Recursive Macroeconomic Model for Crisis Prediction

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Introduction:

The world remembers 1997 as the year that brought the so-called Asian Tigers to their knees. The Asian Economic Crisis, as is known now, created such financial and political chaos from which the countries worse affected, Indonesia, Korea, Malaysia, and Thailand, are still in the process of recovering. The Mexican crisis, in 1994, likewise brought a sequence of unfortunate economic bankruptcies not limiting to a particular region, but affecting the whole global economy.

Much attention has therefore been given on causes of these events, but a complete description of why such disastrous events occurred and whether we could see the indicators and predict them prior to their happening are yet to be explored in order for the health of global economic existence.

Though there had been a large number of attempts from categorically empirical (Frankel and Rose, 1996 and well documented in Wong 1998 and many others), to mathematical (Turnovsky, S. J., 1997, Eicher and Turnovsky, 1999 and Walz, 2001 and others), to Post Keynesian perspectives (Deprez, J. and Harvey, J. T., 1999) and to well descriptive studies (Wong, 1998, Azis, 2002, 2001) to explain the causes of crisis, to our best knowledge, there is no attempt to build a recursive model to explain such situation. Recursive Macro-Economic models constitute a powerful approach to dynamic economics because the future of

economy is greatly affected by the current status and activities by the agents in the current economy (Ljungqvist, L. and Sargent T.J, 2000). The fundamental concept of recursive methods rests on modeling the position of a dynamic system for future periods based on its position today together with current action of the agents.

What is our study?

In this study we provide the general background of the crisis and consider the various financial and economic arguments to explain the crisis. We use these arguments and consider a hypothetical country with general global financial interlinks. Then we employ the recently discovered methods in recursive macroeconomics to build a dynamic model to explain the general financial picture of the hypothetical country. Our model is different from previously reported since 1) it provides spaces for upgrading or tuning to the model to a particular country with the availability of small amount of data from that country 2) capability of self tuning with a large dataset, 3) ability to simulate the economy under various policy alternatives and 4) incorporation of known theories on behavior of macroeconomic variables.

Causes of Economic Crisis:

Main causes of economic crises can be broadly categorized as monetary policies, politics, economic factors, and social factors. In a recent communication (Athukorala, P and Warr, P. G., 2000) discussed Asian Crisis in two theories (self-fulfilling panic theory and vulnerability theory) summarizing a considerable amount of literature built upon qualitative explanation of Asian Crisis (See for example, Goldstein 1998, Corden 1999 and Garnaut 1998). According to previous studies in qualitative explanation, self-fulfilling panic theory and vulnerability theory can be summarized as follows.

Self fulfilling panic theory sees currency crisis as an unforeseeable financial panic reflecting inherent instabilities in the capital market, and it has been argued that open economic policies to be blamed in those countries (Bhagwati, 1998). Vulnerability theory, in contrast to panic theory, explains crisis being an unsustainable deterioration in macro economic conditions within the affected countries. Policies of IMF and US Treasury are fundamental to the vulnerability theory. Clearly, there is no evidence to prove that Asian crisis being an unfortunate and unpredictable panic but it could be a consequence of countries economic policy misdeeds. It means that true vulnerability theory breaks ground for modeling and predicting crisis rather than believing it as being an unfortunate occurrence. For example, capital flow reversal model of Eicher, Turnovsky and Walz (2000) was well fitted with four different crisis countries. Also, empirical studies of Athukorala and Warr(2000) strongly supported the vulnerability theory due to following reasons:

1) a strong evidence of rapid accumulation of mobile capital,
2) domestic lending booms
3) over valued exchange rate during 1997-98 in all five crisis countries.

In comparison with non crisis countries in the region, Athukorala and War (2000) observed that none of the non crisis countries (China, India, Singapore, Sri Lanka, Taiwan) exhibited first two characteristics and only two of them exhibited the third.

In some empirical studies, to detect unusual economic changes, one variable at a time has been used (univariate approaches), for instance exchange rate (see for example, Goldfajn and Valdes, 1997, Frankel and Rose, 1996, Meese and Rose 1996 and Henry, 1997), GDP growth (for example, Orihata, M., 2001) and financial variables such as credit growth (IMF 2000) as attempts to diagnose crisis. Clearly the univariate approaches can possible mask crisis due to multivariate nature of economics and other variables measurable. On the other hand arbitrary use of standard multivariate techniques can mask the economic

principles and financial links between economic variables such as GDP, Current Account etc.

What kind of Model is suitable for diagnosis of crisis?

Whilst the perfect answer to this question yet remains unsolved, the following models found to have been attempted in the past, and all believe that their method has solved the problem, yet demanding careful criticisms.

* **A Model on Capital flow reversal**

This model was found to fit with crisis countries but the ability to predict a crisis under different scenarios with this model is very limited. For example, this model does not provide answer to economic management problems such as what happen if the local interest rate is cut, what if the foreign investment is reduced at a certain point of time and/or what should be the model outcome for drastic changes in GDP etc. Theoretical outlook of this model is however interesting as it explains what had happened to the crisis countries in terms of trade balance or credit balance.

* **Empirical models on prediction of exchange rate**

It is accepted that exchange rate is an important variable in economic status of a country. Therefore, drastic changes in exchange rate can influence the economy perhaps to a significant level. The prediction of exchange rates based on various models has been attempted previously using empirical models. For instance, Ballie and Selover (1987), Henry (1997) and Henry, Olekalns and Summers (1999). As prediction of exchange rate is only a sub model within the crisis prediction model, we leave some spaces for possibility of implanting these finding and/or any new developments on exchange rate prediction models within our model.

* **A model on GDP maturity**

Economic Growth in macro economic context has a long history starting from Post Keynesian perspectives to modern quantitative macroeconomics models. Basically, empirical evidence suggests that economic growth attains certain maturity. For instance, Orihata (2001) discussed the technical maturity in Japan based on GDP growth and fitted an approximate logistic curve for nominal GDP growth and Solo (1956) discussed the causes of USA economic growth in his contribution to economic growth. Reportedly these models on GDP growth based on S shape curves have been well fitted with empirical investigations. Historical studies also provide evidence for S-curves (see for example, Figure on GDP and Trade Growth in Venezuela in: *The Global Economy: Resource Use Locational Choice and International Trade by Barry, Conkling and Ray, 1993, 371p*)

Therefore some valuable results and concepts were incorporated in our search for an appropriate economic model within a multivariate context incorporating many economic variables yet leaving spaces for additions from which we can answer to many economic management problems.

Our Model:

Depicted in Figure 1 is our model on explaining a crisis in an ideal country which has international interlinks with outside world, in terms of trade and money.

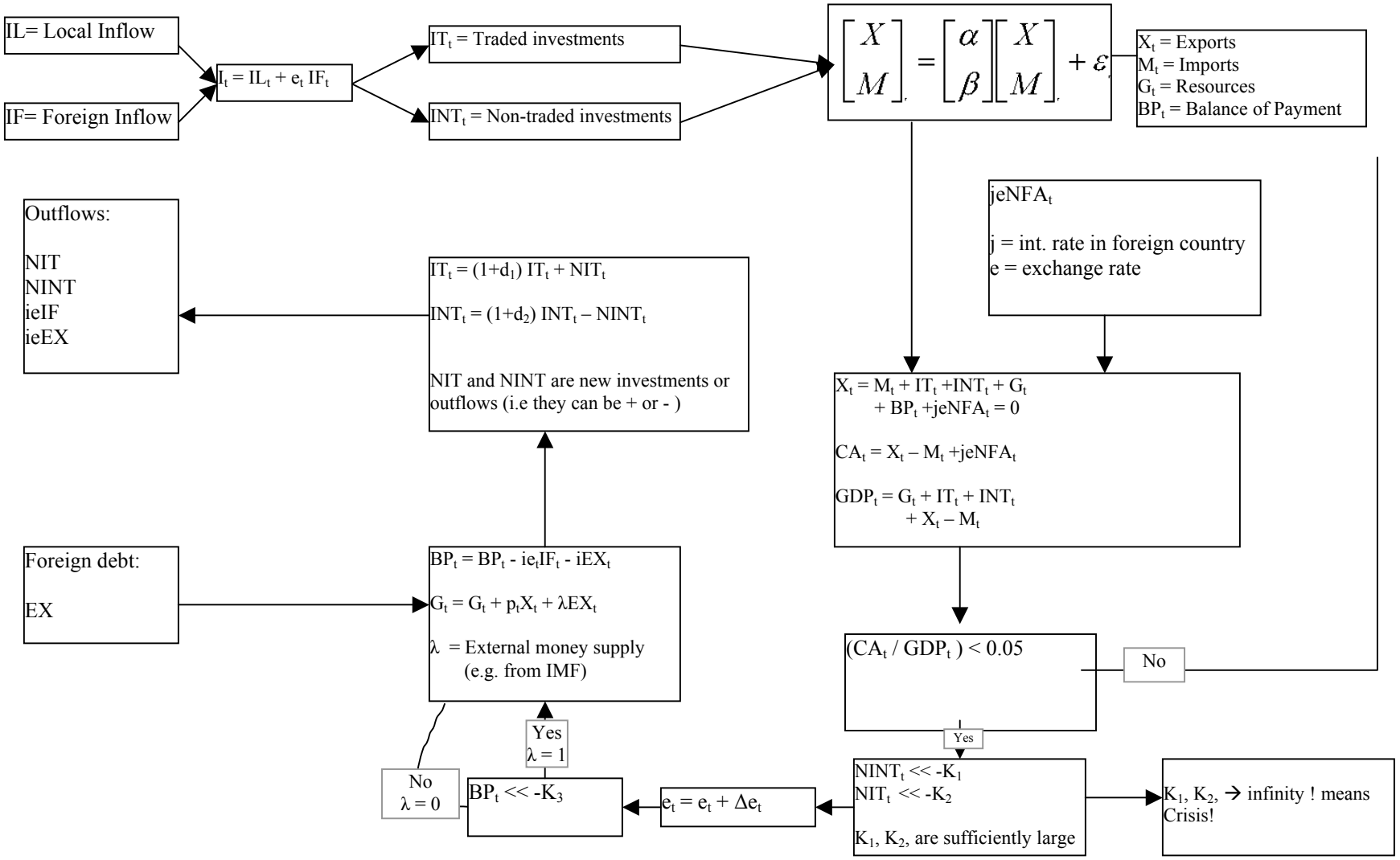


Figure 1: Complete Model Explaining Genesis of Crisis

1. Variables and Measures

In the following Exhibit 1 are variables and measures used in this model.

Exhibit 1: Economic Variables Used in the Model

Notation	Name of the Variable
GDP	**Gross Domestic Product**
i	Local interest rate
j	Foreign interest rate
X	Export
M	Import
NFA	Net Foreign Assets
FA	Foreign Assets
IF	Foreign Inflow
IL	Local Inflow
I	Total Investment
IT	Traded Investments
INT	Non-traded Investment
G	Resources
NIT, NINT	New investment
BP	Computed Balance of Payment
CA	Computed Current Account
GN	Government Expenses
e	Inverse of Exchange Rate

In the above model, we consider a natural economic growth of a country and that could be affected by financial interlinks in an open economy. Money supply to the economy and outflows from the economy is represented at various stages mainly from IF, EX, NIT, and NINT from external sources in addition to the trade balance (X-M) at a given time point. Interrelationships between economic

variables are implanted in the model, for instance multivariate nature of export and import variables being given in a structural equation model as a subsection. If the country has a positive trade balance, it is assumed that the growth occurs naturally. Given that a negative trade balance exists, the country can yet grow until the ratio of Current Account to GDP reach at a certain cut off point. Here we consider an arbitrary cut off point at 5%. If the CA/GDP < 0.05, country is at a recession. At this point, new investments in both traded and non-traded decreases naturally up to a certain level (k1 and k2 levels in our model) at which country has to seek external financial assistance. Here we introduce new investments or outflows informs of NINT, NIT, jeIF, and jeEX. These financial outflows can make the economic status of the country worse at a certain stage. It could follow that sufficiently large k1 and k2 means a crisis. Although the conceptual models provide clear explanation of the genesis of crisis, establishing quantitative simulation model is a challenging exercise.

Among previous studies on economic crises, there exist theories and discussions within the context of either mathematical modeling or in empirical investigations separately yet establishing that their models have solved the problem.

According to our model, countries underwent economic crisis are still in the process of recovering and undergoing problems. For instance, national accounts of these countries still have lower ratio of current account to GDP (Table 1) indicating economic problem and slow growth.

Table 1 Percentages of CA/GDP in Crisis Countries

Country	1999	2000	2001	2002
Malaysia	15.9	9.9	7.8	0.3
Indonesia	4.1	5.3	3.1	1.5
Thailand	10	7.5	5.5	4.1
Korea	5.8	2.7	2.0	1.9

Source: ADB outlook 2002

Simulation Experiment with Model Variables:

In this section, we describe model variables, simulation experiments and some results. First we consider an ideal country in an open economy. Then we study how economic management and/or mismanagement create economic growth or slow down. We finally establish two economic models one for rich economic growth and another for crisis economy yet leaving much space for expansion and future development.

GDP Growth (GDP):

We assume that ideal economic growth of a country follows an S- shape growth curve. This assumption is well known and widely applied in historical as well as recent studies. For example Orihata (2001) showed that Japanese Economic growth has attained to a technical maturity using an empirical S-shape growth curve model, and his model was well fitted with empirical data.

For the purpose of simulating GDP growth, we considered the following recursive formula to generate an S-shape growth curve:

$$GDP_i = GDP_i + \Delta\, GDP$$

and

$$\Delta\, GDP = \frac{c_1\, k\, c_2 \exp\left(-kt\right)}{\left(i + c_2 \exp\left(-kt\right)\right)^2}$$

It is easy to show that the above formula provides an S –shape growth curve as follows.

$$\text{Let } t_i - t_{i-1} \text{ be small.}$$
$$\Rightarrow \Delta GDP \text{ is very small and that}$$
$$dGDP = \frac{c_1 k c_2 \exp\left(-kt\right)}{\left(i + c_2 \exp\left(-kt\right)\right)^2} dt$$
$$\text{and it follows that}$$
$$GDP = \frac{c_1}{\left(i + c_2 \exp\left(-kt\right)\right)}$$

It turns out that the above recursive formula reduces to a general growth curve. For instance, Orihata's empirical formula on Japanese economic maturity is a sub set of the above general growth curve.

Although general growth curve gives a good approximation to modeling GDP, it does not provide space for entering available data. Therefore, the recursive version of the general growth curve is preferred for simulation studies as well as applied economic modeling.

Notice that the growth period of and the rate at the GDP maturity both in the general GDP growth formula and its recursive counter part could be adjusted using different values for parameters c1, c2 and k; as seen for example in Figure 2.

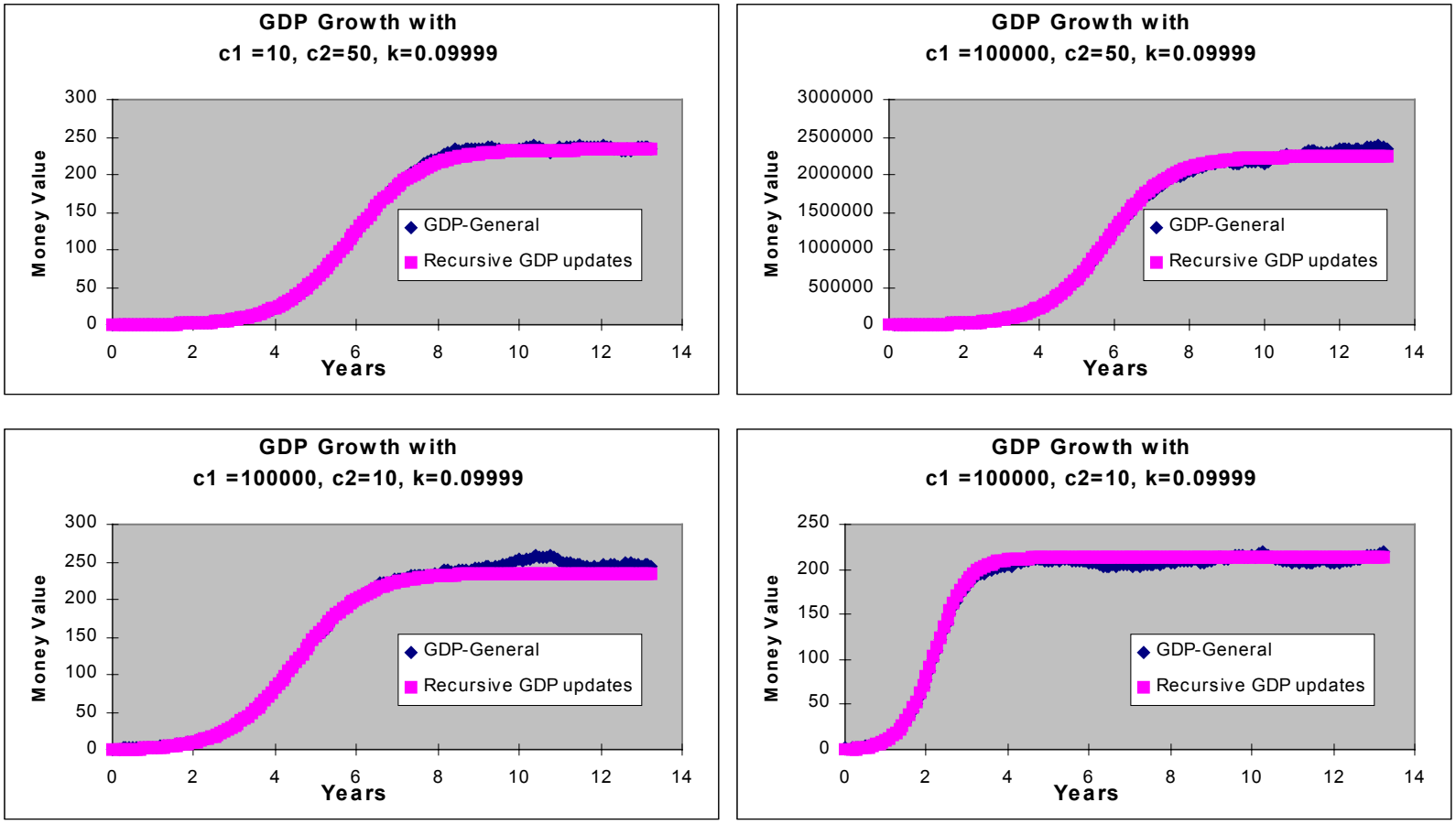


Figure 2: GDP Growth S Curves for Different Parameter Values

This constant can vary with the countries economic and political status. We arbitrary imposed this constant equal to 0.4 in our subsequent simulation experiment. However, under different policy scenarios, an economist can decide the value of this constant or estimate it based on available data. Total investment is then available as IL+IF.

Traded and Non-traded Investment (IT, INT)

Total investment of a country shares traded and non-traded investments. It is well known that these components play an important role in the economic especially in its dynamic movement with international interlinks. For instance non-traded components shares long term benefit to a country whereas traded investment could be short-term and the most vulnerable part of sudden economic movement. Further non-traded investment can be a burden to an economy depending on the phase of economic development. However, actual measurements on traded and non-traded investment may not be readily available but clearly important in our model. Therefore, for the purpose of simulation experiment, we consider the proportion (pt) of traded and non-traded investment. This unknown proportion can vary with various macroeconomic management and policy alternatives yet the factors influence this proportion is unknown. At this stage we surmise that a macro- economist in a country can judge this proportion to a certain degree of accuracy, but for the purpose of our simulation experiment, it is considered that this proportion is p = 0.8. However, we did not restrict our model for an arbitrary constant such as 0.3 or 0.8, and we leave spaces for entering various values or even time varying parameters thus demanding for future research. For instance, one can study the effect of the proportion of traded to non- traded investment on the health of the economic using our model:

Given P_t is known,

$IT = P_t I$ and $INT = (1-P_t) I$

Recursive formula for Simulation of Export and Import (X, M):

In our study, we considered that Import and Export share the economy while holding a strong correlation thus imposing a multivariate system. This multivariate system was modeled as follows.

$$\begin{pmatrix} X \\ M \end{pmatrix}\begin{pmatrix} \alpha_1 & \alpha_2 \\ \beta_1 & \beta_2 \end{pmatrix} = \begin{pmatrix} dx \\ dm \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix}$$

$$\Rightarrow X_t = X_t + dx_t \text{ and } M_t = M_t + dm_t$$

$$\text{it is assumed that } \varepsilon \sim N(0,\Sigma)$$

Notice that the matrix of parameters consists of export driven (alpha) and import driven (beta) components in the above multivariate system.

The estimation of these parameters is quite possible empirically using multivariate structural equation modeling provided that the data on export, import related variables are available.

Resources (G):

We approximated that fixed economic resources are proportional to non-traded investment in our simulation experiment. Once again this approximation requires further refinements with data, and our model generously leave a space for it. For the purpose of simulation studies, we simply considered a constant proportion for estimating initial value of resources, for example 0.07 so that one can study the effect of this proportion on the economy in simulation experiments. Later, we modeled resource growth using the following deterministic relationship:

$$G_t = G_t + P_t X_t + \lambda EX,$$

where, EX being the external money supply to the country. In the above equation, λ is an indicator variable that gets values 1 or 0 indicating external money supply or no external money supply.

Also, it is possible to establish a stochastic model for resource growth, and it was not intended in the present study.

Furthermore, analysis and modeling resource growth of a country require some positive contribution of macroeconomists. Whilst there are many studies on natural resources and their growth (see for example, Berry, Conkling and Ray (1993), dynamic and stochastic changes in Global Economy demand further research and contemporary studies.

Net Foreign Assets (NFA):

We considered a common knowledge that foreign assts (FA) is directly proportional to GDP growth. In our simulation study we considered a proportion of contribution to FA from GDP, and it is possible to adjust this to any pre-assumed value in our model. Hence for simplicity, net foreign assts was modeled in our simulation study as follows.

$NFA = \phi\ GDP - IF$

It is also possible that this proportion varies with economic management alternatives.

Foreign and Local Interest Rates (j,i):

Foreign interest j is in fact a multidimensional variable which is difficult to model as a single entity. However, it is quite possible to model interest rates in related countries separately and then employ in our model. Study of interest rate

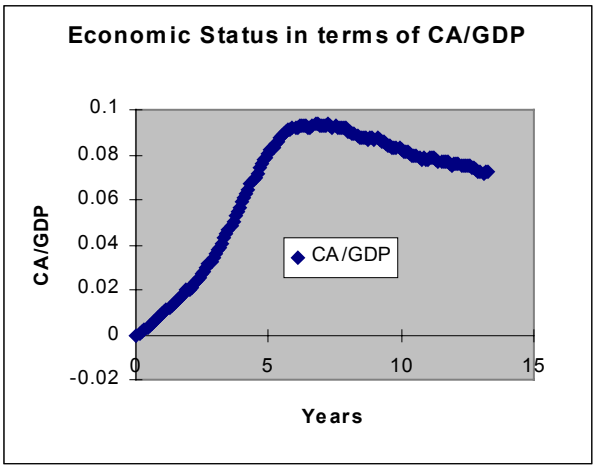
movements in different countries is beyond the scope of this model. Therefore we considered some values for foreign interest rate as a composite variable in our model.

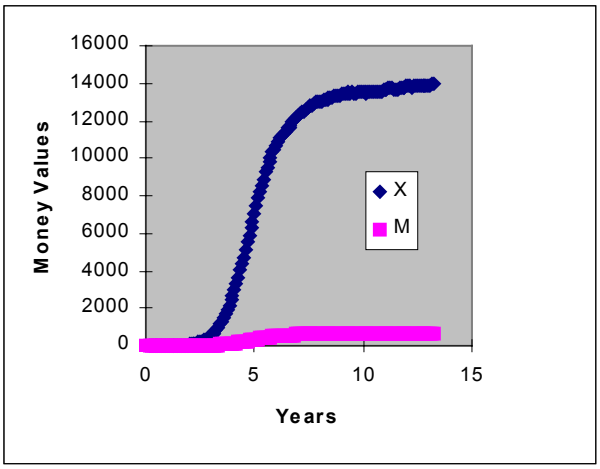
Consequently, national accounts were estimated based on simulated data in our model and these accounts were used to see the signals of economic stability or crisis. Some improvement to our basic model was made considering Government expenses. Here we considered Government as an agent who burrow finance from foreign sources and facilitate repayments and new investments. Clearly foreign burrowing is considered as an accumulation process corrected by government actions. Different scenarios are then tested with our models.

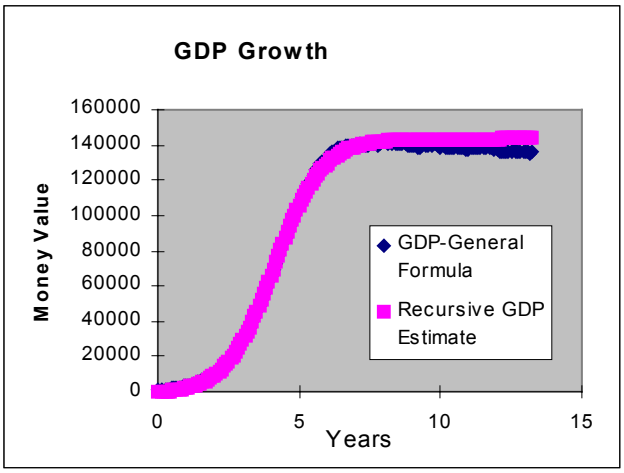
Some Results and Conclusions

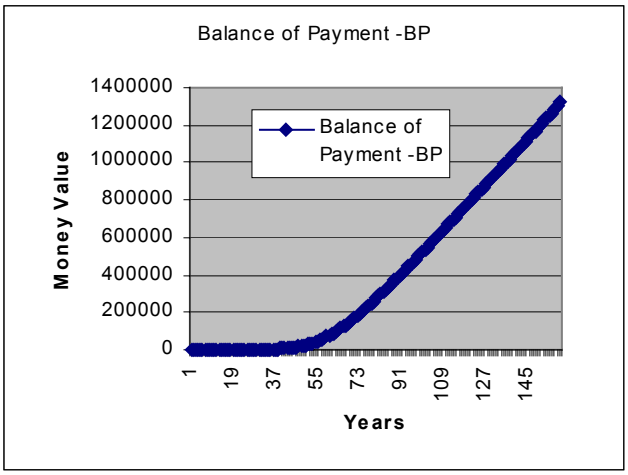
We investigated better economic growth and the slow economic growth using our model. Some simulation experiments on better economic growth are summarized in Exhibit 2.

Exhibit 2: Simulation Result of a Country with Better Economic Growth









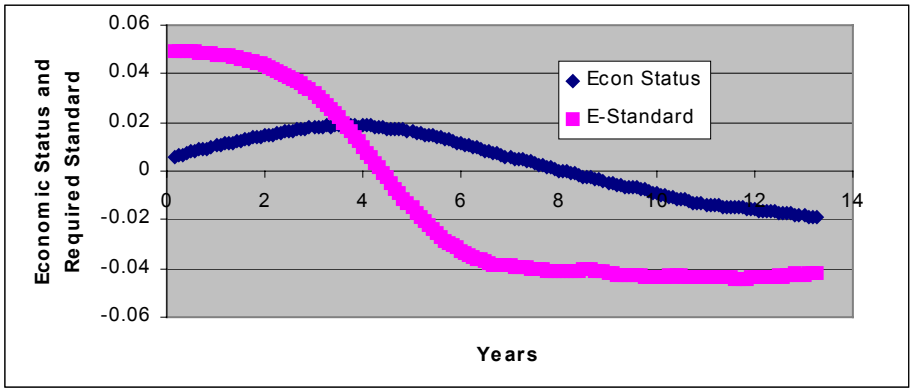
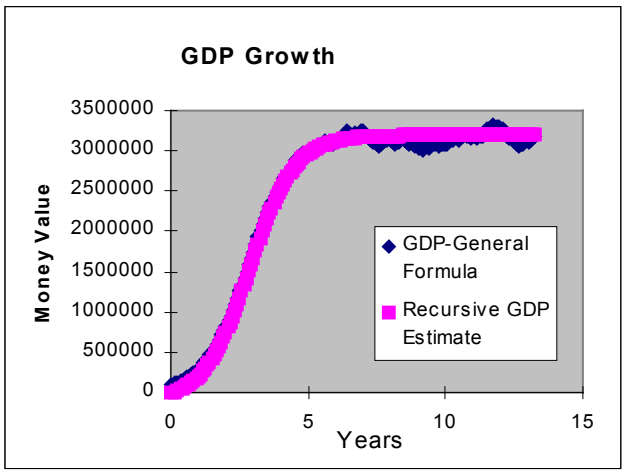
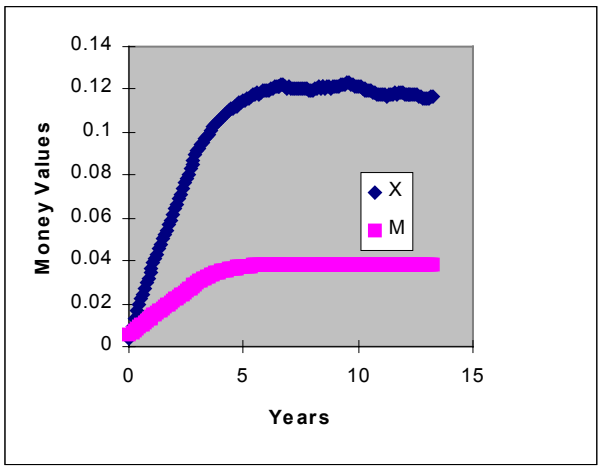
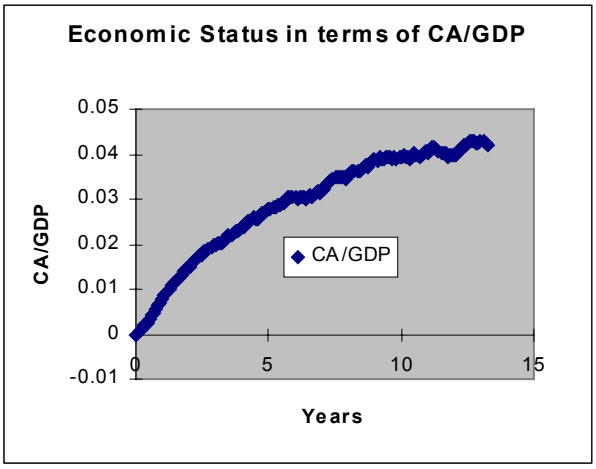
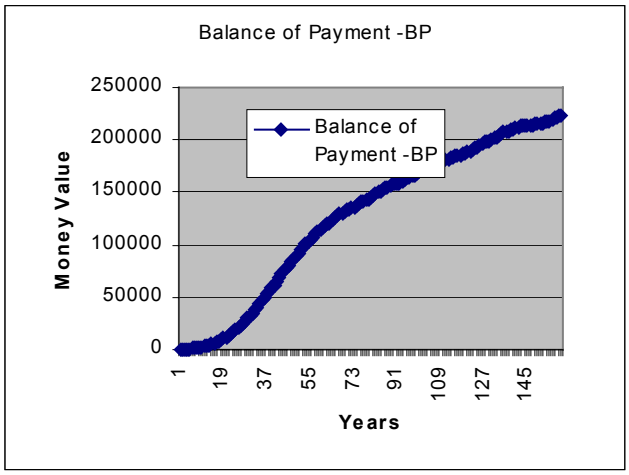


Exhibit 3: Simulation Result of a Country with Poor Economic Growth









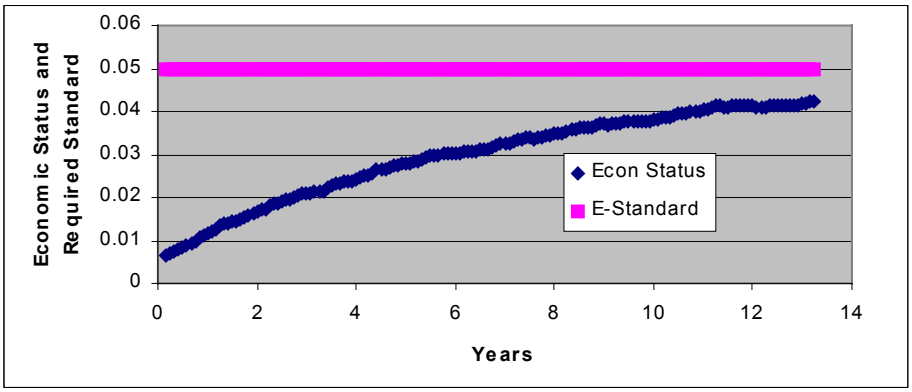
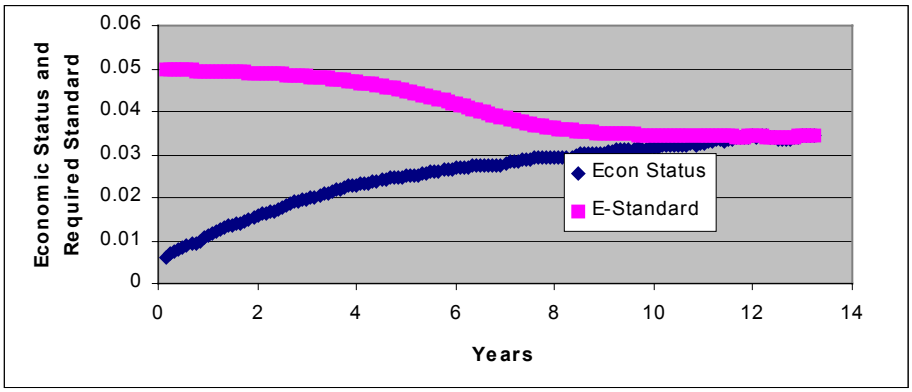


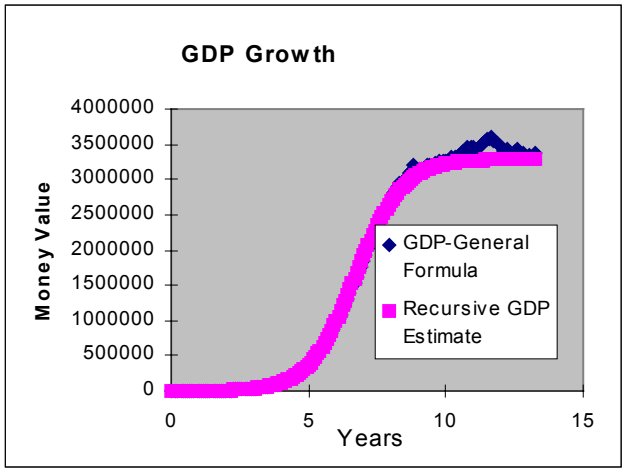
Exhibit 3 shows the result of a poor economic growth according to our model. In this economy, small trade balance, low growth of export compared with imports and poor management of investment, in particular traded to non-traded investment were implanted so that there is a continuous economic retardation.

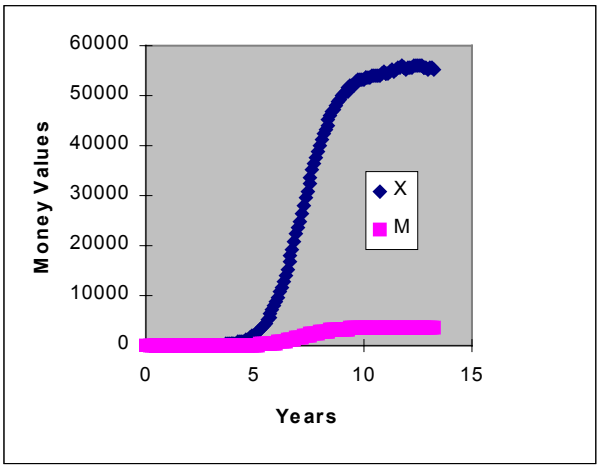
Exhibit 4 provides an economic outlook due to mismanagement in an ideal country with a potentially better economic growth. The mismanagement was done imposing unnecessary foreign burrowing and poor interest rate setting and NFA with foreign investments in lower interest rate countries.

Exhibit 4 Bad Interference of Economic Mismanagement

4a) Before mismanagement:





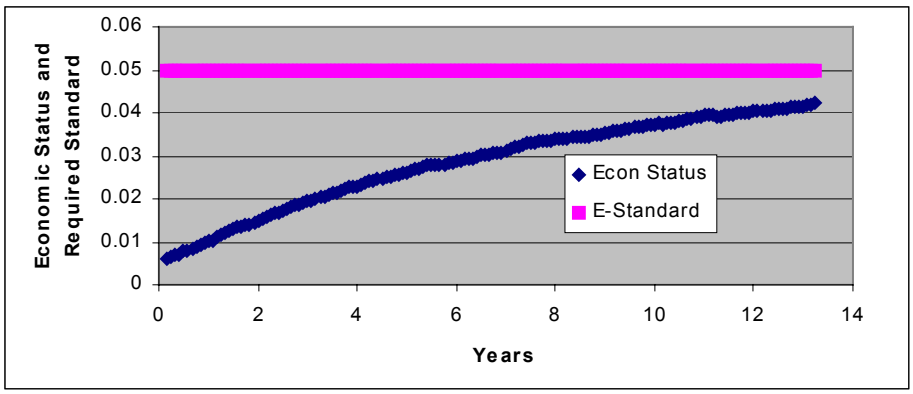


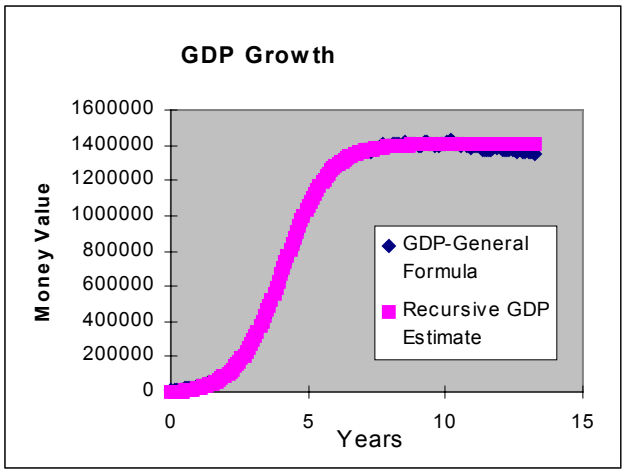
Prior to wrong economic measures, the economy of the above country is growing steadily achieving the economic standard for growth in about 10 years time.

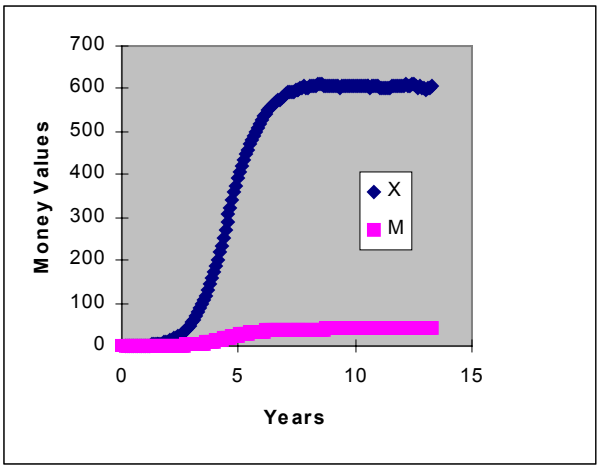
4b) After mismanagement:

The mismanagement was imposed with arbitrary foreign burrowing of $10000000 and a misdeed of $30,0000 together with an increase of interest rate from 3.5% to 7%. Then the simulation results given below shows that the countries economic status are well below the required standard despite its rapid economic growth and expansion of trade balance.

After mismanagement







In sum, our model is a protocol that could be used to study "what if things change" in macroeconomic context.

In the following Result 1, we provide the mathematical inequality for selecting parameters η, i and p.

Result 1

$$\eta/i\left(1+p\right)<1$$

Proof of this result is given in Appendix 1.

In Appendix 2 is the mathematical condition established for selecting parameters for better economic growth or slow economic growth in relation to our simulation experiment. This condition is summarized in Result 2

Result 2

$ej\phi-\frac{p\eta}{i}>0.05\ -\frac{X-M}{GDP}$ => Better economic growth

$ej\phi-\frac{p\eta}{i}<0.05\ -\frac{X-M}{GDP}\Rightarrow$ Slow Economic Growth

It follows that

$$\left\{\begin{array}{c} ej\phi-\frac{p\eta}{i}\ Economic\ Growth \\ 0.05\ -\frac{X-M}{GDP} Required\ economic\ condition \end{array}\right\}\ \begin{array}{l} ej\phi-\frac{p\eta}{i}>0.05\ -\frac{X-M}{GDP}\Rightarrow Better\ Economy \\ ej\phi-\frac{p\eta}{i}<0.05\ -\frac{X-M}{GDP}\Rightarrow Poor\ Economy \end{array}$$

According to our model, economic mismanagement could be the reason for Asian Crisis, and the effect of bad economic management could last for a considerable period of time. Remedial actions in form of better economic and political measures are essential to mitigate the effect of financial crisis. These results agree with actual data on economic status of crisis countries. Any developing country could be a highly potential candidate for next financial crisis should they exercise bad economic and political management, and developed country being no exception.

In conclusion, what we have presented here is a crisis prediction model built on the foundations of recursive macroeconomic theory. The tool allows macro-economists for testing various scenarios of economic management. While it does not replace the macro-economists role or provide them with a direct solution to economic crisis, it allows testing and monitoring of various indicators that could affect a crisis. The model lays the foundation for future research on better economic management using the recursive model. The most characteristic feature of our model is that it considers the importance of mixing theoretical modeling and empirical investigations. For instance, simulated data for all variables can be replaced with actual data at any point of time within this model. Provided that the model is tuned to a particular country, it could be used to solve economic management problems in any country together with expertise of local macroeconomists. The authors are in the processing of making a user-friendly tool suitable for practitioners.

Appendix 1:

It is known that I > 0.

$IT = P_t I \text{ and } INT = \left(1 - P_t\right)I$

$\Rightarrow P_t < 1$

Notice that,

$I = \frac{GDP.\eta}{i} + \frac{p.GDP.\eta}{i}$

$= \frac{\eta}{i}\left(1 + p\right).GDP$

$\frac{\eta}{i}\left(1 + p\right) < 1 \text{ or } \eta\left(1 + p\right) < i$

$\text{for } GDP_t = G_t + IT_t + INT_t \text{ and } G > 0 \text{ complete the proof}.$

Appendix 2:

$\frac{CA}{GDP} > 0.05$

$\Rightarrow \left(X_t - M_t + ejNFA\right) > 0.05GDP$

$\Leftrightarrow ejNFA > 0.05GDP - \left(X_t - M_t\right)$

$\Leftrightarrow \left(ej\phi GDP - \frac{pGDP\eta}{i}\right) > 0.05GDP - T$

so,

$\left(ej\phi - \frac{p\eta}{i}\right) > 0.05 - \frac{T}{GDP} \text{ complete the proof}.$

because,

$\eta\left(1 + p\right) < i \text{ from Result } 1$

letting

$p = {}^{i}/_{\eta} - 1,$

$\left(ej\phi - 1 + \frac{\eta}{i}\right) > .05 - \frac{T}{GDP}$

This implies that lower the local interest rate smaller the recession.

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Acknowledgement

Authors acknowledge the support given by their host institutes. First author acknowledges the visiting research opportunity provided by the Graduate School of International Management, International University of Japan and the seed grant awarded by the Faculty of Management, University of Western Sydney and support given by the school of quantitative methods and mathematical sciences. We are thankful to the organizing committee of the International Conference for their positive encouragement