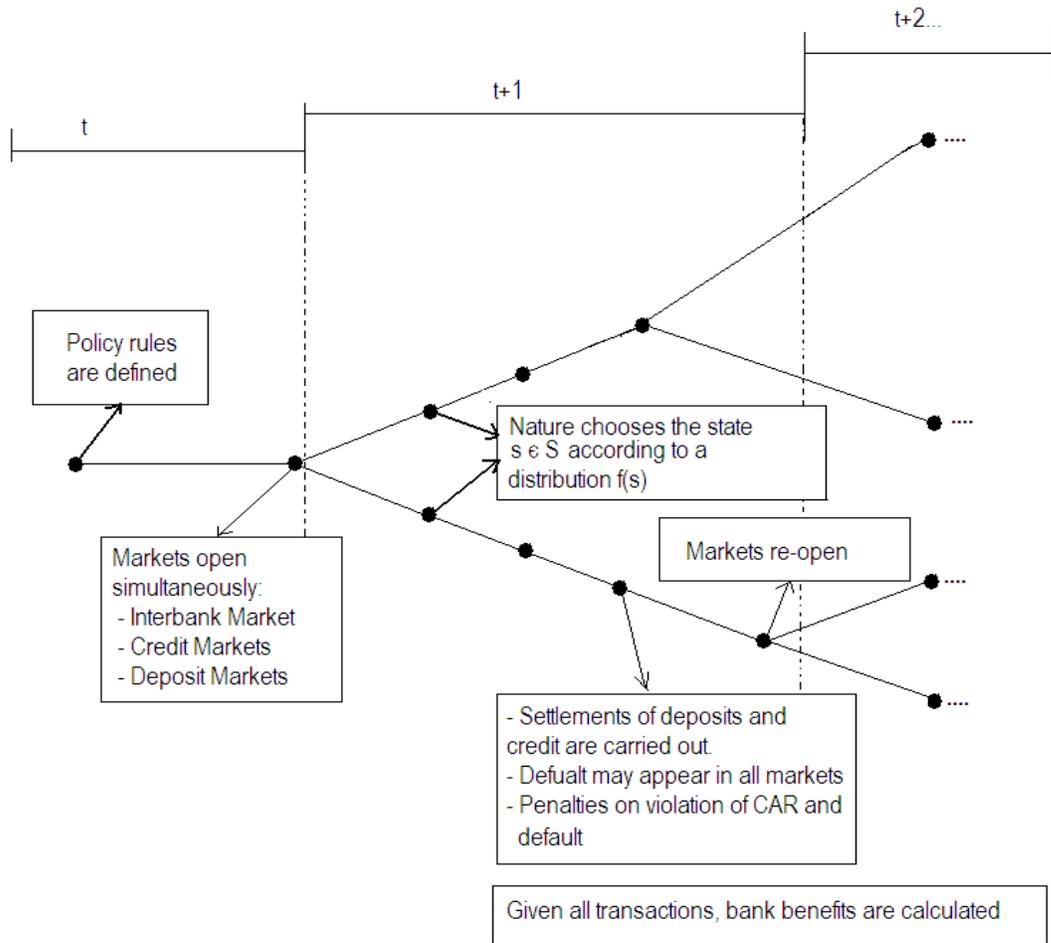
portfolio of securities. Further, all banks in the model, $b \in B = \{\gamma, \delta, \tau\}$, are assumed to operate in a perfectly competitive environment and therefore take all interest rates as exogenously given when making their optimal portfolio decisions.

Bank's optimization problem

In each period $t \in \{0,....,\infty\}$, the bank $b \in B$ maximizes its expected payoff, which is a quadratic function of its expected profitability in the next period (t+1), minus penalties that it has to incur if it defaults on its deposit and interbank obligations. Also, banks that violate their capital adequacy constraint are penalized in proportion to the shortfall of capital.[7] Expectation is taken rationally over two possible states of nature in period $t+1$. That is, each bank forms its expectations rationally, considering two possible states of nature $s \in S = \{i - normal, ii - extreme\}$. Bank b decides how much credit to offer at time t $(\overline{m}_t^b)$, the amount of deposit it seeks $(\mu_{d,t}^b)$, its interbank lending (d_t^b), and its interbank debt (μ_t^b). Bank $b \in B$ also decides endogenously the repayment rate for t+1 $(\upsilon_{t+1,s}^b, s \in S)$.

Formally, the optimization problem of bank b in period t is:

$$\underset{\overline{m}_t, \mu_t^b, d_t^b, \mu_{d,t}^b, \upsilon_{t+1,s}^b, s \in S}{\max} \quad E_t(\prod{}_{t+1}^b) = \sum_{s \in S} p_s \left[\frac{\pi_{t+1,s}^b}{10^{10}} - c_s^b \left(\frac{\pi_{t+1,s}^b}{10^{10}} \right)^2 \right]$$

$$- \sum_{s \in S} p_s \left[\lambda_{ks}^b \max[0, \overline{k}_{t+1,s}^b - k_{t+1,s}^b] + \frac{\lambda_s^b}{10^{10}}[\mu_t^b - \upsilon_{t+1,s}^b \mu_t^b] + \frac{\lambda_s^b}{10^{10}}[\mu_{d,t}^b - \upsilon_{t+1,s}^b \mu_{d,t}^b] \right] \quad (1)$$

Subject to balance sheet constraint:
$$\overline{m}_t^b + d_t^b + A_t^b = \frac{\mu_t^b}{(1 + \rho_t)} + \frac{\mu_{d,t}^b}{(1 + r_{d,t}^b)} + e_t^b + Others{}_t^b \quad (2)$$

and subject to positive expected profitability:
$$(1 + \rho_t)\upsilon_{t+1,s}^b \mu_{d,t}^b + (1 + r_{d,t}^b)\upsilon_{t+1,s}^b \mu_{d,s}^b + Others{}_t^b + e_t^b \leq$$
$$\upsilon_{t+1,s}^{h^b}(1 + r_{d,t}^b)\overline{m}_t^b + (1 + r_t^A)A_t^b + \widetilde{R}_{t+1,s}d_t^b(1 + \rho_t), \quad s \in S \quad (3)$$

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[7] This way of modeling default was first introduced by Shubik and Wilson (1977).

where profits are defined as

$$\pi_{t+1,s} = v_{t+1,s}^{h^b}(1 + r_{d,t}^b)\overline{m}_t^b + (1 + r_t^A)A_t^b + \widetilde{R}_{t+1,s}d_t^b(1 + \rho_t) - ((1 + \rho_t)\upsilon_{t+1,s}^b\mu_d^b$$
$$+ (1 + r_{d,t}^b)\upsilon_{t+1,s}^b\mu_{d,s}^b + others_t^b + e_t^b), s \in S \quad (4)$$

the evolution of capital is modeled as

$$e_{t+1,s} = e_t^b + \pi_{t+1,s}^b, \quad s \in S \quad (5).$$

and the capital adequacy ratio is defined by:

$$k_{t+1,s}^b = \frac{e_{t+1,s}^b}{\overline{\omega}v_{t+1,s}^{h^b}(1+r_t^b)\overline{m}_t^b + \widetilde{\omega}(1+r_t^A)A_t^b + \omega\widetilde{R}_{t+1,s}d_t^b(1+\rho_t)}, \quad s \in S \quad (6)$$

Where

Assets

$\overline{m}_t^b$: amount of credit that bank b offers in the period t

A_t^b : bank b's investments

d_t^b : bank b's interbank lendings

Liabilities

$\mu_{d,t}^b$: bank b's deposits

μ_t^b : bank b's debt in the interbank market in period t

e_t^b : bank b's capital

Default Metrics

$\upsilon_{t+1,s}^b$: repayment rate of bank b in t+1,s

$v_{t+1,s}^{h^b}$: repayment rate of h_t^b in t+1, s

$\widetilde{R}_{t+1,s}$: repayment rate expected by banks from their interbank lending in t+1

$k_{t+1,s}^{b}$: Capital adequacy ratio

Interest Rates

r_{t}^{b} :   lending rate offered by b

$r_{d,t}^{b}$:   deposit rate offered by b

ρ_{t} :   interbank rate in period t

Miscellaneous

p: probability that state $s \in S$ occurs in t+1

c_{s}^{b} : risk aversion coefficient in the utility function

Equation (2) implies that , at the end of period t, the assets of bank $b \in B$, which consists of its credit extension, interbank lending, and market book investments, must be equal to its liabilities obtained from interbank and deposit borrowing and its equity, where 'Others' represents the residual. Equations (3) shows that banks will only conduct activities if it expects positive profits, dependent on which of the $s \in S$ actually occurs. As expected, the profit that bank b incurs in the next period is equal to the difference between the amount of money that it receives from its asset-side investments and the amount that it has to repay on its liabilities, adjusted appropriately for default in each market as captured in equation (4). As shown in equation (5), capital is endogenised in the model by adding profits earned in each period t to its initial capital, which in turn becomes its capital in period t+1. Finally, equation (6) implies that the capital to asset ratio of bank b in period t+1 is state $s \in S$ occurs is equal to the corresponding ratio of capital to risk-weighted assets.

Central bank and regulator

In this framework, both regulatory and monetary policies are non-neutral.[8] Monetary and regulatory policies influence the distribution of income and wealth amongst heterogeneous agents and hence have real effects. The central bank controls the overall liquidity of the economy and determines interest rates.[9] The central bank conducts monetary policy by conducting open market operations (OMOs) in the interbank market. In each period, the central bank sets the level of the policy rate (ρ_t). By this, it can either supply base money $M_t \geq 0$, or issue government bonds, $\bar{B} \geq 0_t$ but not both at the same time, to clear the interbank market.

The central bank, operating as the regulator, also sets the capital adequacy requirements in state $s \in S$ of the next period for all banks ($(\bar{k}^b_{t+1,,s}, b \in B)$ as well as imposes penalties on their failures to meet such requirements $\lambda^b_{ks}, b \in B, s \in S$. The central bank also sets the risk weights on loans, interbank and book investments $(\overline{\omega}, \omega, \widetilde{\omega})$.

Private agent sector

In each period, household borrower $h^b, h^b \in H^b = \{\alpha^\gamma, \beta^\delta, \theta^\tau\}$, demands consumer loans for bank b and chooses the default rate on his loans for each of the two possible states, $s \in S$, in the next period. Given that participation in the credit market is assumed to be limited, each household's demand for loans in period t is a negative function of the lending rate offered by their 'nature' selected bank. The forth agent, Mr. ϕ, supplies his deposits to each bank $b \in B$. Following, Goodhart *et al.* (2006b), the behavior of these agents are endogenised by assuming the following reduced-form equations.

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[8] The Central bank and the regulator may, but need not, be a single institution. In Jamaica, both functions are carried out by the Bank of Jamaica.
[9] The nominal interest rate is equal to the real interest rate plus the expected rate of inflation.

Household borrowers' demand for loans

The following functional form for household's loan demand is assumed to be dependent on the future evolution of GDP and bank sector loan rates [r_t^b]. That is, each household's demand for loans is a negative function of the lending rates. In addition, their demand for loans also depends positively on the expected GDP in the subsequent period. Thus in each period t from his nature-selected bank b, $\forall h^b \in H^b$, and $b \in B$ each household determines its demand for loans: [10]

$$\ln(\mu_t^{h^b}) = a_{h^b,2} trend + a_{h^b,3} \ln[p(GDP_{t+1,i}) + (1-p)GDP_{t+1,ii}] + a_{h^b,4} r_t^b \quad (6)$$

where,

$\mu_t^{h^b}$ = amount of money that agent $h^b \in H^b$ chooses to owe in the loan market of bank $b \in B$ in period t

$GDP_{t+1,s}$ = Gross Domestic Product in period t+1 if state $s \in S$

r_t^b = lending rates offered by bank b

Mr. ϕ supply of deposits

Mr. ϕ's deposit supply with bank b in period t depends not only on the corresponding deposit rate offered by bank b but also on the rates offered by the other banks. Also, since banks in our model can default on their deposits obligations, the expected rate of return on deposit investment of Mr. ϕ with bank b has to be adjusted for its corresponding expected default rate. Mr. ϕ deposit supply is a positive function of the expected GDP in the subsequent period. Mr. ϕ's deposit supply function with bank $b \in B$, $\forall h^b \in H^b$, in period t is formulated as follows:

$$\ln(d_{b,t}^\theta) = z_{b,1} + z_{b,2} \ln[p(GDP_{t+1,i}) + (1-p)GDP_{t+1,ii}] + z_{b,3}[r_{d,t}^b(p\upsilon_{t+1,i}^b + (1-p)\upsilon_{t+1,ii}^b)]$$
$$+ z_{b,4} \sum_{b' \neq b \in B}[r_{d,t}^{b'}(p\upsilon_{t+1,i}^b + (1-p)\upsilon_{t+1,ii}^{b'})] \quad (7)$$

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[10] The variable 'trend', has the value of 0 at the beginning of the simulation and increases linearly by increments of 1 over the time horizon of the simulation.

where,

$d_{b,t}^{\theta}$ = amount of money that agent φ chooses to deposit with bank $b \in B$ in period t.

$r_{d,t}^{b}$ = deposit rates for bank b in period t and $r_{d,t}^{b'}$ = competitors deposit rates

$\upsilon_{t+1,s}^{b}$ = repayment rate of bank b in t+1,s

Household's loans repayment rates

Each household's repayment rate on his loan obligation to his nature-selected bank for each of the two possible states in period t+1, $s \in S$, is a positive function of the GDP level by state as well as the aggregate credit supply available in previous period. This latter variable captures the effect of a 'credit crunch' in the economy as a whole whereby a fall in overall credit supply in the economy aggravates the default probability of every household. That is, given that households are liquidity constrained, higher interest rates increase their debt obligations in the future causing defaults to rise. The functional form of the repayment rate of household $h^{b}, \forall h^{b} \in H^{b}$, to his specific bank $b \in B$, in state $s \in S$ of period t+1 as follows:

$$\ln(\upsilon_{t+1,s}^{h^{b}}) = g_{h^{b},s,1} + g_{h^{b},s,2} \ln[(GDP_{t+1,s}) + g_{h^{b},s,3} [\ln(\overline{m}_{t}^{\gamma}) + \ln(\overline{m}_{t}^{\delta}) + \ln(\overline{m}_{t}^{\tau})] \quad (8)$$

where $\upsilon_{t+1,s}^{h^{b}}$ is the repayment rate of household h^{b} at t+1 to the bank b if state s occurs and $\overline{m}_{t}^{b}$ is the amount of credit that bank b extends in period t

Gross Domestic Product

GDP in each state of period t+1 is assumed to be a positive function of the aggregate credit supply available in the previous period. The following functional form for GDP in states $s \in S$ of period t+1 is as follows:

$$\ln(GDP_{t+1,s}) = u_{s,1} + u_{s,2}trend + u_{s,2}[\ln(\overline{m}_{t}^{\gamma}) + \ln(\overline{m}_{t}^{\delta}) + \ln(\overline{m}_{t}^{\tau})] \quad (9)$$

Thus the GDP for each possible state at t+1 is assumed to be a positive function of the aggregate credit supply of the economy at time.

Market clearing conditions

There are seven active markets in the model including three for consumer loans, three for deposits and one interbank market. Each of these markets determines an interest rate that equilibrates demand and supply in equilibrium.[11] The interest rate formation mechanism is identical to the offer-for-sale mechanism in Dubey et. al (2005). The denominator of each expression (11-13) represents the supply side whereas the numerator divided by $(1 + r)$, $r \in \{r^b, r_d^b, \rho\}$, corresponds to the demand for all banks.

Bank b's loan market clears: $1 + r_t^b = \dfrac{\mu_t^{h^b}}{\overline{m}_t^b}, h^b \in H^b, \forall b \in B$ $\quad$ (11)

Bank b's deposit market clears: $1 + r_{d,t}^b = \dfrac{\mu_{d,t}^b}{d_{b,t}^{\phi}}, \forall b \in B$ $\quad$ (12)

Interbank market clears: $1 + \rho_t = \dfrac{\overline{B}_t + \sum\limits_{b \in B} \mu_t^b}{M_t + \sum\limits_{b \in B} d_t^b}$ $\quad$ (13)

where $\overline{B}_t$ = government bonds, and M_t = money issued by the Central Bank.

Importantly, these interest rates, i.e. $r_t^b, r_{d,t}^b$, and ρ_t, $b \in B$, are the *ex ante* nominal interest rates that incorporate default premium since default is permitted in equilibrium.

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[11] The interest rate formation mechanism is identical to the offer-for-sale mechanism in Dubey et. al (2005). The denominator of each expression (10-12) represents the supply side whereas the numerator divided by $(1 + r)$, $r \in \{r^b, r_d^b, \rho\}$, corresponds to the demand for all $b \in B$.

Equilibrium Conditions

The equilibrium in this economy in each period is characterised by a vector of all choice variables of active agents. Formally, let

$$- \sigma^b = \{\overline{m}_t^b, \mu_t^b, d_t^b, \mu_{d,t}^b, \upsilon_{t+1,s}^b, \pi_{t+1,s}^b, e_{t+1,s}^b, k_{t+1,s}^b\} \in R_+ \times R_+ \times R_+ \times R_+ \times R_+^2 \times R^2 \times R^2 \times R^2$$

$$\text{for } b \in B; \; \sigma^{h^b} \equiv (\mu_t^{h^b}, \upsilon_{t+1,s}^{h^b}) \in R_+ \times R_+^2 \quad for \quad h^b \in H^b \text{ and}$$

$$- \sigma^\phi \equiv (d_b^\phi) \in R_+ \text{ for } b \in B; \text{ and } GDP_{t+1,s} \in R^2.$$

$$- \eta \in \{r_t^\gamma, r_t^\tau, r_t^\delta, r_{d,t}^\lambda, r_{d,t}^\tau, r_{d,t}^\delta, M_t, \overline{B}_t\}, \; B^b(\eta) = \{\sigma^b : (6) - (10) \text{ hold}\}.$$

Then:

$$- ((\sigma^b)_{b \in B}, \eta, (\sigma^{h^b})_{h^b \in H^b}, \sigma^\phi, (GDP_{t+1,s})_{s \in S}) \text{ is a monetary equilibrium with banks and}$$

default (MEBD) for the economy given $E\{e_t^b, Others^b, A^b)_{b \in B}; p; (\overline{k}_{t+1,s}^b, \lambda_s^b, \lambda_{ks}^b, \overline{\omega}, \omega, \widetilde{\omega})_{b \in B, s \in S}; r_t^A; \rho\}$

iff (i) –(iv) conditions are met :

(i) $\sigma^b \in Argmax\, E_t(\prod_{t+1}^b(\pi_{t+1}^b)), b \in B$ so banks are maximizing their payoff function subject to their budget constraints;

(ii) the loan, deposit and interbank markets clear $(11) - (13)$;

(iii) $\widetilde{R}_s = \dfrac{\sum\limits_{b \in B} \upsilon_{t+1,s}^b \mu_t^b}{\sum\limits_{b \in B} \mu_t^b}, s \in S$, such that bans are correct in their expectations about repayment rates in the interbank market;

(iv) $\sigma^{h^b}, \sigma^\phi and\, GDP_{t+1,s}$, for $h \in H$ and $s \in S$ satisfy the reduced-form equations $(7) -$ (10), i.e., loan demand, deposit supply, repayment rates, and GDP in both states satisfy the reduce form equations characterizing their behaviour over time.

Calibration of the Model to the Jamaican Banking Sector

The calibration exercise is based on annual account data of commercial banks, merchant banks and building societies, which are represented by $b \in B = \{\gamma, \delta, \tau\}$, respectively in Jamaica between 2005 and 2008. Time-series properties of Jamaican banks are calibrated to key features of the banking sector in 2005. Then the behaviour of the banks in subsequent periods is simulated, capturing the evolution of loan, deposits, and net interbank lending endogenously over time.

Calibration of the initial period: 2005

In each period t, excluding Langrange multipliers, conditions (i) - (iv) imply a system of 56 equations in 143 unknown variables, 87 variables of which are exogenous variables/parameters in the model. This implies that there are 87 variables whose values have to be chosen in order to obtain a numerical solution to the model.[12]

The values of all bank's balance sheet items in the initial period, t = 2005 including loans, interbank lending, investment book, deposits, interbank borrowings, and other liabilities , are calibrated using the annual account data for banking sector at end March 2005 (see **Appendix 1**). Loan repayment rates during normal times are also calibrated using actual non-performing loans to total loans data for each banking sub-sector at end-March 2005. Specifically, the NPL ratios for commercial banks, merchant banks, and building societies were 2.59 per cent, 2.09 per cent and 3.85 per cent, respectively at end-March 2005. Note that the framework used repayment rates which are computed as 1 – *NPL Ratio*. The crisis-period default rates, on the other hand, are used to calibrate household repayment rates during extreme times. Thus default rates in *state ii*, are set to 11.03, 10.6 and 12.2 per cent for commercial banks, merchant banks and building societies, respectively.

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[12] In the Appendix, Table 1, shows the values of exogenous parameters/variables in the model and the resulting equilibrium. These values where either (1) calibrated against real data, (2) arbitrarily selected, or (3) endogenously solved.

The probability that state ii will occur, *1- p*, is arbitrarily selected to be 0.10, given that is reflects an extreme event. Since banks rarely default on their debt obligations in the good state, the corresponding repayment rates in the deposit and interbank market for all banks in the next period, i.e. υ_{t+1}^{b}, $b \in B,$ are set to *0.999*. In *state ii*, the bad state, the corresponding repayment rates in deposit and interbank market are set to be higher than those of household repayment rates at 0.95 for commercial banks and building societies, and 0.90 for merchant banks.

The interbank interest rate, ρ_t, set at 12.25 per cent to match the actual median value of the interbank rates quoted in March-2005. The value of risk weight for loans is set to 1 whereas the corresponding values for the market book and interbank lending are set to 0.2. The values of capital to asset requirement set by the regulator for banks in both states of the next period $(\bar{k}_{t+1,s}, b \in B, s \in S)$ is chosen to be slightly higher than those set by the Bank of Jamaica such that $(\bar{k}^{b} - k_{s}^{b} > 0)$, thus avoiding 'corner' equilibria.[13] The values of default and capital violation penalties $(\lambda_{s}^{b}, \lambda_{ks}^{b}, b \in B, s \in S)$ reflect both the tightness of the regulator's policy and the aversion of banks' management to putting themselves at risk of default and/or regulators violations are choose arbitrarily to be 0.9 and 0.1 for the *'normal'* state, and 1.1 and 0.1 for the *'extreme'* state for λ_{s}^{b} and λ_{ks}^{b}, respectively.

The rate of return of the market book is computed using the implicit rate of return of 10.52 per cent based on the interest income from investments of the banking sector and the stock of investments on their balance sheet at end March 2005. Lastly, the nominal GDP in the 'normal' state of 64.95 is set to equal the actual annual GDP at end-March 2006.[14] The value of nominal GDP in the 'extreme' state is arbitrarily set to be 4.0 per cent below the corresponding value of the 'normal' state.

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[13] The assumption being that each bank wants to keep a buffer above the required minimum so that required capital limits are always binding.
[14] Note that the values of all nominal variables, including all balance sheet and P&L entries, are normalized by a factor of ten-billion Jamaican Dollars.

Econometric Techniques used to estimate parameters

The Data

The data used in the econometric estimation of parameters are quarterly in frequency between the period March 1996 and March 2009. All variables were expressed in real terms using the CPI index and, in the case of non-percentage variables, were transformed using logs. Macro-economic variables used included data on private consumption, GDP, the unemployment rate, and the inflation rate. Monetary aggregates included broad money (M3). Interest rates included in the estimation process were the deposit rate (by bank and sector) and loan rates (by bank and sector), the 180-day OMO rate, and the interbank rate. With exception of the 180-day OMO rate, all other interest rates were implicit and computed by dividing the respective interest income/expense from the P&L statements by the banks and the balance sheet position of the relevant asset/liability for the respective bank.[15] Total assets, total loans and non-performing loans (by bank and sector) as well as unsecured lending of the banking system were also collated.

Estimating Household's Demand for Loans in Jamaica

To estimate the parameters for the reduced-form equation (6) for household borrowers' demand for loans long-run relationships (co-integrating vectors) between private consumption, broad money (M3), unsecured lending, credit spread, deposit spread, real GDP, inflation and unemployment were estimated.[16] Standard unit-roots tests were performed on each series to ascertain whether they were non-stationary in levels. The estimation of a co-integration vector requires the variables are non-stationary (see **Table 2**). [17]

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[15] For example, the implicit deposit rate was computed by dividing the interest payments to demand and savings deposits by the stock of those deposits for each bank and each sector.

[16] This approach follows closely the work of Chrystal and Mizen (2005).

[17] The credit spread was computed as the implicit loan rate minus the 180-day OMO rate. The deposit spread was computed as the difference between the implicit deposit rate and the implicit interbank rate. Credit spreads were found to be stationary at the 10.0 per cent level.

Table 2 Augmented Dickey-Fuller unit root test (Null Hypothesis of Unit Root)

Variable	Exogenous	Test Statistic	Critical Value (1%)	Probability
Unsecured lending	Constant	-2.43	-3.57	0.1372
	Cons, trend	-3.03	-4.14	0.1332
Private consumption	Constant	1.27	-3.57	0.9982
	Cons, trend	-0.99	-4.18	0.9348
Broad money	Constant	-2.47	-3.56	0.1267
	Cons, trend	-1.94	-4.14	0.6163
Credit spread	Constant	-3.22	-3.58	0.1130
	Cons, trend	-2.93	-4.18	0.1608
Deposit spread	Constant	-2.42	-3.57	0.1405
	Cons, trend	-3.63*	-4.16	0.1248
Real GDP	Constant	-1.67	-3.59	0.4375
	Cons, trend	-3.22*	-4.21	0.1148
Inflation	Constant	-1.99	-3.57	0.2875
	Cons, trend	-2.70	-4.16	0.2394
Unemployment	Constant	-1.50	-3.56	0.5231
	Cons, trend	-3.70	-4.14	0.1311

At the 5% level of significance the null hypothesis of a unit root was rejected.

The Johansen (1995) procedure was then applied to determine the number and magnitude of the co-integrating vectors. For the test, a lag-length of one was used as indicated by the Schwarz information criterion (SIC) in the context of a vector autoregression (VEC) for the variables in levels.[18] Further, no deterministic component was included inside the cointegration vector. Finally, all variables were introduced as endogenous. The results of the Johansen cointegration test are reported in Table 3. The Trace test-statistic shows three cointegrating vectors and the Max-eigenvalue test-statistic shows at-most two cointegrating vectors. In order to estimate the long-run coefficients for the parameters in

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[18] The Hannan-Quinn information criterion and the Akaike information criterion both suggested the use of three lags, however degrees of freedom constraints limited the use of so many lags in the vector error correction model.

equation (6) the following four restrictions were imposed on coefficients in the VEC i) the coefficient on unsecured consumer lending was restricted to be equal to one ii) the coefficient on money was restricted to be equal to zero, iii) the coefficient on consumption was restricted to be equal to zero, iv) the coefficient on the deposit spread was restricted to be equal to zero.

Table 3 Johansen Cointegration tests

No. of CV	Trace Statistic	Critical Value (5%)	Prob.**
None *	256.41	159.53	0.00
At most 1 *	157.51	125.62	0.00
At most 2 *	100.92	95.75	0.02
At most 3	66.38	69.82	0.09
At most 4	37.82	47.86	0.31
At most 5	22.75	29.80	0.26
At most 6	9.45	15.49	0.33
At most 7	1.46	3.84	0.23

No. of CV	Max-Eigen Value	Critical Value (5%)	Prob.**
None *	98.90	52.36	0.00
At most 1 *	56.59	46.23	0.00
At most 2	34.54	40.08	0.18
At most 3	28.56	33.88	0.19
At most 4	15.07	27.58	0.74
At most 5	13.30	21.13	0.43
At most 6	7.99	14.26	0.38
At most 7	1.46	3.84	0.23

* denotes rejection of the hypothesis at the 5 per cent level

Given the aforementioned restrictions, the estimated vector error-correction model is shown in equation (14) below and the coefficients GDP and credit (CS) were used as the elasiticities in the household demand function of equation (6):-

$$L_t = 1.31\ln(GDP_{t+1}) - 3.66(CS_t) + 0.48(\pi_t) - 11.27(\Delta Unemp) \quad (14)$$

Thus the income elasticity parameter $[a_{h^b,3}]$ and the interest rate elasticity of loan demand $[a_{h^b,4}]$ of equation (6) were set at 1.31 and -3.66, respectively.

Estimating Household's Repayment rate on Loans in Jamaica

The parameters for the reduced-form equation for household repayment rates (equation 9) were estimated by way of a panel regression. The unbalanced panel dataset included bank-specific information of the ratio of personal non-performing loans to total loans (NPLs) as the dependent variables and banks-specific data for total loans and real GDP as independent variables. To model estimated is shown in equation 14:-

$$\ln(1 - NPL_{i,t+1}) = \alpha_i + \beta_1 \ln(GDP_{t+1}) + \beta_2 (loans_{i,t}) + \mu_{i,t} \quad (14)$$

where $\mu_{i,t}$ is the error term, and i and t refer to bank and moment of time, respectively.

The Hausman test-statistic of 1.33, with a p-value of 0.51 point to the use of a random-effects panel regression model which is estimated using exponential generalized least squares (EGLS) (see **Table 4**). The estimated regression derived an elasticity of the repayment rates with respect to the GDP of 1.303 which was used to inform the parameter $[g_{h^b,s,2}]$ and the elasticity for the amount of loans of the previous period of -0.0189 for the parameter $[g_{h^b,s,3}]$ in equation (9).

Table 4 Random-effects estimation of Household Repayment Rates

Method: EGLS			
Number of Observations	643		
Number of Individual Banks	14		
Dependent variable:	$\ln(1 - NPL_{i,t+1})$		
	Coefficient	Std. error	t-Statistic
α_i	-15.24	2.01	-7.56***
β_1	1.303	0.173	7.506***

β_2		-0.0189	0.0092	-1.83*
Adj-R^2		0.1220		

*** indicates significance at the 1% level and * indicates significance at the 10% level

Estimating the long-run relationship between Gross Domestic Product and Loans

The estimation of a co-integration relationship between real GDP and total loans was performed to obtain the credit-elasticity of GDP [$\mu_{s,3}$] as well as the coefficient on the trend component [$\mu_{s,2}$] in the reduced form equation for GDP.[19] Table 5 presents the augmented Dickey Fuller unit root test show that both real GDP and total loans were found to be non-stationary variables at the one-per cent level.[20] The Johansen co-integration test, which was performed with 3 lags,[21] point to the existence of a co-integrating vector between real GDP and total loans at a significance level of 5% (see **Table 5**).

Table 5 Augmented Dickey-Fuller unit root test (Null Hypothesis of Unit Root)

Variable	Exogenous	Test Statistic	Critical Value (1%)	Probability
GDP (logs)	Constant	-2.04	-3.584	0.268
	Cons, trend	-2.79	-4.175	0.206
Total Loans (logs)	Constant	-0.38	-3.584	0.903
	Cons, trend*	-3.38	-4.175	0.137

* At the 5.0 per cent level of significance the null hypothesis of a unit root was rejected.

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[19] The latter was obtained by including a trend in the estimated co-integration vector.

[20] Once confirmed to be non-stationary, it is possible to use the error correction representation of a co-integrated system to test for the presence of co integration relationships between the variables (Johansen 1995).

[21] The lag-length of three was confirmed by the Hannan-Quinn and Akaike information criteria which was calculated in the context of a vector auto-regression for the variables in levels.

Table 6 The Johansen Co-integration tests

No. of CV	Trace Statistic	Critical Value (5%)	Prob.**
None *	17.67	12.32	0.00
At most 1	1.58	4.12	0.24
No. of CV	Max-Eigen Value	Critical Value (5%)	Prob.**
None *	16.17	11.22	0.00
At most 1	1.59	4.12	0.24

* denotes rejection of the hypothesis at the 5.0 per cent level

The estimated co-integrating vector, which is normalized on the coefficient associated with GDP, is shown in equation (15).

$$\ln(GDP_{t+1}) = -0.0016t + 0.2411\ln(L_t) \quad (15)$$

Thus the elasticity for loans (L_t) of 0.2411 was used to calibrate the parameter $\mu_{s,3}$ and the coefficient of the trend function of -0.0016 was used to calibrate the parameter $\mu_{s,2}$ of the reduced form equation (9).

Estimating the Supply of Deposit by agent ϕ

An unbalanced panel data regression, with bank-specific data for 14 banks was used to estimate the reduced-form equation for the supply of deposits (equation 10). Real deposits where used as the dependent variable and the real GDP as well as real deposit rates were used as the independent variables. The panel data model to be estimated is shown in equation 16 below.

$$\ln(D_{i,t}) = \alpha_i + \beta_1 \ln(y_{t+1}) + \beta_2(dr_{i,t}) + \beta_3(dr_{i,t}^{'}) + \mu_{i,t} \quad (16)$$

where $D_{i,t}$ are real deposits, y is the real GDP, $dr_{i,t}$ is the bank deposit rate and $dr_{i,t}^{'}$ is the deposit rate of the other two groups of banks. The χ^2 distributed test-statistic of the Hausman test (null hypothesis of random-effects against the alternative for fixed effects)

was 10.08, with a p-value of 0.0179 indicating that the best specification was a fixed-effects model (see **Table 7**).

Table 4. Fixed-effects estimation of Household Supply of Deposits

Method: Pooled Least Squares			
Number of Observations	637		
Number of Individual Banks	14		
Dependent variable:	$\ln(D_{i,t})$		
	Coefficient	Std. error	t-Statistic
α_i	-36.38	10.56	-3.344***
β_1	3.458	0.896	3.746***
β_2	-0.356	0.034	-10.455***
β_3	-1.067	3.125	-0.398
Adj-R^2	0.82		

*** indicates significance at the 1.0 per cent level and * indicates significance at the 10.0 per cent level

Thus the elasticity of the supply of deposits of agent ϕ with respect to the GDP $[z_{b,2}]$, the banks own deposit rate $[z_{b,3}]$, and the interest rate of the other banks $[z_{b,4}]$ were 3.458, -0.356, and (-1.246*0.5), respectively. However, the parameter for interest rate of other banks was set to zero because the coefficient was found to be insignificant at the 10.0 per cent level.

Simulation Results

For each sub-sector of the banking system in Jamaica, the endogenously generated variables include loans, deposits, household's repayment rates, and net interbank lending (See **Figure 3**).[22] The simulation results are presented against the actual observed values for the period 2005:1 to 2008:1.

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[22] The values of the banking sectors market book, other liabilities and GDP are calibrated against real data over the sample period and are exogenous in the model. All interest rates are also exogenous in the model.

The simulation results for loans over the period indicate a strong empirical fit. Importantly, the model also captures the relative size of the loan portfolios of the various sectors as well as the general trend in the actual data. These results for loans lend credence for the long-run elasticities for GDP and credit spreads that were derived using the vector-error correction model. It should be noted, however, that for commercial banks the model overestimates the pace of growth in loans towards the end of the 3-year horizon.

The behaviour of the simulation model for deposits also performed reasonably well over the medium-term forecast horizon. In this case, there was an underestimation for the stock of deposits for both commercial banks and merchant banks. In contrast, the stock of deposits for merchant banks were overestimated in the initial period but the forecast picked the first quarter of 2008 period well.

For household repayment rates, the reciprocal of non-performing loans, all of which track the actual data well. The simulation exhibits the best fit for both commercial banks and building societies. That is, the simulation captures the general improvement in the NPL ratios over the period. For merchant bank, the model overestimated the deterioration in their loan portfolio intra-period but picked the first quarter of 2008.

Figure 3. Dynamic Simulation of the Banking Sector in Jamaica (2005 – 2008)
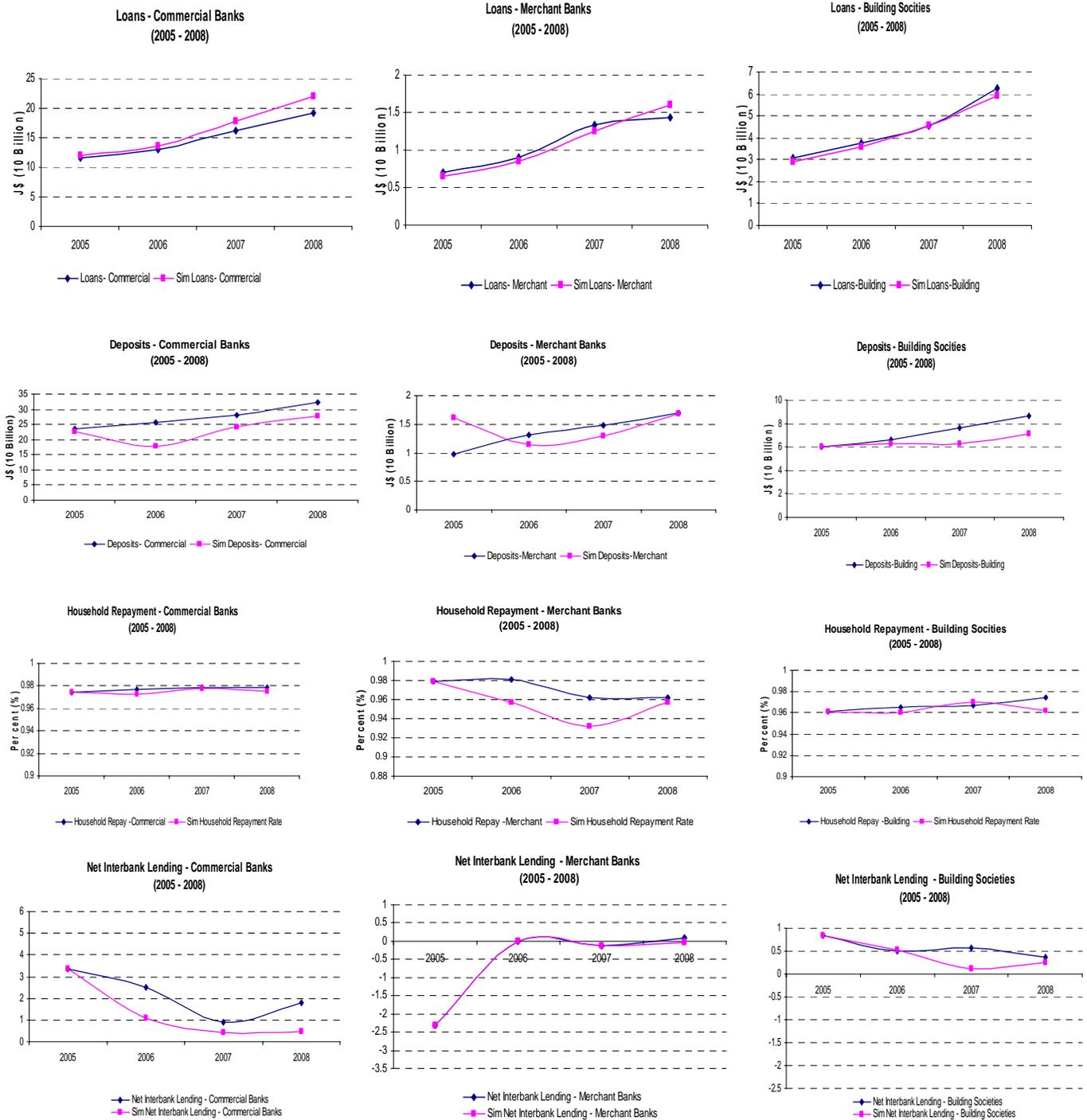
Turning the interbank market, the stylized fact associated of the behaviour over time of net lending in the interbank market is captured. More specifically, over the period commercial banks and building societies (to a lesser extent) are net lenders in the inter-bank market while merchant banks are net-borrowers in the inter-bank market. Just as importantly, the model also captures the dynamics in the inter-bank market whereby merchant banks depend less and less on the interbank market for financing, commensurate with the decline in interbank lending by the other two participants in the market over the period.

CONCLUSION

This paper evaluated the performance of a general equilibrium model of the financial system when applied to the case of Jamaica. The model incorporates heterogeneous banks and capital requirements in a general equilibrium model with incomplete markets, money and default. Further, agents in the model interact in several financial markets, including a credit, deposit and an interbank market in an infinite horizon setting.

The framework confirms the existence of monetary equilibrium with banks and default (MEBD) has two non-trivial implications for the assessment of financial stability. Firstly, agents may choose in equilibrium a positive level of default. Secondly, financially fragile regimes are not incompatible with the existence of orderly markets under certain conditions (Tscomocos (2003)). The second property ratifies the importance of institutions, such as the Central Bank, to preserve both financial stability and the orderly functioning of markets. Thus there are multiple instruments that the central bank and/or the regulator might use to improve upon an inefficient equilibrium, and mitigate or prevent the detrimental consequences of financial fragility.

The simulation results suggest that the model performs satisfactorily in the prediction of medium-term trends which are relevant to the assessment of financial stability.[23] The

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[23] Similar results were obtained in a similar study by Saade *et al.* (2007) for the case of Colombia.

model is calibrated to conform to the time-series data of the Jamaica banking system between 2005 and 2008 and can be readily used to assess financial fragility given its flexibility, computability, and the presence of multiple contagion channels and heterogeneous banks and investors. As such, the impact of monetary and regulatory policy, credit and capital shocks in the real and financial sectors can be investigated in a single coherent framework which is empirically tractable as it is theoretically sound. Further experimentation with the framework should enhance the supervisory surveillance of the banking sector by highlighting the possible trade-offs between the attainment of price stability and financial stability in Jamaica.

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APPENDIX II: Algorithmic Information

GAMS/CONOPT is a GRG-based algorithm specifically designed for large non-linear programming problems expressed in the following form

Min or max f(x)	(1)
Subject to g(x) = b	(2)
lo < x < up	(3)

where x is the vector of optimization variables, lo and up are vectors of lower and upper bounds, some of which may be minus or plus infinity, b is a vector of right hand sides, and f and g are differentiable nonlinear functions that define the model. N will in the following denote the number of variables and m the number of equations. (1) is the objective function (2) will be referred to as the (general) constraints and (3) as the bounds.

The CONOPT Algorithm

The algorithm used in GAMS/CONOPT is based on the GRG algorithm first suggested by Abadie and Carpentier (1969). The key steps in any GRG algorithm are:

1. Initialize and Find a feasible solution.
2. Compute the Jacobian of the constraints, J.
3. Select a set of n basic variables, x_b, such that B, the sub-matrix of basic column from J, is non-singular. Factorize B. The remaining variables, x_b, are called non-basic
4. Solve $B^T u = df / dx_b$ for the multipliers u.
5. Compute the reduced gradient, $r = df / dx - J^T u$. r will by definition be zero for the basic variables.
6. If r projected on the bounds is small, then stop. The current point is close to optimal.
7. Select the set of super-basic variables, x_s, as a subset of the non-basic variables that profitably can be changed, and find a search direction, d_s, for the super-basic variables based on r_s and possibly on some second order information.
8. Perform a line search along the direction d. For each step, x_s is changed in the direction d_s and x_b is subsequently adjusted to satisfy $g(x_b, x_s) = b$ in a pseudo-Newton process using the factored B from step 3.
9. Go to 2.

APPENDIX II.

Table 5. Initial Equilibrium for Banking Sector CGE model for Jamaica (t = 2005)[24]

Initial Equilibrium			Exogenous variables in the model		
$r_t^\gamma = 0.1625$	$k_{t+1,i}^\delta = 0.17$	$e_{t+1,ii}^\gamma = 0.041$	$Other_t^\gamma = 3.403$	$a_{\alpha^\gamma,1} = -2.305$	$\lambda_{i(\forall b\in B)}^b = 0.1$
$r_t^\delta = 0.1501$	$k_{t+1,ii}^\delta = 0.12$	$e_{t+1,i}^\delta = 0.014$	$Other_t^\delta = 0.899$	$a_{\beta^\delta,1} = -5.288$	$\lambda_{i(\forall b\in B)}^b = 1.1$
$r_t^\tau = 0.1419$	$k_{t+1,ii}^\tau = 0.13$	$e_{t+1,ii}^\delta = -0.04$	$Other_t^\tau = 0.249$	$a_{\theta^\tau,1} = -2.33$	$z_{\gamma,2} = 7.358$
$r_{d,t}^\gamma = 0.043$	$k_{t+1,ii}^\tau = 0.11$	$e_{t+1,i}^\tau = 0.02$	$g_{\alpha^\gamma,i,1} = -5.035$	$z_{\gamma,1} = -9.10$	$z_{\delta,2} = 3.258$
$r_{d,t}^\delta = 0.081$	$\pi_{t+1,i}^\gamma = 0.259$	$e_{t+1,ii}^\tau = 0.009$	$g_{\alpha^\gamma,ii,1} = -5.14$	$z_{\delta,1} = -14.34$	$z_{\tau,2} = 3.258$
$r_{d,t}^\tau = 0.072$	$\pi_{t+1,ii}^\gamma = 0.254$	$\tilde{R}_{t+1,i} = 0.989$	$g_{\beta^\delta,i,1} = -5.14$	$z_{\tau,1} = -12.51$	$z_{b,3(\forall b\in B)} = 0.656$
$\mu_{d,t}^\gamma = 23.395$	$\pi_{t+1,i}^\delta = 0.050$	$\tilde{R}_{t+1,i} = 0.954$	$g_{\beta^\delta,ii,1} = -5.531$	$\bar{k}_{t+1,s(\forall s\in S)}^\gamma = 0.15$	$z_{b,4(\forall b\in B)} = -0.923$
$\mu_{d,t}^\delta = 1.625$	$\pi_{t+1,ii}^\delta = -0.006$	$\mu_t^{\alpha^\gamma} = 13.9$	$g_{\theta^\tau,i,1} = -5.593$	$\bar{k}_{t+1,s(\forall s\in S)}^\delta = 0.20$	$r_t^A = 0.0997$
$\mu_{d,t}^\tau = 6.00$	$\pi_{t+1,i}^\tau = 0.048$	$\mu_t^{\beta^\delta} = 0.741$	$g_{\theta^\tau,ii,1} = -5.577$	$\bar{k}_{t+1,s(\forall s\in S)}^\tau = 0.17$	$p = 0.90$
$k_{t+1,i}^\gamma = 0.11$	$\pi_{t+1,ii}^\tau = 0.032$	$\mu_t^{\theta^\tau} = 3.303$		$\lambda_{ks(\forall b\in B,s\in S)}^b = 0.1$	
$k_{t+1,ii}^\gamma = 0.08$	$e_{t+1,i}^\gamma = 0.011$	$\bar{B} = 1.87$			
$\bar{m}_t^\gamma = 12.025$	$d_{\tau,t}^\phi = 5.594$	$\mu_t^\delta = 2.519$	$a_{h^b,3(\forall h\in H^b)} = 1.31$	$e_t^\gamma = 4.084$	$\bar{\omega} = 1$
$\bar{m}_t^\delta = 0.644$	$d_t^\gamma = 6.465$	$\mu_t^\tau = 0.403$	$a_{h^b,4(\forall h\in H^b)} = -3.66$	$e_t^\delta = 0.582$	$\omega(\tilde{\omega}) = 0.2$
$\bar{m}_t^\tau = 2.893$	$d_t^\delta = 0.236$	$\upsilon_{t+1,i}^{\alpha^\gamma} = 0.994$	$A_t^\gamma = 16.01$	$e_t^\delta = 1.652$	$\rho_t = 0.061$
$d_{\gamma,t}^\phi = 22.431$	$d_t^\tau = 1.241$	$\upsilon_{t+1}^{\beta^\delta} = 0.975$	$A_t^\delta = 4.69$		$a_{\alpha^\gamma,2} = 0.025$
$d_{\delta,t}^\phi = 0.902$	$\mu_t^\gamma = 3.148$	$\upsilon_{t+1}^{\theta^\tau} = 0.93$	$A_t^\tau = 4.02$		$a_{\beta^\delta,2} = 0.12$
					$a_{\theta^\tau,2} = 0.12$
$\upsilon_{t+1,ii}^{\alpha^\gamma} = 0.570$	$\upsilon_{t+1,i}^\gamma = 0.989$	$\upsilon_{t+1,ii}^\delta = 0.959$	$c_i^\gamma = 0.23$	$g_{h,s,2(\forall h\in H^b)} = 1.203$	
$\upsilon_{t+1,ii}^{\beta^\delta} = 0.591$	$\upsilon_{t+1,ii}^\gamma = 0.954$	$\upsilon_{t+1,i}^\tau = 0.997$	$c_{ii}^\gamma = 0.35$	$g_{h,i,3(\forall h\in H^b)} = -0.02897$	
$\upsilon_{t+1,ii}^{\beta^\delta} = 0.571$	$\upsilon_{t+1,i}^\delta = 0.996$	$\upsilon_{t+1,ii}^\tau = 0.950$	$c_i^\delta = 0.12$	$g_{h,ii,3(\forall h\in H^b)} = -0.0337$	
			$c_{ii}^\delta = 0.96$		

[24] All balance sheet figures are nominal and reported in units of 10.0 billion Jamaican Dollars.