A Value at Risk Approach to Fiscal Sustainability: A Case Study for Thailand

BY

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Abstract of the Dissertation

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During the 90's, a series of international financial crises caught many financial institutions and governments flatfooted and somewhat defenseless against speculative attacks. Many institutions were surprised by these crises and even their magnitudes. This has left many economist and financial experts searching for better early warning systems. This dissertation looks at the various early warning systems economists and financial experts are developing and their effectiveness. In particular, this dissertation looks at the IMF early warning signaling approach and discusses some of the difficulties with this approach. A key problem with this approach is the lack of correlations between the signals. This dissertation then looks at the Monte Carlo Simulation Value at Risk approach to fiscal sustainability to assess this tools ability to provide advance warning of potential crisis. This approach is applied to the fiscal sector of Thailand to assess the effectiveness of the model. In reviewing the approach, what was discovered was that, although, this approach takes into account the correlations between the various risk

factors; it does not fully take into account the structural difference in applying such an approach to the fiscal sector of a country as compared to a financial institution's portfolio of investments. The approach also does not fully account for the monetary and fiscal policies of a country. Finally, this dissertation looks at the various risk management issues surrounding the Value at Risk approach and the implications that these issues have upon fiscal sustainability and financial crisis.

Dedication

This dissertation is dedicated to several people. I would like to dedicate this dissertation to my mother and father, Miriam Beverly Lindo and Osmond Alford Lindo Sr., and to my sister, Anastasia Beverly Lindo and brother, John Alford Lindo. I would also like to dedicate this dissertation to two very special women. They are, Rhonda Vonshay Sharpe and Marbelle Laude Nebres. Thank you for all for your help and support. Thank you.

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I.) Introduction

During the 90's, a series of international financial crises caught many financial institutions and governments flatfooted and somewhat defenseless against speculative attacks. Many institutions were surprised by these crises and their magnitudes. This has left many economist and financial analyst searching for answers for why these crises were not anticipated. As a result many have blamed the various rating agencies such as Moody's and Standard & Poors for not providing sufficient warnings for many of these crises. (Goldstein, Kaminsky, and Reinhart 2000 [49]; IMF 1999 [57]; Radelet and Sachs, 1998 [50]; Reinhart 2002 [51]). In response to these accusations, both Moody's and Standard & Poors claim that their ratings do provide advance warnings when the likelihood of a crisis increases or may occur, but that it is very much dependent upon the type of crisis that is most likely to occur. As Amadou N.R. Sy [52] states it "The main line of defense given by rating agencies is that their ratings are meant to provide an assessment of the likelihood of default, not the likelihood of currency crisis." As for the meaning of default, Standard & Poors defines it as "The failure of an obligor to meet a principal or interest payment on the due date contained in the original terms of the debt issue." Yet as Reinhart (2002) [51] notes, if it weren't for the assistance of the IMF and the international community at large "There is little doubt that Mexico, Korea, Thailand, and Turkey would have produced a sovereign default." Given this fact, many now believe that relying upon these rating agencies to provide an advance warning of a brewing crisis would be unwise.

The Asian financial crisis clearly demonstrated the need to develop early warning systems which are better equipped to assess a government's ability to manage its public debt and any possible contingent liabilities it may have to deal with. With this in mind, the IMF, the World Bank, and various other global financial institutions are developing systems that can identify in advance any possible contingent liability and at the same time assess its effect upon the public sector. The fact that a country must ultimately confront any contingent liability that may lead to the collapse of its economic system has led the IMF to develop a system of indicators that are used to monitor the health of a country's financial sector. The idea behind this approach is that "various indicators that monitor financial state of a country's financial sector behave differently on the eve of a crisis." This signaling approach is part of the process which the IMF conducts under its Financial Sector Stability Assessment.

While the IMF has focused on developing this approach as part of an overall early warning signaling system, others are looking at tools normally reserved for the domain of corporate finance to assess fiscal sustainability in the context of these contingent liabilities and the government debt. One such tool that many government risk managers are implementing is the Value at Risk approach. This approach has the advantage of taking into account the correlation between various factors such as a country's exchange rate and the domestic interest rate that impact both the fiscal and financial sector of a country. In a paper by Barnhill and Kopits [9], the authors apply such an approach to the country of Ecuador with some promising results. This dissertation will apply their approach to the fiscal sector of Thailand as a means evaluating whether this approach can be effectively used as an early warning system.

Thus the chapters of the Dissertation are:

II.) Overview of IMF early warning system for financial problems

III.) Value at Risk Overview and Background

IV.) Assessment of Barnhill and Kopits' Model

V.) The application of VaR model to the Fiscal sector of Thailand

VI.) Model Conclusion

II.) Overview of IMF early warning system for financial problems

The early warning system that the IMF has been developing is based on a set of financial indicators designed to provide signals when a particular sector or sectors of a country's financial system enter into a zone of danger that may adversely affect the overall well being of the economy. These indicators are constructed to capture the salient features of that sector and are used by the IMF in its Financial Sector Assessment Program under the umbrella of Financial System Stability Assessment. This assessment is usually conducted with the specific goal of timely identifying possible vulnerabilities in the financial system in a timely fashion so that stabilizing adjustments can be made. The impetus for developing such a program was the 1997 Asian Crisis. This crisis lead to a consensus that better cooperation and coordination between all pertinent parties such as the IMF, the World Bank, and The Bank for International Settlements (BIS) were needed to help countries better identify potential weakness within their financial systems (IMF 2000) [59]. Thus in May, 1999, with the hope that such cooperation/coordination would help in preventing future international financial crises from occurring, the Financial Sector Assessment Program was launched.

Under the Financial Sector Assessment Program, the first step in assessing the weakness in a particular sector of a country's financial system involves collecting a relevant data set for that sector. For example, given the IMF's and the World Bank's desire to assess vulnerabilities in the banking sector involves the collection of the following data set has been recommended by the IMF (IMF 2000) [59]:

Annual data for recent periods
General
Basic balance sheet and income statement data, in particular, capital, assets, risk-weighted assets, profits, and net interest income
Credit risk
Breakdown of total loans by classification categories
Loan loss provisions (total or by the above classification groups)
Breakdown of loans by currency of denomination(and by classification)
Breakdown of loans by Sectors (and by classification)
Interest rate risk
Maturity or repricing structure of assets and liabilities and off-balance sheet positions
Holdings of debt securities by banks, and the duration of these holdings
Exchange rate risk
Currency breakdown of assets, liabilities, and off-balance-sheet positions
If substantial, off-balance-sheet positions, and other information (such as deltas of Fx options) may be needed
Interbank contagion risk
Uncollaterized lending (and similar) exposures between bank i and j, for all pairs of banks
Other risks
Depending on the features of the financial system, may include more detailed data on exposures such as equity holdings, real estate exposures (including collateral), commodity exposures
Other data
Selected macroeconomic indicators (e.g., interest rates, exchange rates, output growth rates)
Selected data on borrowers (e.g., corporate sector leverage, by economic sector)

Source: IMF's Financial Sector Assessment Program Handbook (2000) [59]

Once this comprehensive data set is gathered, the IMF constructs either an aggregate portfolio to represent the country's financial system or a set of portfolios to represent key institutions in the financial system (IMF 2000) [59]. The IMF then identifies possible weaknesses in the system and applies various stress tests as a means of identifying how these vulnerabilities behave under duress. The key fact is that these possible vulnerabilities are identified in advance by expert analysis whereupon stress testing is applied by the IMF to estimate the possible changes that may occur within the constructed portfolio. These estimated changes are then recorded as a means of assessing how shocks are dispersed throughout the system. These changes are also used in constructing financial soundness indicators which are then compared against benchmarks to determine the potential of financial distress within that sector or system (IMF 2000) [59]. By understanding how various shocks propagate throughout the system, breaking points can be identified and corrected before the fruition of a crisis.

In stress testing the financial system, the IMF creates a scenario which is then applied either to an aggregate portfolio or is applied to multiple portfolios (IMF 2000) [59]. The application of the created scenario is within the context of macroeconomic framework. For example, in the Financial Sector Assessment Handbook, the IMF develops the following scenario within a particular hypothetical macroeconomic context.

Example 1:

Suppose that housing prices had risen sharply on the strength of rapid employment growth, rising household disposable incomes, and low interest rates, thereby fuelling a mortgage-lending boom. Analysis of bank balance sheets and income statements show (sic) a strong dependence on mortgage lending both in the stock of assets and in the flow of income. A possible scenario could involve a rise in unemployment, a fall in disposable incomes, and a sharp rise in interest rates affecting the debt servicing capacity of households. The outputs from a macro model could provide a range of information on employment, real incomes, prices and interest rates, which could be used to formulate a specific stress test for bank balance sheets.[1]

[1]. Appendix D, Stress Testing example. Pg. 382

In applying a stress test the IMF would then simulate a set of possible changes in prices, disposable income, and interest rate, apply these changes to the assets and liabilities in the portfolio, and record the resulting changes that occur in this aggregate portfolio of assets and liabilities for the banking system. Once these aggregates are calculated they would then be mapped back to the individual balance sheets of the financial institutions so these institutions can assess where the weaknesses are within their respective balance sheets. This method of stress testing is called the Top-Down approach (IMF 2000) [59].

The other approach, known as the Bottom-up approach, entails applying the stress test directly to each individual bank's portfolio of assets and liabilities, translating these changes back to the balance sheets of these banks, and then aggregating up to the national level. This approach is the approach that is most typically used due to the relative ease of accessing data for a representative set of banks rather than for the entire system (IMF 2000) [59]. The estimates are then aggregated upwards to understand how a shock might be dispersed throughout the system.

In addition to evaluating the propagation of various shocks throughout the system, the IMF also uses the aggregates it collects to construct statistical indicators to evaluate the overall health of the system. These indicators are used by the IMF to provide an early warning of a possible financial system crisis. The ways in which these indicators are used within an early warning system will be discussed later on. In addition, these Financial Soundness Indicators are also compared to Benchmarks to further identify potential trends and flaws within the system. An interesting facet of these indicators is their ability to be incorporated in sensitivity analysis. For example, in the IMF Financial Assessment

Program Handbook, sensitivity analysis is applied to assess the exchange rate risk in a bank's net open position. The Basel Accord defines a bank's net open position as the sum of net spot position + net forward position + net future income. The value of this sum is defined in terms of the domestic currency. As such, a depreciation of the exchange rate lowers the value of the sum if it is positive. Using the terminology in that Handbook, let

F=net spot position

C=the amount of bank capital

A_{RW}= its risk-weighted assets.

Assume that there is an equal proportional change in the value of the bank's net spot position and a change in the exchange rate so that

$$\frac{\Delta e}{e} = \frac{\Delta F}{F}.$$

Also assume that there is a 1-1 relationship between the change in capital and the change in a bank's net spot position so that

$$\frac{\Delta C}{\Delta F} = 1.$$

Given the above assumption made in the Handbook, the IMF can now assess how a depreciation affects a Bank's capital to risk-weighted asset ratio, $\frac{C(e)}{A_{RW}}$. The effect of exchange rate depreciation can now be expressed in terms of one of the financial soundness indicators $\frac{F}{e}$ previously estimated. In the following symbolic computation, a discretization of the quotient rule for derivatives, which is not illustrated in the Handbook, this effect is shown.

$$\frac{\Delta\left[\frac{C(e)}{A_{RW}(e)}\right]}{\Delta e}=\frac{\frac{\Delta[C(e)]}{\Delta e}A_{RW}-C(e)\frac{\Delta(A_{RW})}{\Delta e}}{A_{RW}{}^{2}}$$

$$=\frac{\frac{F}{e}A_{RW}-C(e)\frac{\Delta(A_{RW})}{\Delta e}}{A_{RW}{}^{2}}$$

$$=\frac{\frac{F}{e}A_{RW}-C(e)\frac{\Delta(A_{RW})}{\Delta C}\frac{\Delta C}{\Delta e}}{A_{RW}{}^{2}}$$

$$=\frac{\frac{F}{e}A_{RW}-C(e)\frac{\Delta(A_{RW})}{\Delta C}\frac{F}{e}}{A_{RW}{}^{2}}$$

$$=\frac{1}{e}\frac{F}{C}\frac{C}{A_{RW}}\left[1-\frac{C}{A_{RW}}\frac{\Delta A_{RW}}{\Delta C}\right]$$

The importance of this computation is the expression of a key banking indicator in terms of various IMF financial soundness indicators (IMF 2000) [59].

In a survey by Owen Evans, Alfredo M. Leone, Mahinder Gill, and Paul Hilbers [25], the authors provide further insight into which IMF indicators are considered the most relevant for assessing the financial soundness of a country's financial system. The authors divide these indicators into two categories, aggregate microprudential indicators and macroeconomic indicators. Indicators categorized as aggregate microprudential indicators measure the financial soundness of individual institutions within the financial system. On the other hand those indicators categorized as macroeconomic indicators measure the financial soundness of the overall system. The indicators in each category are then subdivided into several groups. The further subdivision of aggregate microprudential indicators into smaller groups is based on a framework known as the

CAMELS framework. The CAMELS acronym stands for **C**apital adequacy, **A**sset quality **M**anagement soundness, **E**arnings and profitability, **L**iquidity, and **S**ensitivity to market risk. This rating system is used by FDIC regulators to rate the financial health of an individual bank. In the CAMEL ratings system a rating of 1 or 2 for a bank is considered good but a rating of 3 of 4 is considered a sign of trouble ahead.[2] The idea is to use this framework as a guide to assess the financial health of a financial system. Additionally, within the aggregate microprudential indicators category there is a subcategory called market based indicators. The reason for further subdividing the aggregate microeconomic indicators category into smaller groups is the fact that the indicators within each group can better measure particular risks that affect the financial soundness of individual institutions.

As such, let us take a further look at the risks that the indicators in each group measure. Indicators in the capital adequacy group measure exchange rate, credit, and interest rate risks. One such indicator is the $\frac{capital}{risk\ weighted\ assets}$ ratio. As previously mentioned, this ratio measures the amount of capital available given a bank's risk adjusted assets. A decline in the trend of this ratio may signal to the respective authorities and to investors that banks are increasingly exposed to various risks. Of particular importance is whether or not a country reports the composition of a bank's capital in terms of Tier 1, Tier 2, or Tier 3 capital. By BIS Standards Tier 1, Tier 2 and Tier 3 capital are defined as following:

- Tier 1 capital is defined as the book value of all stock plus retained earnings

[2] (Lopez, 1999) [44]

- Tier 2 capital is the sum of loan loss provisions

- Tier 3 capital consists of subordinated short-term debt of maturity length two years.

The weights for each type of asset are based on its credit risk. As such by the Basil Accord, banks should set aside Tier 1 capital in the amount of 4% of their risk adjusted assets.

Indicators in the asset quality subcategory measure the risk of insolvency for financial institutions. One such indicator is the $\frac{debt}{equity}$ ratio. An increase is this ratio signals to observers that a bank might not have enough equity to cover its financial obligations. The indicators in the management soundness category measure the soundness of management decisions. For example, expense ratios provide clues to the efficiency of bank operations. Indicators in the earnings and profitability category monitor the profitability of banks and corporations in the economy. For example, the return on equity indicator which is $\frac{net\ profit}{equity}$ monitors the profitability of the financial sectors equity. An increase in this indicator is a sign of increasing profitability either in the overall sector or in certain subsectors. A very important set of indicators are liquidity indicators. These indicators are key indicators in monitoring the activities of the Central Bank and the relationship between various banks in the economy. For example, Central Bank credit to financial institutions can provide signals of potential solvency problems in the system. Additionally such indicators as interbank rates may be used to signal which institutions are considered vulnerable to financial distress. Finally, sensitivity to market risk indicators may be used to measure how sensitive a bank's balance sheet is to market volatility. The sources of volatility may be exchange rate fluctuations, interest rate risk, equity price risk, and commodity price risk.

The indicators in the macroeconomic category are also subdivided into the groups pertaining to economic growth, balance of payments, inflation, interest and exchange rates, lending and asset price booms, contagion effects, and other factors. Indicators of economic growth of the overall economy help to signal the capacity of domestic borrowers to service their financial obligations. As such a slowdown in the economy can increase the number of nonperforming loans on a bank's balance sheet. Balance of payments indicators such as those used to monitor a country's current account or its terms of trade are vital in signaling potential vulnerabilities due to large external capital inflows and or changes in terms of trade. Inflation indicators help to monitor price volatility and its corresponding effect on portfolio investments. As noted by the authors, lending and asset booms have often preceded severe financial crises. Thus, indicators that monitor lending and asset price booms are helpful in signaling the advent of such events. Listed in table 1 is a summary of the financial indicators deemed by the authors to be essential in assessing the health of a financial system.

Table 1

Summary of Macroprudential Indicators	
Aggregate Microprudential Indicators	**Macroeconomic Indicators**
Capital Adequacy	**Economic Growth**
Aggregate Capital Ratios	Aggregate growth rates
Frequency distributions of Capital Ratios	Sectoral slumps
Asset Quality	**Balance of Payments**
Lending institutions	Current Account Deficit
Sectoral credit concentration	Foreign exchange reserve adequacy
Foreign currency denomination lending	
Nonperforming loans and provisions	
Risk profile of assets	
Connected lending	
Leverage ratios	
Borrowing entity	**Inflation**
Debt-equity ratios	Volatility
Corporate profitability	
Other indicators of corporate conditions	
Household indebtness	
Management Soundness	**Interest and Exchange Rates**
Expense ratios	Volatility in interest and exchange rates
Earning per employee	Level of domestic real interest rates
Growth in number of financial institutions	
Earning and Profitability	**Lending and Asset price booms**
Return on assets	Lending booms
Return on equity	Asset price booms
Income and expense ratios	
Structural profitability indicators	
Liquidity	**Contagion effects**
Central Bank credit to financial institutions	Trade spillovers
Segmentation of interbank rates	Financial market correlation
Deposits in relation monetary aggregates	
Loan-to-deposits ratios	
Maturity structure of assets and liabilities	
Measures of secondary market liquidity	
Sensitivity to Market Risk	**Other factors**
Foreign exchange risk	Directed lending and investment
Interest rate risk	Government recourse to the banking system
Equity price risk	Arrears in the economy
Commodity price risk	
Market-based indicators	
Market prices of financial instruments, including equity	
Credit ratings	
Sovereign yield spreads	

Source: IMF Macroprudential Indicators of Financial System Soundness (April 2000) [25]

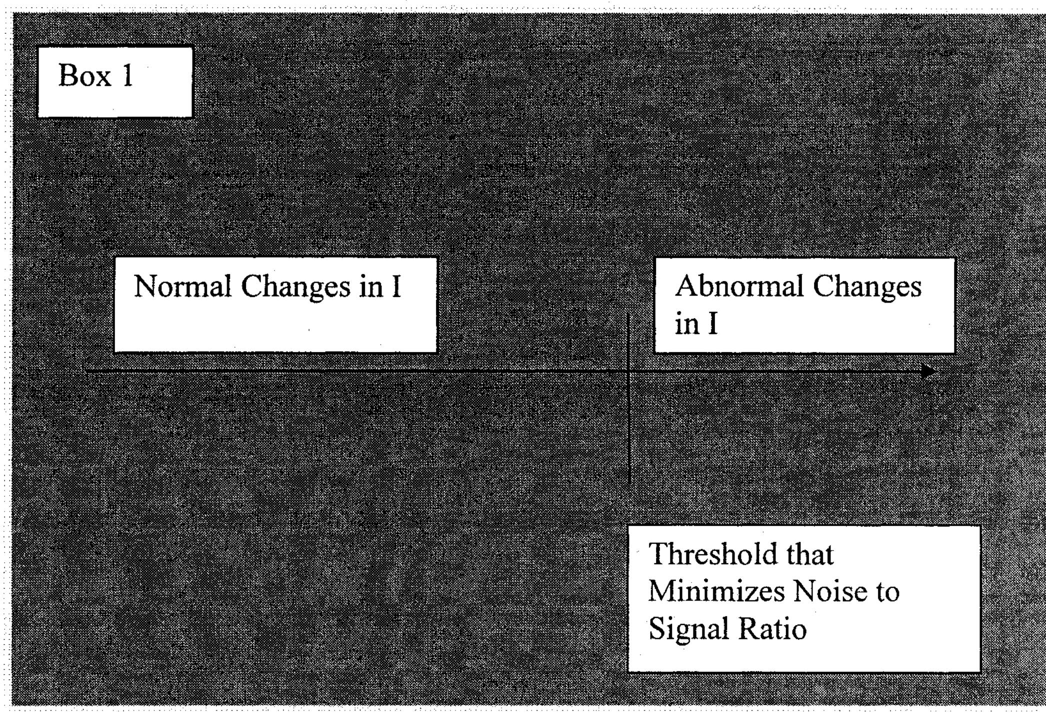
While the authors give an overview of which indicators are important in assessing the health of a country's financial system, the issue that needs to be addressed is how these indicators are used by the IMF within the context of an early warning system. The utilization of the IMF indicators in an early warning is based on the work of Kaminsky, Lizondo, and Reinhart (1997) [39]. In their paper, the authors Morris Goldstein, Graciela L. Kaminsky, and Carmen M. Reinhart [49] show how indicators that predict banking and currency crises are utilized. Many of these indicators are also used in assessing the health of a financial system. In determining the usefulness of these indicators for predicting financial crises the authors first determine the dates when each type of crises began. These dates are then used to break up the data so that the early warning system can be calibrated and tested. In order to gain a clearer picture of how much advance warning time an indicator provides, the authors used monthly data instead of annual data whenever possible.

In the Kaminsky, Lizondo and Reinhart's [39] view, an economy usually behaves differently on the eve of a crisis, which means the indicators should signal changes in economic behavior. This nonparametric "signaling" approach, first developed by Kaminsky and Reinhart (1996) [40] to detect currency crisis, is used to detect such changes in the economy. This approach depends on specifying a signaling window, usually of 18 to 24 months in duration. If, during that time frame, the indicator provides a signal and a crisis follows, then that signal is considered a good signal. On the other hand, if the indicator provides a signal and a crisis does not follow, then that signal is considered a bad signal. An indicator emits a signal when a change in that indicator during that time frame exceeds an "optimal" threshold. One of the key concepts in determining the optimal threshold value is the noise-to-signal ratio which means the number of false signals over the number of good signals. To determine the optimal threshold for an indicator the authors conduct a hypothesis test. The null hypothesis is the range of values that indicate the economy is in a “state of tranquility”. The alternative hypothesis is the range of values that indicate that a crisis is imminent. The critical value or threshold is defined in terms of a percentile.

H_o : Economy in tranquil state when $| \Delta I | \leq I^{th}$ percentile

H_a : Economy on eve of crisis when $| \Delta I | > I^{th}$ percentile

This threshold or percentile divides those changes in the value of the indicator that are considered normal for an economy, that is, in a “state of tranquility”, from those changes that are not normal for an economy that is supposedly in a state of tranquility. For each indicator the optimal threshold is calculated by minimizing the noise-to-signal ratio. This means a search is done until the threshold that gives the smallest number of false signals to good signals is found. Further, the size of the rejection region can vary only between 10 percent and 20 percent (Goldstein, Kaminsky, and Reinhart 2000) [49]. In other words the optimal threshold that minimizes the noise-to-signal ratio must lie either between the 80th percentile and 90th percentile or between the 10th percentile and the 20th percentile. This is illustrated in the box 1.



For example, looking at the current account balance/GDP ratio the optimal threshold is the 20th percentile.[3] In others, any change in this indicator that is worse than 80 percent of all changes is considered a signal that a crisis may be imminent (Goldstein, Kaminsky, and Reinhart 2000) [49].

Once the thresholds for each indicator are determined, the actual values that delineate normal changes from abnormal changes for each individual country can be calculated. The thresholds remain constant across countries but the values differ for each country. For example, Goldstein, Kaminsky and Reinhart [49] found that in looking at the ratio of Short-term capital inflows/GDP, the optimal threshold value was the 85th percentile. However the authors' note that in country that is a low capital importer country, that percentile may correspond to an increase in capital inflow of ½ of percent of

[3] Assessing Financial Vulnerability (2000), Goldstein, Kaminsky and Reinhart, pg. 29

GDP.[4.] On the other hand, for a country that is a high capital importer, the 85th percentile may correspond to a change in capital inflow of 3% of GDP.[5]

Once the thresholds are determine, then the probability that the indicators predict a crisis can be found. To do this the authors construct a 2 X 2 frequency table.

Table 2

	Crisis occurs in the following 24 months	No crisis occurs in the following 24 months
Signal	A	B
No signal emitted	C	D

Source: Goldstein, Kaminsky and Reinhart (2000) pg. 30 [48]

From frequency table 2, the following probability can be calculated for each indicator.

The unconditional probability of a crisis is:

$$P(Crisis) = \frac{(A+C)}{(A+B+C+D)}.$$

The probability of a crisis, conditional on a signal is:

$$P(Crisis|Signal) = \frac{(A)}{(A+B)}.$$

The marginal contribution of the signal for predicting a crisis is:

$$P(Crisis|Signal) - P(Crisis)$$

This table can also be used to tabulate the noise to signal ratio. This ratio in terms of the table is:

$$N/S = \frac{\left[\frac{B}{(B+D)}\right]}{\left[\frac{A}{(A+C)}\right]}$$

[4]. Morris Goldstein, Graciela L. Kaminsky, and Carmen M. Reinhart (2000) pg.28

[5] Morris Goldstein, Graciela L. Kaminsky, Carmen M. Reinhart (2000) pg. 28 [48]

The proportion of crisis that accurately is called is defined as

$$PC = \frac{A}{(A+C)}.$$

In Table 3 and Table 4, the authors present the following results for the indicators used to predict banking crises and for the indicators used to predict currency crises.

Table 3 Ranking the monthly indicators: banking crises

Indicator	Noise-to-Signal	Percent of crises accurately called	$P(Crisis \mid Signal)$	$P(Crisis \mid Signal) - P(Crisis)$	Rank in Kaminsky (1998)	Difference In Rank.
Real exchange Rate	0.35	52	24.0	**14.1**	1	0
Stock Prices	0.46	76	23.4	11.2	3	0
M2 Multiplier	0.46	63	18.3	9.0	4	0
Output	0.54	90	17.3	7.2	5	0
Exports	0.68	79	14.3	4.7	7	+1
Real interest rates	0.68	96	16.8	4.2	6	-1
Real interest rate differential	0.73	100	15.6	3.7	8	0
Bank Deposits	0.73	64	12.9	3.1	9	0
M2/reserves	0.84	72	11.4	1.7	10	0
Excess real M1 balances	0.88	44	11.0	1.2	13	+2
Domestic credit/nominal GDP	0.89	46	10.9	1.1	11	-1
Reserves	0.92	83	10.7	0.8	12	-1
Terms of Trade	1.01	92	11.6	-0.1	14	0
Lending-deposit interest rates	1.48	56	8.3	-3.5	15	0
Imports	1.75	64	6.0	-4.1	16	0

Source: Goldstein, Kaminsky, and Reinhart(2000) [49] and Kaminsky(1998)

Table 4 Ranking the monthly indicators: currency crises

Indicator	Noise-to-Signal	Percent of crises accurately called	$P(Crisis \mid Signal)$	$P(Crisis \mid Signal) - P(Crisis)$	Rank in Kaminsky (1998)	Difference In Rank.
Real exchange Rate	0.22	58	62.1	**35.2**	1	0
Banking crisis	0.32	100	46	17.0	2	0
Stock prices	0.46	66	47.6	18.3	4	1
Exports	0.51	80	42.4	15.0	3	-1
M2/reserves	0.51	75	42.3	14.9	5	0
Excess real M1 balances	0.57	71	43.0	12.5	6	0
Reserves	0.57	57	40.1	12.3	7	0
M2 multiplier	0.58	72	38.9	12.2	8	0
Domestic credit/nominal GDP	0.59	72	39.2	11.6	9	0
Excess real M1 balances	0.68	57	35.6	8.3	10	0
Domestic credit/nominal GDP	0.74	77	35.4	6.5	11	0
Terms of Trade	0.77	89	32.0	5.5	12	0
Imports	0.87	59	30.1	2.9	14	1
Real Interest rates	1.00	86	26.1	-0.1	12	-1
Lending-deposit interest rates	1.32	63	24.4	-4.8	16	1
Bank deposits	1.32	43	22.3	-5.2	15	-1

Source: Goldstein, Kaminsky, and Reinhart(2000) [49] and Kaminsky and Reinhart(1999) [40] (In Appendix A, a description of how the indicators in Table 3 and 4 are constructed is described.)

In Table 4, the relevant top three indicators for predicting a currency crisis using monthly data are the real exchange rate, whether or not a country is in the midst of a banking crisis, and the change in export volume. Similarly, from Table 3 the top three indicators that are relevant to predicting banking crises are the real exchange rate, stock prices and the M2 multiplier. While the real interest rate differential predicts 100% of all banking crises, its noise-to-signal ratio is much higher than that of the other three. This means this indicator emits many more false signals than good signals in relation to the other indicators. Note that as the noise-to-signal ratio approaches one, the number of false signals is almost the same as the number of good signals.

A.) Critique of IMF early warning system

In critiquing the IMF early warning system, the first observation is that the nonparametric indicator "signaling" approach does not lend itself readily to testing the statistical significance of the indicators. One cannot calculate the standard error or the variance of the statistics because the optimal threshold value is based on a search criterion that is somewhat subjective, because the goal is to minimize the noise to signal ratio. While this minimization may be optimal in determining whether or not an indicator emits too many false signals to be effective, the cost of such a minimization process is in terms of the cost involved in cleaning up the crisis which the signal missed (Demirguc-Kunt, Detragiache, 1999) [19]. This is the trade off between a Type I and Type II error. A Type I error occurs when the indicator signals that the economy is in a tranquil state when it actually on a verge of a crisis. A Type II error occurs when the indicator signals that the economy is on the verge of a crisis when it actually in a tranquil state. While the goal in developing an effective indicator system may be to minimize the number of Type II errors, the cost making a Type I error can be tremendous. Craig Burnside, Martin Eichenbaum and Sergio Rebelo [14] quantify the possible cost of a Type I error. They noted that the cost of the Asian Crisis to Korean and Thailand is estimated to exceed 25 percent of their respective GDP. Secondly, the minimization of the noise to signal ratio to calculate an optimal threshold involves using a sample of countries that economically may or may not be similar in structure. For example, Kaminsky and Reinhart [40] used the following countries when calibrating their signaling model: Argentina, Bolivia, Brazil, Chile, Colombia, Czech Republic, Egypt, Greece, Indonesia, Israel, Malaysia, Mexico, Peru, The Philippines, South Africa, South Korea, Thailand, Turkey, Uruguay, and Venezuela. They calculated the optimal threshold in terms of a percentile for the group and apply that percentile on an individual basis for each country to determine the actual threshold value. As stated earlier, for a country that is a low capital importer that threshold value may correspond to a change as small as ½ percent of GDP. What is not clear is why a change in ½ percent of GDP may be considered a signal for a country that is a low capital importer (Willett 2007). When considering the magnitude of how much capital is being imported to GDP, ½ percent change may indeed be very small.

The second key issue that must be recognized is the fact that the indicators are utilized on an individual basis to predict crises. As noted by Asli Demirguc-Kunt and Enrica Detragiache [19], if many of the indicators are flashing simultaneously, the likelihood of a crisis should increase. Yet as Demirguc-Kunt and Detragiache [19] note, the early warning system that the IMF utilizes, which is based on the Kaminsky and Reinhart [40] model, does not combine systematically in predicting the likelihood of a currency or banking crisis. Goldstein, Kaminsky and Reinhart [49] address this problem by creating a composite index. Using their notation, this composite index I is a weighted sum of all the individual indices where each individual index in the sum is weighted by the inverse of the noise to signal ratio.

Table 5

	Crisis occurs in the following 24 months	**No crisis occurs in the following 24 months**
$I_{lower} \leq I \leq I_{upper}$	A	B
No signal emitted	C	D

Using table 5, they assess the probability of a crisis if the weighted sum of the indicators I lies within a certain range. The probability of a crisis using this composite index I is:

$$P(Crisis|I_{lower} \leq I \leq I_{upper}) = \frac{(A)}{(A+B)}.$$

In Table 6, probability values are calculated for the range of values that this composite index I can take on.

Table 6

Range of Indicator Values	Probability of a Currency Crisis	Probability of a banking crisis
0-1	0.10	0.03
1-2	0.22	0.05
2-3	0.18	0.06
3-4	0.21	0.09
4-5	0.27	0.12
5-7	0.33	0.13
7-9	0.46	0.16
9-12	0.65	0.27
12-15	0.74	0.37
Over 15	0.96	n.a.
Memorandum	Unconditional Probability of a currency crisis	Unconditional Probability of a banking crisis
	0.29	0.10

n.a. =not applicable
Source: Kaminsky (1998)

There are several points to note about this approach. The first is the weighting scheme used to develop the composite index. By weighing each indicator by the inverse of their noise-to signal ratio, indicators that are deemed more accurate carry more weight. Accuracy does not mean importance. For example, an indicator such as real interest rate may be very relevant for certain countries, while the terms of trade may be far more important for other countries. Depending on whether a country faces the possibility of a banking crisis or a currency crisis, the weights placed on the indicators for each type of crises are respectively 1.4705 (real interest rate) and .99 (terms of trade) and 1.00 (real interest rate) and 1.29 (terms of trade). What happens in the case when both a currency and banking crisis occurs? The second thing to note is the fact that even when 12-15 indicators are flashing the probability of banking crises is 0.37 from the results generated by Goldstein, Kaminsky and Reinhart [49]. Should it not be higher?

In examining the model further, the other key fact to be noted is lack of any mention of the correlation between the indicators. For example, is there a positive or negative correlation between the real exchange rate indicator and imports indicator? If there is, how strong is the correlation? This is important because the thresholds are based on percentile bases that may or may not be relevant for particular countries. For example, if there is a strong negative correlation between one indicator and another, and one indicator is signaling a crisis because it has crossed its threshold, the other indicator may not signal since it may not have crossed its threshold. Thus while the nonparametric "signaling" approach, described by the authors and utilized by the IMF, performs better than most other early warning systems, it has left many critics wanting and searching for something better.[6]

[6] Assessing Early Warning Systems: How Have they worked in Practice. Andrew Berg, Eduardo Borensztein and Catherine Pattillo pg. 462-501 [10]

III.) Value at Risk Overview

The objective of the IMF's signaling approach is to monitor possible disturbances in the financial sector of country. Monitoring these disturbances can help a country mitigate possible contingent liabilities arising from the financial sector. Yet the origins of these disturbances may originate from sectors outside of a country's financial sector. For example, many domestic banks in emerging countries use government debt as collateral to gain access to international loans. If the government defaults on the debt or if the government runs an expansionary monetary policy that increases the inflation rate, this debt will lose its value. The erosion of the value of the debt, which is used by banks as collateral, may lead investors and depositors to believe that these banks may not be able to remain solvent. IMF's signaling approach does not take into account the impact the government actions can have upon the financial sector. It also does not take into account the impact that actions taken by the financial sector have upon the government.

Lately, many public and supranational institutions are attempting to incorporate financial risk measurements usually used in the domain of the private sector to better assess the financial risk pertaining to investing in particular countries. The reason for the increased emphasis on implementing corporate risk management tools in the arena of country risk assessment is based on a need to systematically incorporate the correlation between the various underlying economic factors. As such, many in the risk management profession whose primary focus is on the risk of investing in particular countries have started to apply a particular tool called the Value at Risk methodology. This is a tool often employed in the banking industry to assess the risk entailed in their portfolio of investments.

The following example is paraphrased from an example illustrated by Mario I. Blejer and Liliana Schumacher [11]. At the micro level, the Value at Risk approach entails calculating based on various risk factors a Value at Risk metric for which the probability that losses will exceed that value over a given time horizon equals α%. In other words given the various risk factors and a particular time horizon, an institution or an investor is interested in finding that value for which it can be (1- α) % confident that losses will not exceed that value. Notice that this Value at Risk metric depends on three factors; namely, the confidence level, the time horizon, and the risk factors facing the investment.

For example, a U.S. dollar-based investor holding a long-spot position of DM 100,000 is concerned about the potential losses that he might suffer if there were a sudden depreciation of the DM versus the dollar. Making an assumption that the fluctuations in the exchange rate follow a particular probability distribution; in 95 percent of all simulated scenarios the exchange rate depreciated no more than 0.03 percent over a 24 hour period. If the current exchange rate is DM 1= $0.7, the value at risk of holding the DM position is

$$\mathbf{VaR}=100{,}000 \times 0.7 \times 0.0003 = \$21.$$

This value at risk metric indicates that given a DM 100,000 risk exposure to exchange rate variations, the worst loss that the investor is expected to incur in 95 percent of all scenario outcomes over the next 24 hours is $21. The metric also indicates that there is a 5% chance that a loss of over $21 could occur in the next 24 hours. In other words, the probability of L, which is the potential loss, exceeding x_α, which is our value at risk metric, is equal to 100α %. Mathematically, $\mathbf{VaR} \equiv \min\{x_\alpha \in \mathbf{R} \mid \Pr(L > x_\alpha) = \alpha\}$. Thus, in the case that loss is considered positive, the VaR at significance level α is the 100(1-α) percentile of the loss distribution. Similarly, if we are considering income, so that losses are negative, the VaR at significance level α is the 100α percentile of the income distribution.

There are three primary ways to implement a Value at Risk approach. The first approach is known as the historical approach. This is illustrated in the above example. In implemented this approach, one uses the historical information from past returns as a guide for what the future may look like. Suppose for example you buy 100 shares of a stock that mimics the Thai SET Price index, intending to hold on to it for 10 days and then selling it. In the figure 1, is the price dynamics of this index

Figure 1

Suppose at that initially each share is worth 545.31 Baht so that the total value of your portfolio is W=54,531.0 Baht. Suppose that you want to know how much you might lose tomorrow if you decided to hold on to the portfolio of stocks. What the historical approach entails is using past market prices and assuming that historical price changes reflect what may happen in the future. Thus, if the price at time period t is s_t=545.31 then the historical approach entails creating t possible different price change scenarios whereby one possible change in the price tomorrow is

$$S_{t+1} = \frac{S_i}{S_{i-1}} \quad \text{where } i=0 \ldots\ldots\ldots t.$$

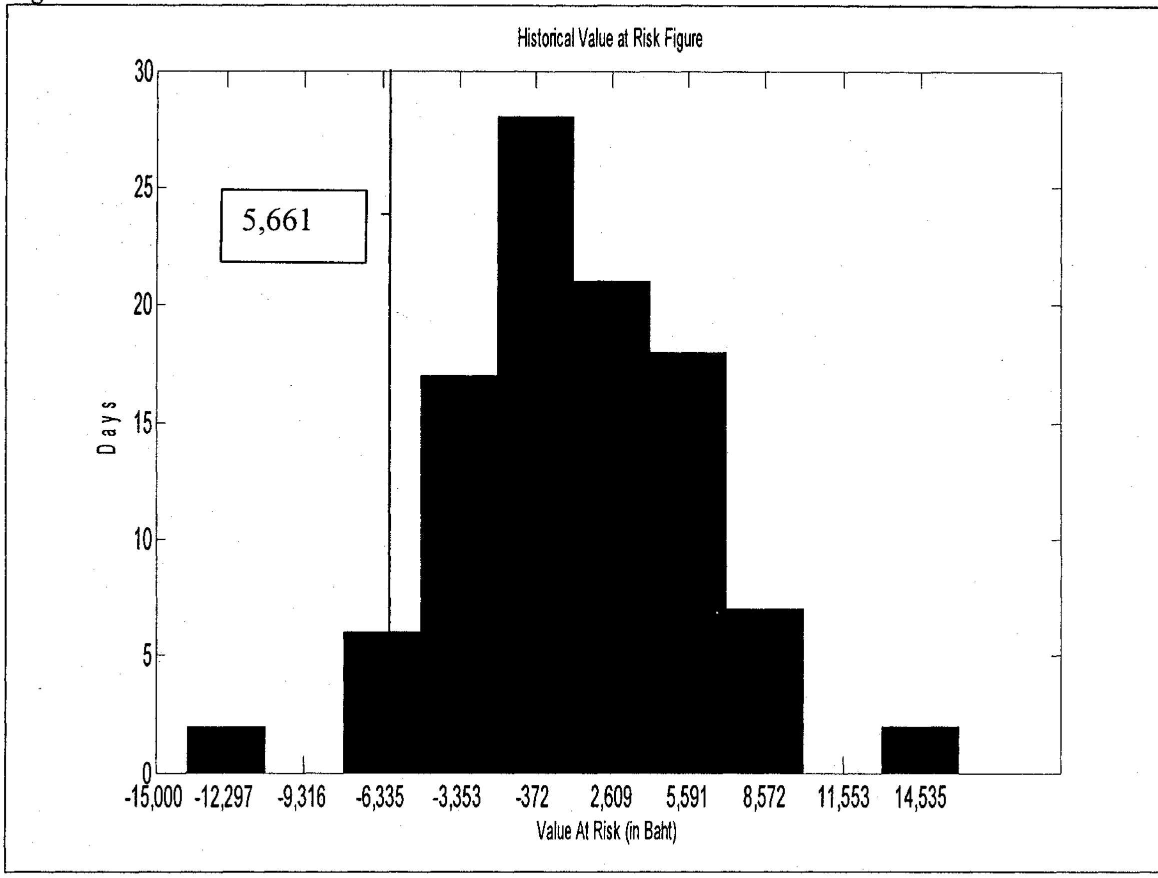
For example in the table 7, we have 102 different market values. Using the method described by Hull [39], we get:

Table 7

Days	Historical Prices	Scenario	Scenarios	Possible future prices
1	100			
2	114.614	1	1.1461	624.9798
3	134.28	2	1.1716	638.8852
4	139.208	3	1.0367	565.3229
5	152.589	4	1.0961	597.7143
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
97	523.335	96	1.0716	584.3542
98	571.307	97	1.0917	595.3149
99	538.463	98	0.9425	513.9547
100	526.972	99	0.9787	533.6949
101	536.637	100	1.0183	555.2892
102	545.341	101	1.0162	554.144

Thus, the Value at Risk is just the final portfolio value minus the initial portfolio value. From the figure below the Value at Risk denoted VaR= 5,661.90 Baht. In other words, $P(\Delta W \leq 5{,}661.9) = 0.05$. In other words you can be 95% confident that the value of your portfolio will not fall more than 5,661.90 baht in terms of value based upon historical changes in prices. In figure 2, the distribution of the Historical Value at Risk values are displayed.

Figure 2



Another method of implementing a Value at Risk approach is based upon the Variance Covariance approach. Here we assume that returns follow a normal distribution and we calculate the variances and covariance of the returns. For example, in our example the volatility of the returns is $\sigma = 0.0086$. If we plan to hold this portfolio for only one day, the relative Value at Risk at the 95% confidence level is:

$VaR_{0.95} = 1.65 * 0.0086 * (54{,}534.00) * \sqrt{1} = 772.64\ baht.$

The absolute Value at Risk is:

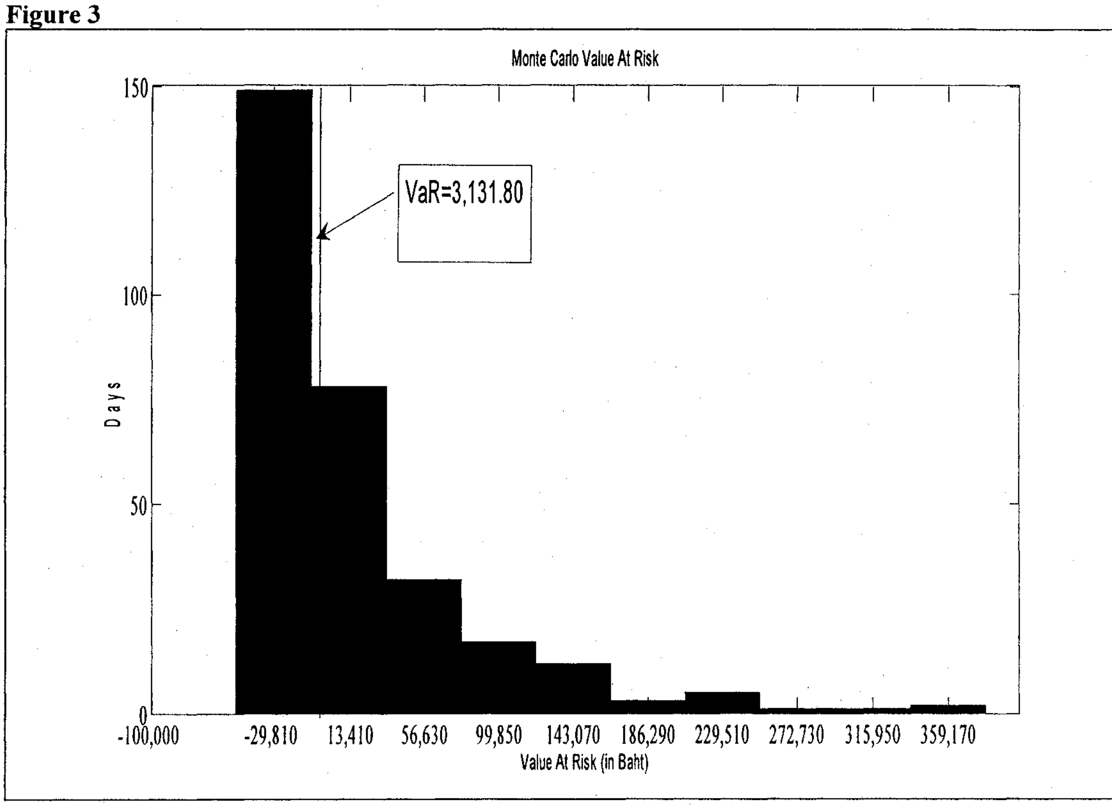
$VaR_{0.95} = 54{,}534.00 * \mu - 1.65 * 0.0086 * (54{,}534.00) * \sqrt{1} = 137.91\ baht$

where μ=0.0168.

A further approach is Monte Carlo Simulation. Here we assume that the stock follows a particular asset path $\Delta S = \mu S_t \Delta t + \sigma S_t \Delta w$, where $S_{t+1} = S_t + \Delta S$. If the number of periods is

N, then one creates a large number of stock scenarios by repeatedly simulating the stock dynamics over the N periods. In the figure 3, 300 replication of the asset path were simulated over 102 periods.

Figure 3



While the distribution may no longer appear normally distributed, the simulation was done under the assumption of normality. That is one of the keys with Monte Carlo simulation. Here the Value at Risk is VaR= 3,131.80 baht. Notice that for each approach one gets a different answer. Most practitioners in the field of financial risk management usually implement the Monte Carlo Simulation Approach. A key question is how the Value at Risk measure is affected by the holding period and the significance level. Utilizing the variance-covariance method, Table 8 shows the affects of the holding period and the significance level on the portfolios relative Value at Risk.

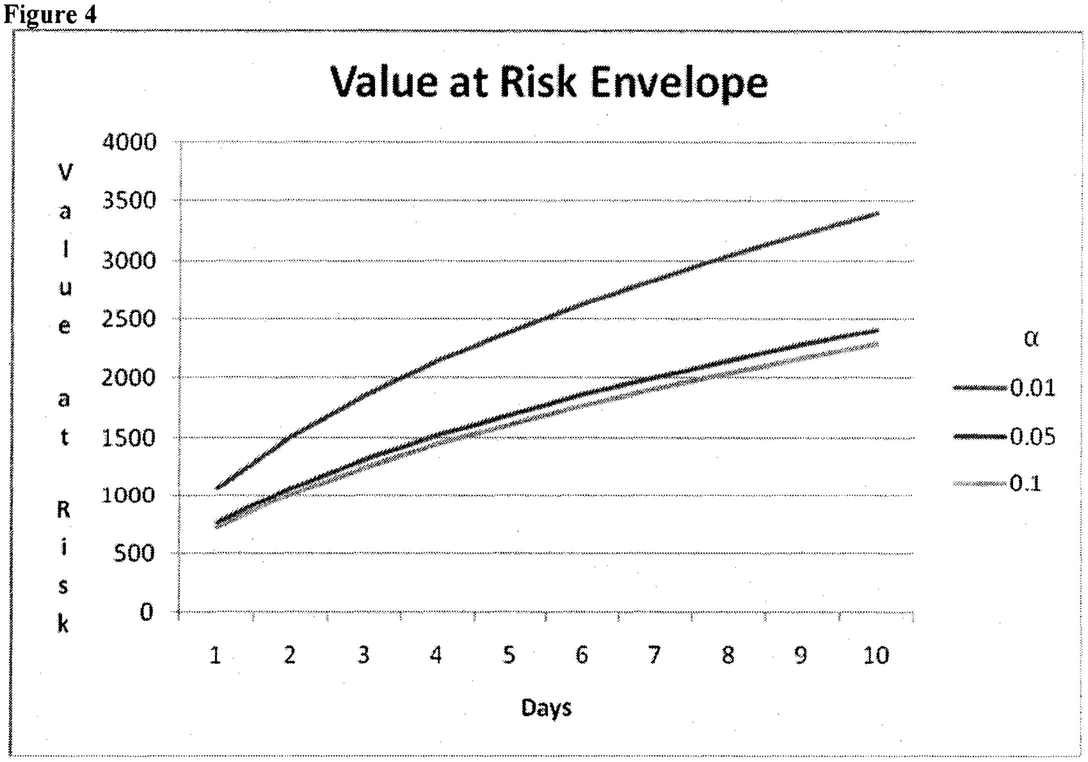
Table 8

		Significance level		
		0.01	0.05	0.1
Holding period	1	1074.918	772.644	724.3013
	2	1520.164	1076.511	1024.317
	3	1861.813	1318.452	1254.527
	4	2149.837	1522.417	1448.603
	5	2403.591	1702.114	1619.587
	6	2633.002	1864.572	1774.169
	7	2843.967	2013.968	1916.321
	8	3040.329	2153.022	2048.633
	9	3224.755	2283.625	2172.904
	10	3399.191	2407.152	2290.442

A Similar table as that found in Carol Alexander book Market Models: A Guide to Financial Data Analysis [2]

Notice that the longer you hold the portfolio of stocks, the more your Value at Risk goes up and as the confidence level goes up or your significance level goes down, your Value at Risk goes up. In looking at an envelope of Value at Risk values, figure 4 shows that at each significance level as the holding period increase the Value at Risk metric also increases. A decrease in the significance level shifts the curve upward.

Figure 4



IV.) Assessment of Barnhill and Kopits' Model

In a recent paper by Theodore M. Barnhill Jr. and George Kopits [9], the authors utilize a Value-at-Risk approach as a means of measuring the capacity of a government to service its public debt. The foundation of this model relies on several assertions which will be investigated in greater detail later, but before the model can be fully explained, a clearer appreciation of the economic environment surrounding their model is required.

In the late 90's the country of Ecuador went through a series of financial crises that eventually culminated in a complete financial/economic meltdown in 1999. The genesis of the meltdown can be traced back to the favorable financial and economic conditions that prevailed in the early 90's. With the implementation of the Brady Plan, Ecuador had achieved some modicum of economic normalcy. From 1990-1997, the average annual growth rate of GDP was slightly over 3.5%. Although inflation still remained fairly high, the central Bank of Ecuador, through its exchange rate based stabilization program, had succeeded in bringing inflation under a considerable degree of control. From 1993 to 1995, the average annual inflation rate fell to 40% from a high of 50% during the 80's. By the end of 1995, the inflation rate had fallen to 22% before climbing back to 30% by the end of 1997. In response to the improved macroeconomic conditions and the normalization of relations with the international financial community, Ecuador experienced an ever increasing influx of foreign capital. Nevertheless, the inability to maintain fiscal discipline hampered and ultimately crippled the country's ability to sustain economic growth. Ecuador's dependence on oil revenue as its primary source of financing for government expenditures exposed it to the volatilities of the market. As such, with the steady decline in oil prices in the latter half of the 90's, Ecuador's revenue stream became increasingly unreliable.

Since the 1970's, an increasing proportion of the government's revenues had been constitutionally earmarked to various sectors of Ecuador's society. This fact coupled with mounting wage bills, escalating interest payments on dollar denominated public debt, and the realization of several contingent liabilities created an environment that would eventually lead to the unfortunate series of financial and economic crises that erupted in Ecuador in the late 1990's. Several exogenous shocks such as the Mexican debt crises, El Niño, and an ongoing conflict with its neighbor Peru eventually prompted investors to re-evaluate Ecuador's capacity to service its external debt. Thus in 1995, based on this evaluation, Ecuador experienced a sudden stop and reversal of investment capital flows into the country which had a precipitous effect on Ecuador's financial system.

During the late 80's and early 90's, Ecuador's Central Bank was primarily responsible for controlling the rate of growth of inflation; and to this end it had achieved some degree of success. To achieve this success, the CBE instituted an exchange-rate-stabilization program whereby the exchange-rate was used as an anchor for prices. The exchange rate was pegged to the U.S. dollar within a crawling band. This committed the Central Bank to use its international reserves to keep the exchange rate within the band. The result of this commitment was that the growth rate of the money supply had to be constrained so as to maintain a relatively constant exchange rate level. This constraint reduced inflationary expectations. With the reduction in inflationary expectations came the positive benefits of an increase in the real wage, a real appreciation of the exchange rate, and an increase in foreign capital inflows. As a consequence, there was a domestic boom and a very discernable expansion of credit.

As foreign capital poured into Ecuador in the early 90's, an implicit guarantee by the Central Bank to provide assistance in the event of a financial crisis emboldened many banks to assume an unnecessary risk regarding investing in Ecuador. Many failed to minimize or even hedge against the risk involved in their portfolio of assets. Similar to the cases involving the banks of Asia, Ecuador's banks borrowed money internationally with shorter maturity periods than the money they lent to their domestic customers. Additionally, many of these international loans were denominated in U.S. dollars while their domestic counterparts where denominated in sucres. As a result of the sudden stop and reversal of capital inflows, several domestic banks found themselves in acute financial distress.

To a certain extent the financial distress that these banks faced could be directly attributed to a specific course of action undertaken by the BCE. Faced with the sudden reversal of capital flows, the Central Bank, in its ongoing battle against inflation, drastically contracted the money base so that it could maintain the exchange rate peg. This contraction thrust the nominal interest rate upwards to nearly 50% or approximately 30% in real terms. The resulting liquidity crunch swiftly overwhelmed any bank that had pronounced maturity mismatches. Chief among these banks was Banco Continental. With approximately 6.4% of all onshore deposits, Banco Continental quickly found itself in an untenable position and, by 1996, the bank imploded. The Central Bank hastily stepped in to restore the solvency of Banco Continental but this action did not mitigate the fact that many other banks were facing the same dire dilemma. The most alarming aspect of this event was the fact that although depositors could foresee the eventual collapse of Banco Continental, they were unable to avoid monetary losses due to a particular aspect in the law. Namely, Ecuador's laws prevented depositors from transferring funds from failing financial institutions to financially sound ones. Thus, many investors and depositors could only watch in dismay as the very financial institution holding their funds teetered at the edge of insolvency. This left many other investors and depositors, who weren't at the moment facing this particular predicament, nervous. Meanwhile borrowers, faced with higher domestic real interest rates and a lower dollar equivalent interest rate, increased their rate of borrowing of funds denominated in dollars thus further exposing the financial system to additional credit risk.

In 1998 an additional series of exogenous shocks would finally trigger the severe meltdown that would follow in 1999. Towards the end of 1997 and at the beginning of 1998, El Niño floods destroyed extensive swaths of agricultural land located on the coastal plains of Ecuador. The impact of this natural disaster was immediately felt on the balance sheets of the banks located in that region. Their clients' inability to repay their loans, due to the destruction of their exports crops, quickly crippled the assets side on the banks' balance sheets. Since interest rates still remained fairly high and the fact that the financial markets available to these banks were still fairly shallow, many banks were left with no other recourse but to seek help from the BCE. Depositors and investors realizing that their respective financial institutions were swiftly headed towards financial difficulties and remembering the particular aspect of the law quickened the pace at which they withdrew their funds from these institutions. Thus, the law preventing bank patrons from removing their funds from a distressed institution helped to spark a contagion.

Nobody wanted to find themselves in the same unenviable position of the bank patrons of Banco Continental. Banks, which initially were sound financially, found themselves in short order in the midst of a major liquidity crunch. Repeatedly, bank after bank desperately requested additional funds from the CBE in an attempt to remain solvent. What was originally just a small fire that originated at Banco Continental in 1995 quickly grew into a raging brushfire that threatened to raze the very foundation of Ecuador's entire financial system.

In recognizing the huge amount of money that was now being pumped into the system, the BCE sold equal amounts of foreign currency reserves in an effort to mop up the excess liquidity. Additionally, the BCE once again raised interest rates in defense of the exchange rate. Nevertheless, the depletion of the BCE foreign currency reserves led to further speculative pressure on the sucre. This increased not only the rate at which funds were being withdrawn from financial institutions rumored to be on the verge of collapse, but also the rate at which the sucre was exchanged for dollars. In an attempt to aid the BCE, in its efforts to resolve the growing banking crisis, the government imposed a 1% financial tax on all withdrawals for any domestic financial institution. The hope was that this tax would abate the rate at which funds were being withdrawn. The government also eliminated the income tax, hoping that it would stimulate the economy.

However, the government's lack of fiscal discipline, the growing monetization of the banking crisis, and the realization of various contingent liabilities accelerated the growth rate of inflation. Thus, with inflation headed towards a dangerous level and the rate its reserves were being depleted relatively high, the BCE made the decision to allow the sucre to float freely in the market. While the resultant depreciation helped to relieve the pressure of the wage bill, because the public debt was mainly denominated in dollars, the interest payments on this debt ballooned. The depreciation also severely hurt any banks with large unhedged foreign/dollar liabilities. Many banks which were successfully weathering the crisis were now basically insolvent. This triggered a new cycle of financial difficulties, further increasing the rate at which the economy was being dollarized.

In April 1998, the dramatic closure of the bank Solbanco rippled through out the financial community toppling several other banks, notably Banco de Prestamos in August, 1998. Eventually Filanbanco, the largest asset based bank with the second-largest deposit holdings, came under siege, as many investors sought to withdraw funds in a “flight to quality.” The request for CBE liquidity support by Filanbanco brought the total emergency bailout by the CBE to 30% of the monetary base by the end of September 1998. With the CBE foreign currency reserves nearly exhausted, inflation growing at an unprecedented rate, and the economy in a serious downturn, the government of Ecuador found itself unable to make payments on its foreign debt obligations. Therefore, in September, 1999, Ecuador suspended payments on its external commercial and Paris Club debt. The total public debt to GDP ratio skyrocketed to nearly 130% by the end of 1999. Meanwhile the sucre continued its rapid depreciation into oblivion. As such, by the end of the year, the government made the fateful decision to dollarize the economy. By January 2000, the crisis had exacted a heavy toll on the economy of Ecuador. GDP was lowered by 76%, while the Debt/GDP ratio rose to 156%. The obvious question to ask is this: how could this meltdown have been prevented?

In their paper, Theodore M. Barnhill Jr. and George Kopits [9] attempt to show how an effective early warning system can help policy makers see weakness in the fiscal and financial system that may lead to such a meltdown and at the same time assess the probability that various weakness may contribute to an eventual meltdown. Using tools mainly utilized in the arena of corporate finance, the authors attempt to show how a country, if treated as a firm, can better assess the risk of defaulting on its debt obligations. The main tool they utilize is the Value at Risk approach.

How can such an approach help policy markers understand and manage complex economic decisions? The public perception about a government's ability to manage its fiscal and financial obligations is critical to maintaining the necessary financing needed for stable economic growth. It is this perception that can either created investor confidence or investor trepidation. Such confidence or trepidation can have a direct impact on a government's ability to get and maintain financing. If investors' fear that a government is unable to meet its fiduciary responsibilities, they may be unwilling to allow the government to rollover its debt obligations or they may demand that the government pay a higher interest rate on its current debt obligations and on any future debt obligations. Fiscal sustainability is essentially determined by the relationship between the primary budget balance and key parameters that affect the servicing capacity of the public debt. The key parameters in servicing the public debt are the inflation rate, the fixed and variable interest rates, and the exchange rate. These key parameters are affected by whether a government runs a primary budget surplus or whether it runs a primary budget deficit. Budget deficits usually create the need for government bond financing. A government's action to issue debt can crowd out effect on other investment projects by raising market interest rates. If a government cannot issue debt in its own currency then borrowing international will further expose that government to external shocks. The occurrence of such external shocks can create pressure to depreciate that country's currency. The devaluation of a country's currency can increase the cost of the debt to such an extent that the country may be forced to default. Furthermore, an expansionary fiscal policy may create inflationary pressure. Such an increase in the inflation rate may lead investors to reduce their demand for that country's bonds. This can make it very difficult to rollover the existing debt. The fact that interest payments on government debt is part of the government's primary budget expenditures implies that, at some point, a government must run a primary budget surplus to reduce this growing expenditure. Otherwise if a government does not reduce or stabilize this growing expenditure, the debt will eventually explode in size and quickly become unsustainable. Historically, governments and the IMF have assessed the risk pertaining to the fiscal sustainability by conducting medium to long-term scenario projections of the public debt, based on reasonable assumptions about future macroeconomic trends supplemented with demographic and environmental expectations. The scenario simulations are then summarized in present-value terms to enable policy makers to have a sense of the benefits and cost of their policies.

The problem with this type of assessment is that it is deterministic. It fails to fully integrate the stochastic changes of the various underlying risk factors in a manner that can properly convey information on the effects that these factors may have on the likelihood of a sovereign default. Moreover, the assumptions that these governments often make regarding future macroeconomic trends tend to be biased towards ensuring a more sanguine outlook on future economic conditions within the country. This is especially the case in countries where natural resources are abundant and where there is an assumption that commodity prices will remain high in the foreseeable future.[7]

The Value-at-Risk approach initially employed by Theodore M. Barnhill, Jr. and George Kopits [9] in essence entails simulating a distribution of possible future financial conditions for the government and then assessing the probability of a financial failure that may ensue due to a loss of access to financing. According to Barnhill & Kopits [9], the first step in this simulation is to establish the risk- free net present value worth of the public sector from the primary budget balance sheet and any contingent or realized liabilities. Barnhill & Kopits [9] write the risk-free net present value worth of the public sector W_0 in the following manner;

$$W_0 = PV(Z) - PV(\Delta C) - B_0$$

where PV(Z) – is the present value of the primary budget balance
PV(ΔC)- is the present value of the unrealized contingent liabilities
B_0 – is the initial outstanding debt.

In Barnhill & Kopits' [9] view the determination of the primary budget balance Z is simply the sum of all the revenue generated from tax receipts, issuance of bonds, and resource sales minus mandatory government expenditures and debt/interest payments. If Z is positive then the government is running a primary budget surplus; if negative, the government is running a deficit or expanding on the deficit it has already accrued. PV(ΔC) is the present value of the unrealized contingent liabilities. In Barnhill & Kopits [9] terminology, mathematically this is just; $PV(\Delta C)=\sum_{t=0}^{\infty}(1+r)^{-t}\gamma_t \Delta C_t$ where γ_t is the probability that ΔC_t will be realized at time period t. ΔC_t, the unfunded contingent

[7] (Barnhill and Kopits, pg. 4)

liabilities, may be attributable to pension funds, social security programs, deposit schemes, natural disaster insurance, and explicit/implicit government guarantees. The realizations of these liabilities contribute the initial debt level B_o. Barnhill & Kopits then write the risk free net present value of the public sector in functional form as;

$$W = PV(Q, R_H, R_F, F, P_n, P)$$

where Q – is the present and future output level
R_H – is the interest rate at home
R_F - is the interest rate at abroad
F- exchange rate
P_n – world commodity prices and
P – domestic price level

The principal variables in this reduced functional form of the risk-free net present value worth of the public sector are as noted Q, R_H, R_F, F, P_n, and P. In Barnhill & Kopits [9] view the present and future output level determine the revenue the government gains from future tax receipts. The spread on government bond yields is determined by the interest rate at home and abroad. The reason for using the spread on government bonds was never fully explained. However, given the desire by international investors for the highest possible returns on their investments, this spread may be an indication of the amount of risk involved in investing in government bonds. The spread can also be an indication of how great a return over investing in seemingly safer U.S. treasury bonds that an investor gains. This is important because, as noted in a paper by Barry Eichengreen and Andrew K. Rose [24], what has been observed is that a one percent increase in Northern interest rates increase the probability of a Southern banking crisis by approximately three percent. The narrowing of the spread between the interest rates increases the probability γ_t that any contingent liabilities such as implicit/explicit guarantees to the central bank will be realized. In other words, as the spread between

Northern and Southern interest rates narrow, investors begin to assess the risk in investing in Southern banks versus the relative safety of investing in Northern banks. While investing in banks may not be exactly the same as investing in government bonds, the reasoning for investing in Western bonds, i.e. U.S. treasury notes, vs. investing in emerging markets bonds is similar. The inclusion of the exchange rate is a way of measuring the cost of government debt in terms of the country's currency and in terms of the U.S. dollar. F is dependent upon the regime under which the country operates. Under a fixed exchange rate regime, F can be omitted and the risk-free net present value worth of the public sector is then dollarized. Under any other exchange rate regime, the present value of net public worth depends on the exchange rate value. This becomes particularly relevant if the exchange rate is somehow overvalued. If a country's currency depreciates, the value of Z will fall when it is converted to U.S. dollars. A decrease in the value of Z will reduce the worth of the risk-free net present value of the public sector. A large enough depreciation eventually produces a crisis of confidence in a country's ability to remain solvent. Notice that solvency does not mean liquidity. Liquidity risk can be incorporated in the model later on. The insertion of P_n and P in the function determines the amount of revenue that will be generated by the sale of natural resources and the affect of inflation on the risk-free net present value worth of the public sector. If $W_o > 0$, the public sector is deemed solvent. This does not mean the government can deal with a liquidity crisis, but what it does mean is that government has the resources to meet its debt obligations.

Now, treating the risk free net present value worth of the public sector as a portfolio, we can calculate the value at risk of this portfolio by using the variance of return on the portfolio. The variance of return on the portfolio is just

$$\sigma_p^2 = w'\Sigma w$$

where w = vector of weights for the various securities (or risk) in the portfolio.
w' = transposed vector weights in the portfolio
Σ = variance-covariance matrix of returns on securities in the portfolio

The relative value- at- risk, over a one year time period, of the net risk-free net present value worth of the public sector is

$$VaR = \alpha\sigma_p W_0$$

where α = standard normal deviate (e.g. 1.65 for the 95 percent confidence level).

Now that we have a value at risk metric, we then construct a risk-adjusted net present value worth of the public sector. This is just;

$$W^* = PV(Q, R_H, R_F, F, P_n, P) - VaR(W)$$

Using Monte-Carlo simulation we can then generate a distribution of values of the risk-adjusted net present value of the public sector and then calculate the probability this value will fall below certain amount.

So far we have only assessed the risk entailing solvency. The question is, how do we incorporate liquidity risk into the model? One approach, explained by Bangia, A., Diebold, F.X., Schuermann, T. and Stroughair, J. [7] is to historically generate the bid-ask spreads changes over time. Bangia assumed that the additional drop in the prices is half the usual bid-ask spread plus the 99th percentile movement in the spread. This is just:

$$\text{Additional Drop}_{99\%} = 0.5\,\bar{s} + 2.32\sigma_s$$

Therefore the liquidity adjusted VaR is

Liquidity Adjusted VaR = VaR + Additional Drop.

Hence the liquidity Adjusted net present value worth of the public sector is:

$W^{**} = PV(Q, R_H, R_F, F, P_n, P)$ – Liquidity Adjusted VaR(W)

Notice that the functional value of the public sector PV(.) is a function of liquidity.

There are several main weaknesses to this particular Value at Risk model. While it is not as static as the sensitivity analysis and medium-term scenario simulation used by the IMF, it is still static in the sense that one can assess only the probability of defaulting at the end of a period of time. It is not dynamic. Currently work is being done on Dynamic Value-at-Risk. Here the portfolio is allowed to adjust over the time period of the model. This allows the probability of default to evolve over time.

The second main weakness is due to the thickness of the tail of the actual distributions; otherwise known as the kurtosis. When the kurtosis of the distribution is greater than 3, extreme events are more likely to occur. As a result, if one uses historical generated data to calculate the VaR metric using normal distribution theory, the financial risk is underestimated.

A.) Model Critique

In his paper the author, Craig Burnside [13], reviews recent literature on various new methodologies under consideration for the assessment of fiscal sustainability. Included in the literature he reviewed was the paper by Theodore Barnhill and George Kopits. In reviewing the paper, Burnside [13] noted several flaws worth mentioning.

Flaw #1:

In calculating the present value of the net government worth, the nominal interest rate remains constant and very much normally distributed. There are two problems in applying such methodology. The first, as the author correctly points out, is the fact that there is very little evidence to support the belief that returns, whether from government bonds or real assets, are normally distributed. Assuming, without verification, that the returns are normally distributed immediately makes the model unreliable.

One problem that Burnside did not notice, but would be noticed by many financial engineers, is the fact that Barnhill and Kopits used a constant β in the Vasicek stochastic interest rate model. The stochastic differential equation in the Vasicek model is of the form $dr=\alpha(\beta - r)dt + \sigma dB$. The term $\alpha(\beta - r)dt$ measures the change in the rate of drift of the interest rate, while the term σdB measures changes in volatility. The Vasicek model for interest rate is mean reverting. In other words, the $\alpha(\beta - r)$ term pushes the interest rate back to β at a rate proportional to α. However notice that β can change if the market regime under which the interest rate is determined changes, i.e. a regime switch from a Bull to a Bear market. Thus using the Vasicek model to get the nominal interest rate needed to calculate the present value of future government revenues leaves much to be desired in terms of whether or not one is using a β that enhances the revenue stream.

Flaw #2

One of the interesting decisions that Barnhill and Kopits [9] make is to exclude discretionary expenditures, such as the occasional levee or seigniorage revenue, from the net budget flow equation. In Burnside's view this was not necessary. He viewed the nominal primary budget balance as a decomposition of two components, namely x_t^P, planned, and x_t^R , residual, expenditures. Therefore excluding the residual distorted the risk adjusted net worth W^*. Burnside is quite correct in this assessment. Barnhill and Kopits seem at times to haphazardly adjust the risk adjusted net worth W^* by including or excluding various residual variables, such as seigniorage, in an attempt to show the government debt could be sustained. There lacks clear guidance as to when certain residual variables should be included or excluded in determining the risk adjusted net government worth W^*.

With regards to the primary variables that were chosen for the model, Barnhill and Kopits made their choices based upon what they deemed relevant within the overall macroeconomic context of the country being studied. Additionally, many of the primary variables values were exogenously determined outside of the model. In other words, such assumptions such as purchasing power parity were not made to explain the interdependency between various model variables The interdependency between the variables that should be endogenously determined should be further researched.

V.) Application of VaR model to the Fiscal sector of Thailand

In his paper, Rudiger Dornbush [20] noted the need for a different type of early warning system to assess fiscal sustainability. Dornbush(1998) [20] suggested that the best method for doing this would be to incorporate a Value at Risk model within the framework of a government's balance sheet. This approach was applied to various sectors of the country of Thailand in a dissertation done by Mei Sze Iris Au(2002) [6]. So what steps are necessary for assessing the sustainability of a country's fiscal sector? A good reference point for evaluating the necessary steps in the assessment process is the paper by Barnhill and Kopits [9]. To understand why this is a good reference point, an understanding of the Asian Crisis is needed. In the same paper, mentioned earlier, Rudiger Dornbusch [20] noted that the eruption of the Asian Crisis in the 90's was unlike any other previous crisis. For all intents and purposes the 1997 Asian Crisis did not fit the mold of a first generation type of crisis, but the crisis seems to have various aspects of a second generation type crisis and a third generation type crisis. For example, in the first generation type of crisis, developed by Krugman, a country usually runs a huge fiscal deficit that it finances through inflationary monetary policy. As a result of this policy and its fixed exchange rate, the currency becomes overvalued. This leads to a huge current account deficit and external disequilibrium. The end result is that, eventually, a currency crisis erupts, forcing the country to devalue its currency once it has expended its reserves in defense of the fixed exchange rate regime. Before the eruption of the Asian Crisis, many of the Asian countries either ran small fiscal deficits or no deficits at all. Thus it is safe to assume that the Asian Crisis was not a first generation type crisis. Neither can the Asian Crisis be fully categorized as a second generation type crisis. For the Asian crisis to be considered a second generation type crisis many of the countries involved had to be facing a choice between maintaining tight fiscal policies as a means of controlling inflation or running an expansionary fiscal policies to lower the unemployment rate. Thus multiple equilibriums are possible; namely, a policy of fiscal contraction, low inflation, high unemployment vs. expansionary fiscal policy, high inflation, and low unemployment. Neither equilibrium point is desirable. As a result, knowledgeable investors flee, leading to the self-fulfilling panic that the government was trying to avoid. In evaluating the Asian Crisis, Dornbusch [20] and Mishkin [47] both noted that many of the Asian countries had a low inflation rate and low unemployment. Coupling these two aspects with the fact that many of these countries had sound fiscal policy further demonstrates that the Asian Crisis of 1997 probably was not second generation. So if the Asian Crisis did not fit the mold of a first generation type crisis nor a second generation type crisis, did it fit the mold of a third generation type crisis? The key aspect of a third generation type of crisis is that a country's balance sheet is rendered vulnerable to a shock due to some microeconomic inconsistencies [5]. For example, a country's fixed exchange rate regime along with the central bank's explicit or implicit guarantees to the banking sector may lead many banks to borrow extensively from international sources. Such borrowing then creates the ideal environment for an external shock to cause a financial crisis. The Asian Crisis of 1997 in the eyes of various economists most resembled a third generation type crisis.

Increasingly, the Value at Risk approach is being adopted by many in the international community as a means of assessing the balance between the stocks of assets and liabilities that exist within different sectors of a country's financial system at particular points in time (Allen, Rosenberg, Keller, Setser, Roubini)[5]. Why is the Value at Risk approach within a balance sheet framework the most appropriate framework for an early warning system? The first reason is the ease with which this approach quickly identifies specific vulnerabilities that lay within a country's economic system. The balance sheet framework, in essence, divides a country's economy into several individual balances sheets corresponding to the various sectors of a country's economy. These key sectors are the government sector, the financial sector, the corporate sector, and the household sector. Each sector owns assets that are liabilities for other sectors. The resulting interdependence means problems that occur in one sector eventually spill over into other sectors. As noted by Frederic S. Mishkin [47], a deterioration of the financial sector balance sheet can result in a capital/credit crunch and thus hinder economic growth. This is the situation that occurred in the 1997 Asian Crisis and this is the situation that is occurring now in the U.S. mortgage market. The deterioration is apparently spilling over into the real sector as it did in the Asian crisis.

A.) Responsibility of the Government Sector

The primary responsibility of the government within a financial system is to foster economic growth and development. To this end, activities such as taxes, government expenditures, government revenues, sales of natural resources, and the issuance of debt are all needed to promote growth. However, by participating in such activities, a government's finances are exposed to certain variances of the market. Within the balance sheet of a government, the risk factors a government faces are mainly inflation, interest rates risk, and exchange rate pressure. Given that most governments, at some time or another, will need the financial markets to finance their expenditures, most government have no choice but to face these risk factors straight on. Additionally governments play a key role in the process of financial intermediation in many emerging market economies. In the words of Michael Kumhof and Evan Tanner [42] "Many financial institutions use government debt as an asset in their financial balance sheets. These assets are used as collateral for borrowing internationally and are considered safe given that government rarely default on their obligations."[8]

Given the various roles that a government plays in the financial intermediation process, how should a government assess the risk that it faces when issuing debt. Initially, the intention was to duplicate the model that Barnhill and Kopits [9] developed

[8] (Kumhof & Tanner, 2005 pg. 7)

for the years 1993-2003. However there is a problem in doing it in this manner. In their model they calculated the risk adjusted net worth of the government, $W^* = PV(Q, R_H, R_F, F, P_n, P) - VaR(W)$, by first calculating the risk-free net present value worth of the public sector $W_o = PV(Z) - PV(\Delta C) - B_o$, and then stochastically simulating the underlying risk factors R_H, R_F, F, P_n, P to calculate the VaR(W). In dealing with the initial debt they claimed that B_o followed an amortization schedule over a certain period of time. They did not clearly state the amortization schedule but, based upon the data set provided by Olivier Jeanne and Anastasia Guscina in "Government Debt in emerging Market Countries: A New Data Set" [35], it is safe to say that most of Thailand's debt was medium term(1-5 years) in duration. So using 3 years as the average length of time, the initial public net worth boils down to this:

$$W_0 = \sum_{t=0}^{\infty}(1+r)^{-t} Z_t - \sum_{t=0}^{\infty}(1+r)^{-t}\gamma_t \Delta C_t - \sum_{t=0}^{\infty}(1+r)^{-t}\Delta B_t .$$

Barnhill and Kopits [9] use the discounted value of the amortized debt payment schedule as a means of showing that a government is solvent when the primary budget balance can cover its debt payments. This forces the initial public net worth to be unnecessarily positive. The most interesting thing to note is that Barnhill and Kopits [9] are applying a corporate finance type of concept, where the concern is that the value of a portfolio of financial instruments does not fall below a certain value, towards monitoring the value of the public sector. The problem lies in the fact that the main point of concern for those in the public debt risk management business is not whether the net worth of the public falls below a certain value but whether or not the initial present value of the primary budget balance can cover possible changes in the value of the public debt or whether the government has enough liquid reserves on hand to cover possible changes. In other words, in looking at various scenarios, if the market price of the debt changes will a government needs to raise taxes, use its foreign reserves, or cut back on government expenditures to meet it fiduciary responsibilities if the market is no longer willing to finance it. 1996 economic data is provided for the public sector of Thailand in the table 9.

Table 9

Budget Balance	Fixed Domestic Debt	Variable Domestic Debt	International Debt
91,7531,968 Bahts	708,934,528 bahts	1,040,663,936 Bahts	146,397,792 Bahts

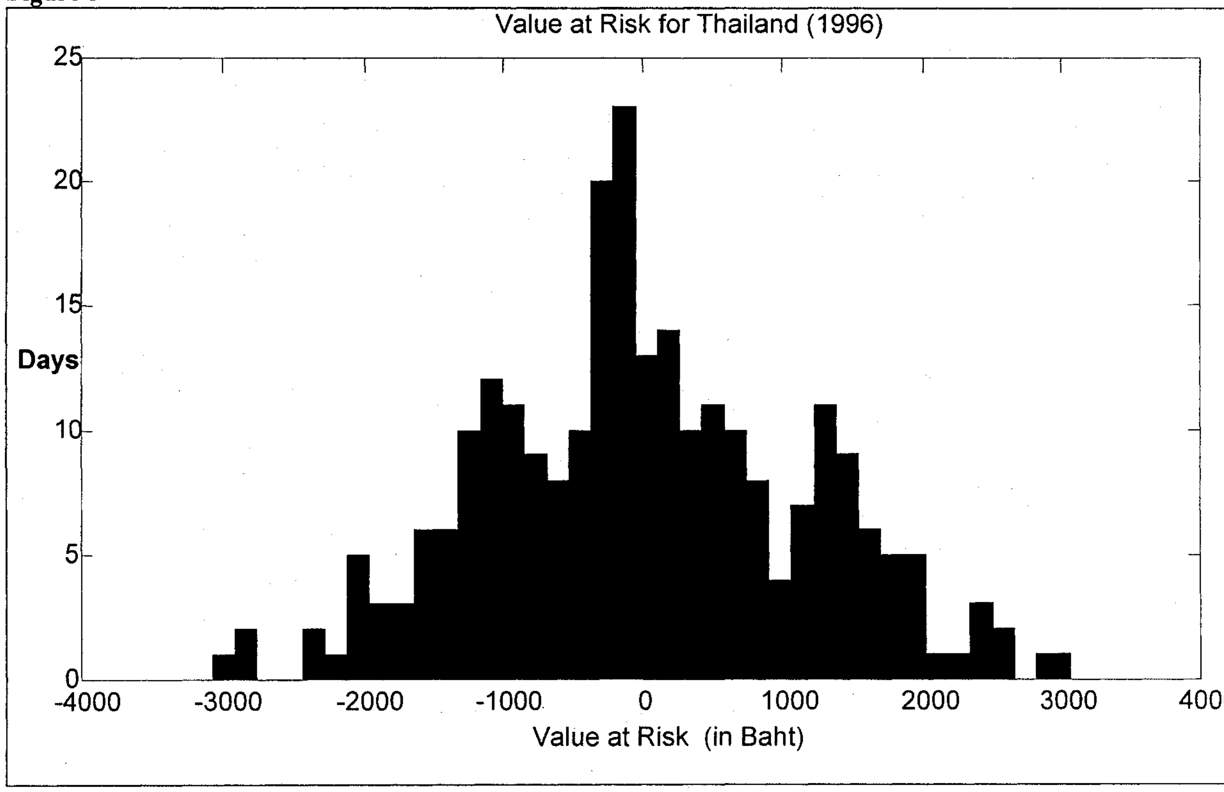
Data from Government Debt in Emerging Market Countries: A New Data Set
Prepared by Olivier Jeanne and Anastasia Guscina [34]

The Net Worth of the Public Sector is:

Net worth=91,7531,968 -708,934,528 -1,040,663,936 -146,397,792 = -978,464,288 Bahts.

This calculation does not take into account that only partial payments are being made on the debt. In applying Barnhill and Kopits method, I only considered the primary budget balance and the public debt. This simplified the equation so that the initial worth of the public sector is: $W_0 = \sum_{t=0}^{\infty}(1+r)^{-t} Z_t - \sum_{t=0}^{\infty}(1+r)^{-t} \Delta B_t$. Another simplifying assumption, this model makes is that the Value at Risk of the public sector depends only on variations in the interest rates. Since Thailand determines its inflation rate policy by determining the 14 day repurchasing rate for government paper, the variable interest rate was used. Simulating, using this interest rate, provided the following figure 5 and Table 10.

Figure 5


Value at Risk for Thailand (1996)
Days
0
5
10
15
20
25
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
Value at Risk (in Baht)

Value at Risk Table of values for the year 1996 for Thailand

Table 10

Government initial worth	Risk adjusted net worth	Value at Risk of the Government Sector
839084.2	838654.8	429.4375
839084.2	840162.7	-1078.5
839084.2	839273.4	-189.25
839084.2	839272.3	-188.063
839084.2	836605.3	2478.938
839084.2	839961	-876.813
839084.2	836610	2474.188
839084.2	839960.8	-876.563
839084.2	837586.5	1497.688
839084.2	838855.3	228.9375
839084.2	839088.6	-4.375
839084.2	839542.7	-458.5
839084.2	838859.6	224.625
839084.2	841380.4	-2296.25
839084.2	839100.9	-16.6875
839084.2	838308.9	775.3125
839084.2	837303.2	1781
839084.2	839959.8	-875.563
839084.2	838875.9	208.3125
839084.2	839309.4	-225.25
839084.2	840212	-1127.81
839084.2	840323.1	-1238.88
839084.2	839191.8	-107.625
839084.2	838551.6	532.5625

The key idea to note is that the VaR for the Government Sector is given by Government initial worth - Risk adjusted net worth. Notice that the risk adjusted net worth is not how much can be lost but rather how much the government is worth given fluctuations in the variable interest rates. As stated earlier, it is not how much the government is worth but whether the present value of the primary budget surplus can cover the debt payments without adjustments either in expenditures or taxes.

When considering the sustainability of the government debt the main concern of government debt managers is the ability of "a government to service its debt without having to resort to adjusting the balance between income and expenditures".[9] As described in the book "Advances in Risk Management of Government Debt"[31] and in "Assessing Sutainability" (2002) by the IMF:

> "Assessing sustainability in the first instance means forming a view of how outstanding stocks of liabilities are likely to evolve over time. This requires projecting the flows of revenues and expenditures- including those for servicing debt – as well as exchange rate changes (given the currency denomination of the debt). Projections of the debt dynamics thus depend, in turn, on macroeconomic and financial market developments, which are intrinsically uncertain and highly variable. Here a key factor is the markets willingness to provide financing, which determines the costs of rolling over debt."

The key phrase in this paragraph is the "markets willingness to provide financing". As stated in the IMF Working Paper by Mark Allen, Christoph Rosenberg, Christian Keller, Brad Setser, and Nouriel Roubini [5], "The stock and flows of assets and a government/countries ability to maintain adequate financing is very much depended upon the public's perception of fiscal and financial solvency." Note fiscal and financial solvency does not necessarily mean that a country has to have on hand the necessary funds to cover its all its fiduciary responsibility but, rather, that a country has the ability to generate the funds to make payments on these responsibilities. Given that perception is the key for determining the cost of financing, the question that remains is what does is meant by debt sustainability. In using David Wilcox's [55] terminology and notation

[9] Analytical Framework for Debt and Risk Management by Lars Risbjerg and Anders Holmlund Pg. 42

from his paper, assessing whether the debt is sustainable can be determined by looking at the evolution of the government debt accumulation equation:

$b_t=(1+r_{t-1})b_{t-1} - (G_t - T_t)$.

Here b_t is the market value of government debt in time period t, b_{t-1} is the market value of the government debt in time period t-1, and the primary surplus/deficit in time period t is $G_t - T_t$. Again, using Wilcox's [55] terminology and idea, if the debt is discounted so that it is in present value terms, the above debt accumulation becomes

$B_t = B_{t-1} - S_t$

where $S_t = G_t - T_t$.

Now suppose we want to understand how the debt evolves over N periods. Starting in period 1 and going to period N (note again that the terminology here is borrowed from Wilcox's Paper [55]) we have:

Periods	Debt Accumulation Equation
1	$B_{t+1} = B_t - S_{t+1}$
2	$B_{t+2} = B_{t+1} - S_{t+2}$
.	....
.	....
.	....
.	....
N	$B_{t+N} = B_{t+N-1} - S_{t+N}$

Now by recursively forward substitution the debt accumulation over the N periods,

$$B_t = B_{t+N} + \sum_{j=1}^{N} S_{t+j}$$

Now let $E(B_{t+N}) \to 0$ as N gets large. This is an assumption that Hamilton and Flavin [28] make but with which David Wilcox [56] strongly disagrees. In other words the expected value of any future debt goes to zero as N gets large. This assumption is made to keep the debt from exploding.

As a result the above equation now becomes

$$E(B_t) = \lim_{N \to \infty} \sum_{j=1}^{N} E(S_{t+j}).$$

The goal of a government risk manager is to minimize this sum of future government surpluses and deficits that may be needed to finance the debt in period t. An additional goal of a government risk manager is to maintain a constant debt to GDP ratio. This is in essence the conventional approach to fiscal sustainability.

Several economists have been very critical of the conventional approach to fiscal sustainability. This is due to their belief that the conventional approach does not fully incorporate the stochastic nature of the underlying factors that contribute to fiscal sustainability. Basically, the conventional approach involves analyzing how a government $\frac{debt}{GDP}$ ratio evolves over a period of time under various hypothetical scenarios. By analyzing the evolution of this ratio, one can assess the sustainability of the government debt. The basic equation utilized in analyzing fiscal sustainability for the public sector is the government accounting equation

$$d_t = \left(\frac{r_t - g_t}{1 + g_t}\right) d_{t-1} - PB_t$$

where $d_t = \frac{D_t}{Y_t}$

$$d_{t-1} = \frac{D_{t-1}}{Y_{t-1}}$$

$1+g_t$ = the rate of Growth of GDP

r_t=real interest rate

PB_t = primary budget balance

D_t = country debt at time period t

Y_t=GDP at time period t

In attacking the conventional approach, Barnhill and Kopits [9] believe that their model, which is based on the VaR approach, can better assess the fiscal sustainability of a country's public sector. This dissertation modifies their model and applies it to the fiscal sector of Thailand to see if their claim rings true.

B.) Value at Risk Model

The manner in which this dissertation applies the Value at Risk methodology to the government sector is very similar to that of Barnhill and Kopits [9] but there are some key differences. The first difference is in the assumption that a government generates revenue from the sales of natural resources. As Barnhill and Kopits [9] stated, their model is "very good for countries that have an abundance of tradable natural resources". However, many emerging market governments in Asia and other parts of the world cannot depend upon the sales of tradable natural resources as a means of generating revenue for government expenditures. This may be due to the lack of tradable natural resources or to the cost of extracting such resources. The assumption here with regards to the cost of extraction is that the cost exceeds, in the short run and medium run, the benefits in terms of market price. As a result this model does not include the sales of natural resources as a part of government revenue. Consequently, government revenue consists mainly of revenue generated from taxes.

The second difference in this model is in terms of how the Value at Risk methodology is applied. In Barnhill and Kopits [9] paper the primary concern is measuring the changes in the government's net worth. From these changes they assess the solvency of the government. But while the change in the net worth may be negative, that doesn't mean that the net worth of the government is negative. For example, the net worth of the government can initially be W_o=8 billion dollars and, after adjusting for various risk factors over the respective time, final value may be W=5 billion. Note the change in the net worth of the government is now ΔW=-3 billion. This change does not mean the government is insolvent since that the final net worth is still positive. Thus, for

Barnhill and Kopits [9] the objective function appears to be the change in the net worth of the government, whereas the objective function in this dissertation is actually the net worth of the government.

C.) Risk Factors

In applying a Value at Risk approach to the objective function there are several key risk factors that should be considered. The key risk factors that the balance sheet of government is most likely to face are interest rate risk, exchange rate risk, and maturity risk. Before proceeding to explain the government objective function, this dissertation will first explain how each type of risk factor affects the key variables in the objective function.

In considering the assets and liabilities of a government's balance sheet there are two types of questions a risk manager needs to answer.

1st Question: What are the primary types of risk that affect the balance sheet of a government?

2nd Question: How do these various types of risk affect the balance sheet of the government sector?

According to Allen, Rosenberg, Keller, Setser and Roubini [5] there are four main types of risk that are important to consider. They are maturity mismatches, exchange rate risk, capital structure, and solvency risk.

The first type of risk, maturity mismatch, can be thought of in terms of interest rate exposure. When there is a gap between the maturity structure of government assets and liabilities the government faces an interest rate exposure. This exposure occurs because the cost of refinancing may go up if the interest rate on short term government liabilities goes up. An extremely simple example of this occurs when a government finances a project that supposedly will provide a return of 5% starting five years from the present. In the meanwhile, to finance the project the government borrows from abroad at a rate of 3%. If the loan matures in one year the government faces the risk that in order to keep financing this project it may have to pay a higher interest rate, say 7%, if market sentiment turns unfavorable towards the government's project.

The second type of risk a government may face is known as exchange rate risk. Suppose that a government borrows 1 million dollars from abroad to pay for a public investment project and agrees to repay this money in one year. The government expects that the revenue it earns from the taxes it receives from the project to be 25 million baht within one year. If in one year the exchange rate is $\frac{25\, baht}{1 dollar}$, the government projected revenue of 25 million baht equals 1 million dollars. Thus the government is able to meet its obligation. However, if the exchange rate one year from now is $\frac{27\, baht}{1\, dollar}$, then the government's projected revenue one year from now is 925,926 thousand dollars. The government is now short 74,074 dollars because of exchange rate depreciation.

According to Allen, Rosenberg, Keller, Setser and Roubini [5], the third type of risk is a "capital structure mismatch". This risk basically involves the method by which a government finances its budget deficit. If a government primarily finances its budget deficit through international bond issues, it exposes its financing to external shocks. If it finances its budget deficit through domestic bond issues, it exposes its financing to internal shocks. The way a government finances its deficit determines how vulnerable the government is to various shocks.

Finally, a fourth type of risk a government faces is a solvency risk. This is basically a case of determining whether the government has enough liquid reserves on hand in case of an emergency. This risk is particularly relevant for countries that have some type of fixed or pegged exchange rate regime. The need to defend the currency may exhaust reserves and leave the country unable to make the necessary payments on its debt.

In modeling the dynamics of these risk factors this dissertation takes the same approach that is used in Barnhill and Kopits [9] by only assuming three main risk factors, namely, exchange rate risk, maturity risk, and inflation risk. The model assumes that the dynamics of two of these risk factors follows a Geometric Brownian Motion, which can be described by the following equation

$$dS_t = \mu_t S_t dt + \sigma_t S_t dW_t$$

Here μ_t measures the drift in the exchange rate in the interval t and σ_t measures the exchange rate volatility in the time interval t. Both the exchange rate and the inflation rate are simulated in this manner.

In modeling the dynamics of the risk free interest rate, this model, similar to the model in Barnhill and Kopits [9] , utilizes the Vasicek Interest Model. In the Vasiceck interest rate model the changes in the interest rate can be described by the following equation

$$dr_t = \beta_t(\mu_t - r_t)dt + \sigma_t dW_t$$

Here β_t = rate of reversion to the long run mean

μ_t = long-run mean interest rate

r_t = spot interest rate

σ_t=average daily interest rate volatility.

Also, similar to Barnhill and Kopits [9], all other interest rates are modeled as spreads over the risk free interest rate. The risk free interest rate was chosen to be the U.S. labor rate.

Given the fact that the risk factors are highly correlated, the approach taken by this dissertation, also implemented in Barnhill and Kopits [9], is to model the risk factors as correlated random variables. This approach, also described in Hull [33], utilizes the correlation structure of the risk factors to generate a set of correlated random variables. There are three risk factors of concern for this dissertation. They are the inflation rate, the interest rate, and the exchange rate. In this case the random variables are correlated in the following manner[10]

$$\varphi_1 = x_1$$
$$\varphi_2 = \rho_{12}x_1 + x_2\sqrt{1-\rho_{12}^2}$$
$$\varphi_3 = \rho_{13}x_1 + \left(\frac{\rho_{23}-\rho_{12}\rho_{13}}{\sqrt{1-\rho_{12}^2}}\right)x_2 + \left(\frac{\sqrt{(1-\rho_{12}^2)(1-\rho_{13}^2)-(\rho_{23}-\rho_{12}\rho_{13})^2}}{\sqrt{1-\rho_{12}^2}}\right)x_3,$$

where x_1, x_2, x_3 are uncorrelated random variables with variance 1. Since there are three stochastic variables of concern, three correlated random variables are generated. These random variables are used in the stochastic differential equations for the exchange rate and the inflation and in the Vasicek interest rate equation. This ensures that the stochastic variables are correlated.

D.) Basic Parameters of the Model

The Key variables in applying a Value at Risk model to the Government Sector are:

PB_t=Primary Budget Balance in time period t

10 Hull(2000) and Barnhill and Kopits (2003)

ΔVD_t =amortized Variable Debt payment schedule in time period t

ΔFD_t =amortized Fixed Debt payment schedule in time period t

$\Delta IntD_t$ = amortized international debt payment schedule in period t

C_t = potential or actual contingent liabilities that may be realized in period t

δ^{i*}= discount factor using the domestic variable interest rate i*

δ^{i**}= discount factor using the domestic fixed interest rate i**

δ^{i***} = discount factor using the international interest rate i***

In terms of amortized debt, the assumption here is that at the end of the year the government of Thailand pays a fixed portion of the principal and the interest. The assumption also is that for domestic debt, whether it is variable or fixed, payments are made over a five year period; and for the international debt, payments are made over 10 years. For example, the government of Thailand had 5,815 million dollars worth of international debt. A typically amortization payment schedule is displayed in the Table 11 for the international debt.

Table 11

Annual Payments on initial Debt of 5,815,000,000 (dollars)	Principal Payments	Interest Payments	Remaining Balance On Principal
977,050,000	351,950,496	625,103,936	5,463,000,000
977,050,000	389,785,248	587,269,184	5,073,200,000
977,050,000	431,687,136	545,367,296	4,641,500,000
977,050,000	478,093,472	498,960,960	4,163,400,000
977,050,000	529,488,640	447,565,792	3,633,900,000
977,050,000	586,408,640	390,645,760	3,047,500,000
977,050,000	649,447,552	327,606,848	2,398,100,000
977,050,000	719,263,232	257,791,184	1,678,800,000
977,050,000	796,584,064	180,470,336	882,200,000
977,050,000	882,216,768	94,837,664	0

Notice that Thailand pays approximately 977,050,000 dollars annually in payments.

The assumptions about the length of time a country has to pay down its debt are based upon the type of datasets this model utilizes. For example, the assumption about the length of time Thailand has in making payments on its international debt came from the Bank of International Settlements website regarding international debt maturity structures. If we assume continuous compounding then the pricing of the government debt is

$$\delta^{i^*} = e^{(i^* + \text{spread over international debt issues})}$$

$$\delta^{i^{**}} = e^{(i^{**} + \text{spread over international debt issues})}$$

$$\delta^{i^{***}} = e^{(i^{***})}$$

So the Value at Risk for the Government can be explained by the equation below as

VaR_Gov_ sector = Present Value(PB) – Present Value(C_t) –discounted debt

Here, the debt profile is the amount of government debt, either domestic or international that is either variable or fixed interest rate. The question that this model attempts to answer is, given the state of the world that government finds itself in terms of the composition of its public debt, under what scenarios will the government's fiscal position become unsustainable? Before attempting to answer this question, this dissertation will first describe a new database that will enable a more comprehensive analysis of fiscal sustainability.

E.) Debt Profile/Structure

In terms of the debt structure of a country, this model utilizes a new database, created by Olivier Jeanne and Anastasia Guscina [35], which clearly shows the composition of debt for various emerging market countries and allows for a more comprehensive fiscal sustainability analysis. One of the main arguments made by many economists, particularly, Eichengreen and Hausamann (1999) [23], is that many emerging market economies are unable to borrow in their own domestic currency to cover their budget deficits. Additionally, while initially a country may have a relatively small amount of international debt as compared to its overall public debt, under various market scenarios the market refuses to rollover this debt and thus such debt can quickly mushroom into an unmanageable amount.

Jeane and Guscina [35] claim that their database refutes the first claim by Eichengreen and Hausmann (1999) [23] of the "original sin", by showing that Asian countries can and do borrow in their own currency. Their database shows that part of the composition of the public debt in Asia was dominated in domestic currency at mainly fixed interest rates for an average duration of 5 to 10 years. Table 12 describes how Jean and Guscina [35] broke down the composition of the emerging market debt.

Table 12

Domestic Currency Fixed Interest Rate	Domestic Currency Variable Interest Rate	Foreign Currency Fixed Interest Rate	Foreign Currency Variable Interest Rate	Indexed Fixed Interest Rate	Indexed Variable Interest Rate
short-term maturity (<1 year) medium-term maturity (1-5 years) long-term maturity (>5 years)	short-term maturity (<1 year) medium-term maturity (1-5 years) long-term maturity (>5 years)	short-term maturity (<1 year) medium-term maturity (1-5 years) long-term maturity (>5 years)	short-term maturity (<1 year) medium-term maturity (1-5 years) long-term maturity (>5 years)	short-term maturity (<1 year) medium-term maturity (1-5 years) long-term maturity (>5 years)	short-term maturity (<1 year) medium-term maturity (1-5 years) long-term maturity (>5 years)

In looking at the composition of Thailand's debt, one can observe from table 13 that Thailand had a total of 44, 254 million Thai Baht of domestic debt in 1996 and the public debt decreased to 31,755 million Thai Baht by 1997.

Table 13

THAILAND		
in millions of Thai Baht	**1996**	**1997**
Total Central Government Domestic Debt (nominal value)	44,254	31,755
% of Total CG Domestic Debt		
Domestic Currency Fixed Interest Rate	40.3	42.7
long-term maturity (>5 years)	40.3	42.7
Domestic Currency Variable Interest Rate	59.2	56.7
short-term maturity (<1 year)	0.0	0.0
medium-term maturity (1-5 years)	59.2	56.7
Foreign Currency Fixed Interest Rate	0.5	0.6
long-term maturity (>5 years)	0.5	0.6

Database of Jeanne and Guscina [35].

In terms of international debt, Table 14 shows that Thailand had a total of 5,815 million dollars of international debt in 1996, but by the end of 1997, due to the crisis, the amount more than doubled.

Table 14

in millions of US dollars	**1996**	**1997**
Total CB+CG International Debt	5,815	14,388
of which Central Bank	0	4,728
of which Central Government	5,815	9,659

Database of Jeanne and Guscina [35].

Notice that approximately 23% of public debt was denominated in domestic currency. The remaining was denominated in dollars. Yes, Thailand can borrow domestically but this hardly refutes the "Original Sin" claim made by Hausmann [23] and others.

F.) Contingent Liabilities and the Financial Sector

Lately the primary sources of contingent liabilities, with which many emerging market governments have had to deal, have arisen from their financial sector. As Kharas and Mishra [41] put it, "Banking crises have been the most important source of government contingent liabilities". The question that arises is how does the structure of a country's financial system lends itself to the possible creation of these contingent liabilities. In evaluating the structure of the financial sector for various countries, Franklin Allen and Douglas Gale [4], note in their that there are two main types of financial structures: of a market based system or a relational based banking system. Each type of system has it costs and benefits.

The predominant feature of a market based system is the key role that capital markets play in raising the necessary financing by firms for various investment projects. In essence, firms have two means of raising capital, either through bank financing or by the issuance of equity or bonds via the stock market or the debt market. At the same time, corporations are monitored and disciplined through market prices with support from government regulations.

A financial sector that is dominated by a small set of banks is structurally considered to be a relational based banking system. Within such a system, corporate financing usually takes the form of long-term bank loans and retained corporate earnings. Such a system lends itself to closer monitoring of investment projects due to the close relationship between the corporations and the banks monitoring their investments. The Achilles heel of such a system lies in the lack of transparency needed to ensure that such a system runs efficiently. A market based system definitely has transparency problems but the issue seems to be more acute in a relational based banking system.

The issues of moral hazard and information asymmetry can quickly lead to a loss of confidence in the financial system. As Stijn Claessens and Daniela Klingebiel [18] put it, "public contingent liabilities can quickly emerge when governments try to limit the loss of confidence in the financial system during periods of financial turbulence." The main reason for this is the need by governments to formalize implicit guarantees, so as to prevent a possible collapse of the financial system. According to Caprio and Klingebiel (1999) [27], "there have been over 112 episodes of systemic banking crises that have erupted in 93 countries since the late 1970's". If a government is forced to deal with any problem that arises in the banking, how can a government properly measure these possible contingent liabilities?

There are three such ways of measuring the possible contingent liabilities that may arise from the banking sector. The first way such way the price of a fiscal contingent liability can be measured is by pricing the value of a put option that the government sells to the financial sector. The price of this option can help a government determine the potential liabilities that it may face. The problem with using such an option is determining when it should be exercised. If the put option is an American option, this would allow the buyer the right to sell his assets to the seller anytime up until the time the option matures.

The second way the actual value of any possible contingent liability could be determined is through simulation. Given the government's ability to acquire information about the amount of assets and the liabilities on the books of various banks, the expected value of the contingent liabilities can be determined by simulating the probability distribution of the net assets of the banking sector. The problem with using the expected value instead of the market value of any possible contingent liability is twofold. Any deposit based upon the expected value rather than market value under prices the true cost of providing an explicit guarantee. If banks were forced to buy private insurance to cover possible losses, they would in likelihood be forced to pay a premium based upon their credit risk. The expected value of any contingent liability in theory should take this risk into account, but in practice such a risk is not taken into account if the government is involved in calculating the guarantee. The pricing of a national deposit insurance by the government amounts to providing a government subsidy if the expected value rather than the market value of liability is utilized. Second, "The expected loss may not be the actual loss that a government faces."

The final way the value of any possible contingent liability can be determined is through implicit guarantee pricing. "If the government issues a guarantee, the guaranteed debt should trade at a price equivalent to risk free bonds. Therefore, the implicit market value of a guarantee can be calculated as the difference between the market value of a risk-free government bond and the market value of the bonds issued by the potential recipient of the guarantee."[11]

This dissertation has taken the same approach utilized by Barnhill and Kopits [9], which is to take the expected value of any contingent liabilities. This approach is the worst of all approaches, but due to the availability of data, it is the best possible approach that can be taken at the moment.

[11] Advances in Risk Management of Government Debt, "Explicit Contingent Liabilities in Debt Management". Pg.107

G.) Model Environment and Results

To test the effectiveness of this model the environment in which the model operates needs to be described. As mentioned earlier, Thailand along with South Korea, Indonesia, and the Philippines suffered a major economic financial crisis in 1997 which has come to be known as the Asian Crisis. This dissertation applies a Value at Risk model to the country of Thailand for the previous year of 1996 in order to test its ability to provide advance warning of a crisis.

In 1996 the GDP of Thailand grew at an annual rate of 2.45%. This was down from a rate of 6.16% the previous year. During that same period the annual rate of inflation was 5.9%, while the mean exchange rate level was 25.36 Bahts/dollar. In table 15, the correlations between the following risk factors of the model are displayed.

Table 15

Correlation Matrix	Exchange rate	CPI	Libor	Variable interest rate
Exchange Rate	1.000	0.8374	0.2934	-0.8180
CPI	0.8374	1.0000	0.4835	-0.9740
Libor	0.2934	0.4835	1.0000	-0.4176
Variable Interest rate	-0.8180	-0.9740	-0.4176	1.0000

Notice that there is a positive correlation between the exchange rate, the inflation rate, and the international interest rate as measured by the U.S. Libor rate. In addition the variable interest rate is negatively correlated with all other risk factors. In running the model, over 200 different scenarios are simulated for each risk factor to price the debt and calculate the present value of the government's Value of Risk metric. (The number of scenarios created was based on the computational power of the computer that this dissertation used.) Initially the model was run without fully incorporating any possible contingent liabilities that the government may face. The idea in running the model in this manner was to check whether or not the government of Thailand was already at the edge of fiscal insolvency in the previous year before the crisis. There are three simulated cases. They are:

Baseline: $VaR = PB_t - \delta^{i***}\Delta IntD_t$

Domestic Debt: $VaR = PB_t - \delta^{i*}\Delta VD_t - \delta^{i**}\Delta FD_t - \delta^{i***}\Delta IntD_t$

Contingent Liability: $VaR = PB_t - \delta^{i*}\Delta VD_t - \delta^{i**}\Delta FD_t - \delta^{i***}\Delta IntD_t - \gamma' C_t$

(The Matlab Code to run each case is included in Appendix B)

In Table 16 and Table 17, the results of the simulation are displayed. There are three simulation cases:

Table 16

	Mean	Standard Deviation	Min	Max	Value at Risk 95 percentile	Value at Risk 99 Percentile
Baseline	8,226,300,000	496,060	8,224,900,000	8,228,000,000	8,225,400,000	8,225,200,000
Domestic Debt	7,972,500,000	582,350	7,970,900,000	7,973,900,000	7,971,600,000	7,971,300,000
Contingent Liability	16,817,854	582,420	15,214,016	18,192,768	15,892,099	15,578,212

Table 17

Denominated in Baht	Mean	Standard Deviation **(not raised to any power)**	Min	Max	Value at Risk 95 percentile	Value at Risk 99 Percentile
Baseline (10^{11})	2.0368	13240152	2.0364	2.0371	2.0366	2.0365
Domestic Debt (10^{11})	1.9729	15255989	1.9725	1.9733	1.9726	1.9726
Contingent Liability (10^{9})	-3.0041	15,255,292	-3.0494	-2.9653	-3.0303	-3.0391

How do we interpret the results in the previous two tables? Let $X_{Baseline}$ be the value of the government where only the difference between the Primary budget balance and the international debt is considered. The Value at Risk for the government sector in the baseline case is 8,225, 400,000 at the 5% significance. In other words there is a 5% simulated probability that the value of the government will be less than 8,225,400,000 dollars over the next year. The confidence with which a simulated estimate of the 5^{th} percentile of the distribution of the value of the government includes the true 5^{th} percentile increases with the number of simulations. Letting $X_{domestic\ debt}$ and $X_{contingent\ liability}$ be the value of the government in the cases where the domestic debt is included, and when the domestic debt and the expected value of the contingent liabilities are included, then at a 5% significance level $X_{domestic\ debt} \leq 7{,}971{,}600{,}000$ and $X_{contingent\ liability} \leq 15{,}892{,}099$. Based upon the standard deviations for the case when the contingent liabilities are included the simulated $P(X_{contingent\ liabilities} \leq 8{,}225{,}400{,}000)=1$. The values in table 16 are based upon the assumption that fluctuations in the exchange rate do not play a role in the value of the government sector. Thus, everything is valued in terms of the U.S. dollar so that there is no exchange rate risk. Thus, the contingent liabilities do not cause the Value at Risk metric to be negative. In addition, the inclusion of the contingent liabilities is in expected value terms, not in market value terms. The probabilities used to calculate the expected value of the contingent liabilities are based upon the government's ability to recover the future value of any nonperforming loans. In calculating the expected value of the contingent liabilities it is assumed that recoverability rate was 64% of any nonperforming loan. In 1996, Thailand had a GDP of $3{,}111*10^9$ Baht. Thus as stated earlier, if Thailand had an implicit guarantee that averaged around 10% of GDP annually for the previous years leading up to the crisis, and if the government believes that it can recover 64% of the value of this contingent liability, then the expected value of this contingent liability is E(contingent liability)=0.64*(0.10)*(3111*10^9)=199,360,000,000.

The methodology used to calculate the expected value of the contingent liabilities is very similar to that found in Barnhill and Kopits paper on assessing fiscal sustainability.

For Table 17 the results are displayed in terms of the local Baht currency. This table incorporates fluctuations in the exchange rate. As a result exchange rate risk becomes a factor. Over the one year time interval the mean value of the exchange rate was $\frac{25.7810\,Baht}{1\ dollar}$. The exchange rate fluctuated between a minimum value of $\frac{22.7572\ Baht}{1\ dollar}$ and max value of $\frac{28.7559\ Baht}{1\ dollar}$ with a standard deviation σ of $\frac{1.1701\,Baht}{1\ dollar}$. From Table 17 there is a 5% simulated probability in the baseline case that the value of the government will be less than 203,660,000,000 Baht. When both the domestic debt and the contingent liabilities are included the probability is $Pr(X_{contingent\ liability} \leq -3{,}030{,}300{,}000) = 0.05$. But it is important to note that the simulated maximum value of the government in the contingent liability case is -2,965,300,000 while the simulated minimum value of the government is -3,094,000,000. In other words all the simulated distribution values in the contingent liabilities case were all negative. Here the interpretation of the simulated Value at Risk value is how much worse can the government's fiscal position get at the 5% significance level with the addition of contingent liabilities. It is also important to note that the simulated value of government varied by a standard deviation of 15 million baht. The distributions in both cases are quite tight.

H.) Model Evaluation

This model seems to suffer from the same affliction that affects Barnhill and Kopits'[9] similar model. The affliction can best be described by the following question. When applying a Value at Risk approach to the government sector, what exactly is at risk in terms of government financing? In a typical value at risk approach, one is usually concerned with the final value of a portfolio of stocks or bonds that he has initially bought at a price of $X. In the event that an investor needs to liquidate this portfolio expeditiously, given changes in market prices under normal conditions, the question then becomes, how much could one lose in terms of the value of the portfolio over the time period needed to liquidate this portfolio? Usually, that time period is 24 hours. When an investor deals with a portfolio of stocks and bonds, he is usually handling financial instruments. From this stock of investments one gains an income flow of returns either through liquidating this portfolio, or through dividends or coupon payments. This flow of income is not exactly analogous to the flow of income that one gains from the primary budget balance of a government. In this model and in Barnhill and Kopits'[9] model, what are considered assets are the primary budget balance and sales of natural resources. While the sales of natural resources are stochastically priced in Barnhill and Kopits [9], the primary budget balance is not stochastically priced. The key point to notice is that the primary budget balance is a flow term while natural resources are stock terms. This is critical in pricing the actual value of the government assets. How does one price the actual value of the primary budget balance? One possibility is to use cash flow analysis and to price the cash flows using a stochastic interest rate, but it is important to note that this cash flow is very much based on the projections of future tax revenues. For an export producing country these tax revenues are definitely a function of future exchange rate values and interest rates.

It is interesting to not how relatively small the simulated standard deviation is in both cases for the distribution of values. In the case where we are only concerned about fluctuations in the interest rate, the simulated standard deviation of $X_{\text{contingent liability}}$ is 582,420 dollars. One way of measuring how much variability there is in the data is to calculate the coefficient of variation. The coefficient of variation $CV = \left(\frac{STD}{mean} \times 100\right)\%$ gives an indication of how large the standard deviation is relative to the mean. The larger this coefficient of variation is the more variability there is in the data. In the case of $X_{\text{contingent liability}}$ the coefficient of variation is CV= 3.46%. Such a small coefficient of variation is an indication that there is very little variability in the data. The fact that there is hardly any variation in the data is not surprising given the fact that up until the point where the Thai government was forced to devalue Thailand had pegged its exchange rate to the dallar and thus there were little variations in prices. This definitely brings into question the appropriateness of such a model given that under normal market conditions variations in prices were minimal to say the least.

VI.) Conclusion

There often is a tendency in the risk management profession to distill very complex economic information so that it can be readily digested and easily used in making critical decisions. While such a refinement may be useful in making decisions that require immediate actions, such a refinement does not come cheaply. In assessing the appropriateness of a Value at Risk model for fiscal sustainability, one gets the feeling that the true nature of how much is at the risk and what is actually at risk is being concealed by a single number. Both this dissertation and Barnhill and Kopits [9] paper had trouble defining what is actually at risk in terms of fiscal sustainability for the government sector. This inability to clearly define what is actually at risk makes it difficult to determine how much is actually at risk. This difficulty largely is due to the differences in the measurement of flows and stocks for government assets. A government's primary balance is mainly a flow item that is very much dependent upon the collection of taxes, which in turn is very much a function of economic conditions and factors often unforeseen by a government - - contingent liabilities arising from the banking sector. The credit crunches that often arise when a country suffers from a banking crisis or is on the edge of a banking crisis in most cases adversely affect business investments and thus taxes. In assessing the Value at Risk model in this dissertation and in Barnhill and Kopits [9], the variables that are modeled stochastically are not the primary budget balance but rather the liabilities of the government sector. Yet in reality the actualization of future taxes needed to maintain a constant debt to GDP ratio and ensure proper servicing of the government's fiscal responsibilities is very much stochastic and dependent upon future economic conditions. An issue that definitely needs to be addressed is the question of how to properly model revenue generated from taxes. If this revenue is to be treated as an asset then knowing how this revenue is generated is very important. This requires that there be a clear understanding of the underlying tax structure of a country. In Barnhill and Kopits [9] paper there was no mention of the major sources of taxes for Ecuador. Neither was there any mention of how Thailand generates revenue from taxes in Meir's [6] dissertation. While this information can be found from such databases as the Government Finance Statistics (GFS), understanding how the economic dynamics of a country affect the underlying tax structure of that country is important for forecasting future sources of government revenue. As is the case for Thailand, many emerging market economies depend upon value added taxes, rather than corporate taxes, as a source of revenue. These are taxes that are applied to the imports and\or exports of the country. What would happen in the event that the exchange rate of that country depreciated? Over time, a depreciation of the exchange rate might actually help generate more revenue from taxes in the case were a country relies heavily upon its exports. As exports become cheaper to the rest of the world, more of it is likely to be demanded. The increase in export sales will generate more revenue for a country that places a value added tax on it. At the same time, if a country is very dependent upon oil imports as a source of energy for manufacturing, depreciation might actually hurt that country by raising the cost of production which in turn reduces the profits domestic companies gain from their exports. The taxes that the government gains from export sales may fall as companies reduce production to minimize cost and maximize profits. For a country that is import oriented, depreciation would definitely raise the cost of its imports. Thus any revenue generated from value added taxes on imports would fall, as consumers and companies buy fewer imports because of rising cost. The reverse arguments can be made for the event of an appreciation of a country's currency.

On the liability side, the issue is the modeling of government debt. Knowing the structure of a country's debt and its repayment schedule is very important to pricing the cost of a country's present and future debt obligations. For example, in Barnhill and Kopits'[9] paper, they assumed that 30% of Ecuador's debt is to be paid over 27 years, while the rest of the debt would be paid over the next 7 years. It is hard to determine whether this is factually the case since information on the maturity structure of the debt for Ecuador is not publically available. Meir's [6] dissertation does not even mention the repayment schedule for Thailand's debt. Meir's [6] dissertation just discounts the entire government debt. The maturity structure of the debt and the type of debt, whether it be short term or long term, or inflation indexed or not, determines the cost of its liabilities. For example in this dissertation, the assumption was made that Thailand had approximately 5- 10 years in which to pay the majority of the domestic debt. This assumption was made by inspecting Anastasia Guscina and Olivier Jeanne's [35] new database on the debt structure of 19 emerging countries, one of which was Thailand. For modeling purposes, it was assumed that Thailand domestic debt had to be repaid within 5 years. In terms of the international debt, it was assumed that Thailand had 10 years to repay back its international obligations. Based on this information, the amortization schedule for the repayment of a country's debt was determined. This allowed the model to determine how much of the debt Thailand was responsible to repay within the time horizon of the model. This also allowed the model actually price and discount the government's fiduciary responsibility given information about market prices. The type of debt that a government issues is instrumental in determining which underlying risk factors should be included in the model. For example, several countries in Anastasia Guscina and Olivier Jeanne's [35] database have issued domestic debt that is inflation indexed.

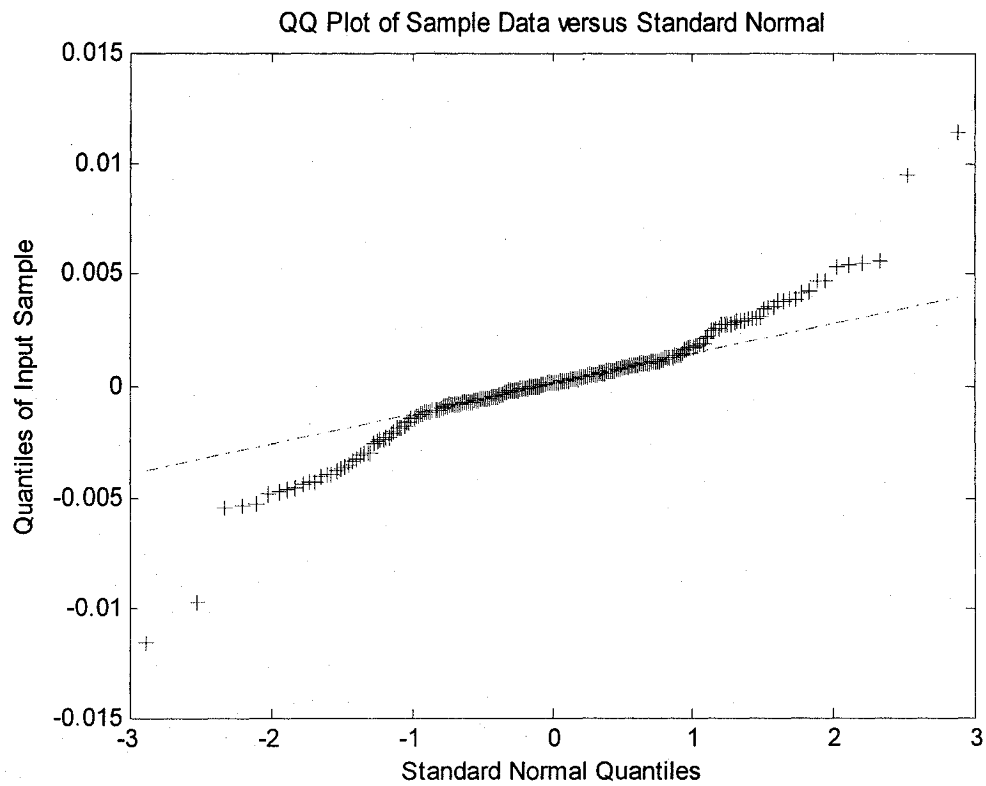
In a policy paper written by David W. Wilcox [55], the author noted that United States, in 1997, joined several other countries in issuing inflation indexed government bonds. In explaining the pricing of this debt, David Wilcox [55] noted that if government issued a inflation indexed 10 year note with a par value of $1,000 at an interest rate of 3 3/8% with semiannual coupon payments, and if the inflation rate ran at a steady 3 percent annually, then the government would be responsible for paying a total of $34.51 (=1/2 x .03375 x $1.03^{1/2}$ x $1000 + 1/2 x .03375 x 1.03 x $1000) each year to the bond holder.[12] Thus, in applying a Value at Risk model to a country, which has debt indexed to the inflation rate, it is necessary to know the inflation rate dynamics to price the government's liabilities. In both this dissertation and in the paper by Barnhill and Kopits [9], the inflation rate was modeled as an asset price. The debt was then priced in real terms. The inflation rate was not modeled in Meir's [6] dissertation. However, with the recent warning by the IMF of worldwide inflationary pressure, it would behoove most risk managers of government debt to include inflation as an underlying risk factor in their models.

Another issue that must be considered is what variables or risk factors should be incorporated into the model. This issue becomes very relevant when considering the economic dynamics of a country. For example, Barnhill and Kopits [9], modeled the commodity price of oil for Ecuador. This is important since oil is one of Ecuador's main exports. While modeling the commodity price of a natural resource is important for countries that rely on it for revenue, for other countries, this may not be relevant. In this dissertation and Meir's [6] dissertation the modeling of the commodity prices for Thailand's exports was not incorporated. Earlier it was mentioned that inflation should be included in the model as way of pricing inflation indexed government debt. An additional reason to include inflation is its effect on the economic dynamics of a country. Inflation affects the type of fiscal and monetary policy a government can implement to maintain

[12] (Wilcox, Winter 1998 pg. 220)

fiscal sustainability. If the debt is inflation indexed, then an expansionary fiscal policy, during a recession, may hinder a country from meeting its fiduciary responsibilities.

There is definitely a question about how the underlying risk factors should be modeled. The underlying risk factors, such as the exchange rate, are modeled using a stochastic differential equation. In generating possible scenarios, the returns are assumed to normally distribute. But it is very much known that market returns are not necessarily normally distributed. A tool that is used quite often to determine whether or not a sample comes from a particular distribution is the qq plot. If the quantiles of sample align themselves along a 45 degree line with the quantiles from a normal distribution then it is somewhat safe to assume that the sample comes from a normal distribution. In modeling the dynamics of the exchange rate it assumed that the changes in exchange rate values are normally distributed. In looking at the qq-plot for the changes in the daily exchange rate value used in this dissertation for the year 1996, we can see from the qq-plot that the sample is not necessarily from a normal distribution.


QQ Plot of Sample Data versus Standard Normal
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
Quantiles of Input Sample
-3
-2
-1
0
1
2
3
Standard Normal Quantiles

As a matter of fact, if one calculates the skewness of the changes and the kurtosis of these changes the numbers one derives are Skewness=-0.1660 and Kurtosis=8.0609. In other words the changes in the exchange rate values are more negative than positive and the tails of the distribution are fatter than what one expects from a sample that is supposedly normally distributed. This suggests that assuming the changes in the underlying risk factors are normally distributed is not only inappropriate, but may increase the likelihood of wrongly estimating future return values.

Using a Value at Risk approach as an early warning system for assessing fiscal sustainability is fraught with many other additional problems. A definite problem confronting this approach is the need to use historical data to parameterize the models. The dependence upon this data can make many of these models ineffective when the underlying economic dynamics that generates this data suddenly changes. Changing economic dynamics can affect the correlations between various model variables such as interest rates, inflation, and exchange rates. These changes can either increase the correlations or change the signs of the correlations between these variables. The change in the correlations can have an unwanted effect upon the variance-covariance matrix used in these models. Because economic dynamics usually change during times of distress, the complete reliance upon these models can lead policy makers in the wrong economic direction. To correct this problem, policy makers and economist need a better understanding of how the correlations between various variables utilized in their respective models change during times of distress. This requires a fundamental understanding of the economic dynamics that generated the data. This is vitally important for stress testing, not only Value at Risk models, but conventional models.

Too often there is too strong of a belief that historical data is a good indicator of future market behavior. Yet measuring future market volatility using historical data can be very misleading. In terms of market volatility and price changes, a Value at Risk approach to assess the sustainability of the fiscal sector has significant cost when market conditions become highly turbulent. Earlier we showed the different ways of calculating the Value at Risk of a portfolio consisting of only one stock. The price utilized was based upon a period of increasing market returns.

The 10-day relative Value at Risk using the variance-covariance method was VaR=2407.15 . The actual price of the stock if one was forced to hold it for 10 days fell from a high of approximately $545 per share to $425 per share. If billions of dollars are invested in this portfolio the actual loses could be tremendous. As markets increase in size, the amount of volatility also increases. Such increases in volatility can have an effect on the correlations between the economic and financial variables used in these models. It is because of this increase in volatility that Value at Risk models tends to underestimate how much risk truly exists. In other words the tails in most Value at Risk models are not as thick as the conditions in financial markets suggest. A correction can be made by assuming that the Value at Risk model, of concern, follows a t-distribution instead of a normal distribution. However, such a correction is usually done as an afterthought. Additionally, the use of the t-distribution requires estimating how thick the tails should be from previous historical data. Even here, it should be noted, that the thickness of the tails can change due to changing economic dynamics.

How the data is measured also plays a role in the measurement of volatility. For example, the use of monthly data versus quarterly data can have an impact on the accurate measurement of volatility. In general, monthly data is more volatile than quarterly data or even yearly data. This is due to the sheer frequency of the data. Additionally, monthly data provides more timely information about changes in economic dynamics. As a general rule, the more frequent the information the more accurate the measurement will likely be. The accurate measurement of market volatility is needed to correctly calculate the size and direction of the correlations in the variance-covariance matrix. This becomes even more important when using an exponential weighted moving average method to calculate the variance-covariance matrix. Such a method was utilized in the dissertation by Meir [6]. This method puts more weight on the most recent observations than on later observations. If quarterly data is used rather than monthly data, the amount of volatility that the exponential weighted moving average method should capture is underestimated. Additionally, a lack of frequency may cause the exponential weighted moving average method to place far too much weight on information that is far less volatile. This will definitely contribute to the model underestimating the risk. Even if monthly data is used, the process of placing the weights on the most recent data can cause the model to emphasize a time period of relative calmness rather than emphasizing those periods of intense volatility. This is a structural break issue that neither Barnhill and Kopits [9] nor Meir [6] examined closely.

As mentioned earlier stress testing is very important for testing the validity of both Value at Risk models and the conventional approaches. There are several approaches that can be taken when stress testing a model. One excellent approach that is discussed extensively, by Diane Reynolds [51] is to group the risk factors into various groups. Once this has been done, according to Diane Reynolds [51], the statistical properties of the risk factors should be determined so that the variables in each group can be properly modeled. Once the groups are developed and the marginal distributions are understood, using such techniques as principal component analysis can be utilize in constructing a variance-covariance matrix. While principal component analysis can be very inaccurate at times, the mathematics of copulas in combination with principal component analysis has been shown to be very effective in constructing a fairly accurate variance-covariance matrix. Once the various groups are created, scenarios can be generated by exploring what would happen if a particular group of risk factors changed by a certain percent. Given the massive number of risk factors that are lately being incorporated in various models, the mathematics of copulas in combination with principal component seems be the most promising in terms of computational efficiency and accuracy.

Value at Risk models are increasingly being used by many institutions to reduce and monitor the amount that is at risk in their portfolio of investments. However, each institution has a particular threshold, in terms of losses, that they do not want exceeded. These thresholds are monitored very closely, and once the likelihood that these thresholds might be exceeded increases, adjustments are made in these institutions' portfolios. The increasing use of Value at Risk models seems to increase the tendency for markets to overreact and panic during periods of high volatility. The panic that ensues as institutional thresholds are exceeded can lead to market herding as people try to simultaneously adjust their portfolios to reduce possible losses. Thus, instead of reducing the likelihood of a crisis, the ubiquitous use of Value at Risk models can actually increase the likelihood of a financial crisis.

The time horizon for most Value at Risk models utilized by banks and corporations is usually one to 10 days. Yet, when applying such a model to the fiscal sector, the time horizon observed in several papers has been a year to 36 months. In Barnhill and Kopits [9] paper and in this dissertation the time horizon was one year. In Meir's [6] dissertation the time horizon was 36 months. The different time horizons create several problems. First, the longer time horizon of one year to 3 years does not take into account all the possible actions that can be taken by a government to increase or decrease its ability to maintain fiscal sustainability. Second many financial institutions use shorter time horizons than governments and thus, they react much more quickly to changes in market dynamics. These shorter time horizons increase price volatility as financial institutions constantly monitor and adjust their portfolios. How these shorter time horizons impact government risk models is definitely worth further researching. Third, Meir [6] used a three year window while Barnhill and Kopits [9] used a one year window. Neither models explored the possibility of structural breaks in the economics dynamics of the variables. The choice of the time horizon is important in capturing market volatility. Arbitrarily choosing a time horizon without fully understanding the economic dynamics during that time horizon can be quite dangerous. This is especially so, if during the time period chosen, price volatility is low.

The availability of data for emerging markets is definitely a problem when applying any kind of early warning system. Getting the correct data to correctly price government bonds can be very difficult when dealing with emerging markets. The one year forward interest rate for Thailand was not provided until after the Asian crisis. This makes it very difficult to test whether or not a Value at Risk model can be effectively used as an early warning system. Backtesting a Value at Risk model for the fiscal sector of an emerging market country is problematic due to the lack of reliable data. Most emerging market countries do not have enough historical data to correctly parameterize the models. For example, the dissertation by Meir [6] did not include domestic debt due the fact that it did not have data on the composition of Thailand's debt. While the signaling approach by Kaminsky, Reinhart and Goldstein [49] was forced to rely on "domestic inflation in lieu of the nominal interest rates, as market-determined interest rates were not available during the entire sample for a number of countries."[13]

The Value at Risk approach and the conventional approach may both indicate that a government is fiscally solvent. However, neither of these approaches take into account

[13] (Morris Goldstein, June 2000, Appendix A)

the liquidity risk that a government faces when it must sell its assets at below market value to cover the realization of contingent liabilities. Even though a government appears solvent over the long term, a fire sale of government assets in the short-run, due to a financial crisis, may create such a liquidity problem that a government may be forced to default. As such, both the Value at Risk approach and the conventional approach need to stress test for possible liquidity problems in the short-run and in the long-run.

The final issue that must be dealt with when applying a Value at Risk model to the fiscal sector is the proper pricing of contingent liabilities. Many governments provide implicit or explicit guarantees to their banking sector. How these guarantees are priced determines whether or not the actual costs of the guarantees are being estimated correctly. In Barnhill and Kopits [9] paper, the cost of possible guarantees to the financial sector was determined by calculating the expected value of such liabilities. This requires that there be an efficient way of calculating the probabilities that such liabilities will occur. The lack of data makes this very difficult to accomplish. The use of options is also impeded by the lack of reliable data. How these guarantees should be priced definitely warrants further research.

Despite the misgivings of many economists, the conventional approach to fiscal sustainability is still a useful tool for forecasting over an extended number of years. The conventional approach to fiscal sustainability can be made far more effective if the underlying variables are stochastically generated over a range of values for key underlying variables. One possibility is to randomly generate a grid of possible scenarios for the interest rate, exchange rate, and growth rate. Based upon this grid an assessment can be made on what it would take maintain a constant debt to GDP ratio. This would in essence create a probability distribution of possible long term outcomes. Even contingent liabilities, such as that which is occurring in the subprime housing market, can be effectively incorporated into the conventional approach. This can be done by assessing what the interest rate, exchange rate, and growth rate need to be to maintain a constant debt to GDP ratio for an additional unit of debt. In concluding, the exclusive use of the Value at Risk approach as an early warning system is fraught with too many problems. Rather this approach should be used in conjunction with the conventional approach as a means of helping policy makers make sound decisions.

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(Reproduced word for word from Assessing Financial Vulnerability, pg. 111-113)

Appendix A

Data and Definitions

The Indicators

Sources include the IMF's International Financial Statistics(IFS), The International Finance Corporation's (IFC) Emerging Market Indicators, and the World Bank's World Development Indicators. When data were missing from these sources, central bank bulletins and other country-specific sources were used as supplements. Unless otherwise noted, we used 12 month percentage changes.

M2 multiplier: the ratio of M2 to base money (IFS lines 34 plus 35) divided by IFS line 14

Domestic credit/nominal GDP: IFS line 52 divided by IFS line 99b (interpolated). Monthly nominal GDP was interpolated from annual or quarterly data

Real interest rate on deposits: IFS line 601, monthly rates, deflated using consumer prices (IFS line 64) expressed in percentage points.

Excess real M1 balance: M1 (IFS line 34) deflated by consumer prices (IFS line 64) less an estimated demand for money. The demand for real balances is determined by real GDP (interpolated IFS line 99b), domestic consumer price inflation, and a time trend. Domestic inflation was used in lieu of nominal interest rates, as market-determined interest rates were not available during the entire sample for a number of countries; the time trend (which can enter log-linearly, linearly, or exponentially) is motivated by its role as a proxy for financial innovation and/ or currency substitution. Excess money supply (demand) during precrisis periods (mc) is reported as a percentage relative to excess supply (demand) during tranquil times (mt)-that is, 100 x (mc –mt)/mt.

M2 (in US dollars)/reserves (in US dollars): IFS lines 34 plus 35 converted into dollars (using IFS line ae) divided by IFS line 1L.d.

Bank deposits: IFS line 24 plus 25.

Exports (in US dollars): IFS line 70

Imports (in US dollars):IFS line 71

Terms of trade: the unit value of exports (IFS line 74) over the unit value of imports (IFS line 75). For those developing countries where import unit values (or import price indices) were not available, an index of prices of manufactured exports from industrial countries to developing countries was used.

Real exchange rate: based on consumer price indices (IFS line 64) and defined as the relative price of foreign goods (in domestic currency) to the price of domestic goods. If the central bank of the home country pegs the currency to the dollar (or deutsche mark), the relevant foreign price index is that of the United States (or Germany). Hence for all the European countries the foreign price index is that of Germany, while for all other countries consumer prices in the United States were used. The trend was specified as, alternatively, log-linear, linear, and exponential; the best fit among these was selected on a country-by-country basis. Deviations from trend during crisis periods (dc) were compared with the deviations during tranquil times (dt) as a percentage of the deviations in tranquil times (i.e., 100 x (dc-dt)/dt).

Reserves: IFS line 1L.d.
Domestic-foreign interest rate differential on deposits: monthly rates in percentage points (IFS line 601). Interest rates in the home country are in percentage points (IFS line 601). Interest rates in the home country are compared with interest rates in the United States (or Germany) if the domestic central bank pegs the currency to the dollar (or deutsche mark). The real interest rate is given by $100 \times [(1 + i_t)p_t/p_{t+1}]$.
Output: for most countries, industrial production (IFS line 66). However, for some countries (the commodity exporters) an index of output of primary commodities is used (IFS line 66aa).
Stock prices (in dollars): IFS global indices are used for all emerging markets; for industrial countries the quotes from the main bourses are used.
Overall budget balance/GDP: consolidated public-sector balance as share of nominal GDP (World Bank Debt Tables).
Current account balance a share of investment: current account divided by grow investment (World Bank, World Development Report database available in CD ROM).
Short-term capital inflows: Short-term capital flows as a percent of GDP, (World Bank, World Debt Tables, database available in CD ROM).
Foreign direct investment (FDI): FDI as a share of GDP (World Bank, World Debt Tables, database available in CD ROM).
General government consumption/GDP: General government consumption, national income accounts basis a percent of GDP, annual growth rate (World Bank, World Debt Tables, database available in CD ROM).
Central bank credit to the public sector/GDP: Annual growth rate (World Bank, World Debt Tables, database available in CD ROM).
Net credit to the public sector/GDP: Annual growth rate (World Bank, World Debt Tables, database available in CD ROM).

Appendix B (Matlab Code)

```
%Value at Risk for the Government Sector
%The Program is called VriskGov
global OX



CPI=single(riskfactors(:,2));
Libormonthly=single(riskfactors(:,5));
exchrate=single(riskfactors(:,1));
VI=single(riskfactors(:,3));
exchratedaily=single(exchrtdaily96(:,1));

str='Here is the initial exchange rate'

initialexchangerate=single(exchrtdaily96(1,1))
e=(1/initialexchangerate)
avexchgrt=mean(exchratedaily);
Libordaily=single(libor(:,2));
str='Here is the spread over the libor rate'
spread=mean(VI-Libormonthly)
totaldomdebt=single(thaidebt(:,1));
th=thaidebt(1,2);
str='Here is the value of the domestic fixed rate and variable rate
debt in dollars'
domfixinterdebt=initialexchangerate*(single(thaidebt(1,1)).*thaidebt(1,
2))*(10^6)
domvarinterdebt=initialexchangerate*(single(thaidebt(1,1)).*thaidebt(1,
3))*(10^6)

str='Here is the value of the international debt in dollars'
internationaldebt=((single(thaidebt(:,4))*(10^9)))
str='here is the value of all thailands debt in dollars'
totaldebtthailandindollars=domfixinterdebt+domvarinterdebt+internationa
ldebt


internationaldebtbaht=(1/initialexchangerate)*((single(thaidebt(:,4))*(
10^6)))

mlibor=mean(Libordaily);

%govbudgetbaht=((govbalance(7,2)+govbalance(7,3))/1000)*(10^9)
%govbudget=initialexchangerate*((govbalance(7,2)+govbalance(7,3))/1000)
*(10^9)
govbudgetbaht=((govbalance(7,2))/100)*(10^9);
govbudget=initialexchangerate*((govbalance(7,2))/100)*(10^9);


%check this very carefully
%dollarcliab=2*10^9
%cliab=(1/initialexchangerate)*dollarcliab

str='here is the value of the contingent liabilities which some claim
be 10% of the GDP in 1996'
```

```
cliab=0.643*(0.10)*(3115*10^9) .
dollarcliab=initialexchangerate*cliab

diffbahtgovcliab=govbudgetbaht-cliab;
difgovcliab=govbudget-dollarcliab;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Amortization schedule for international debt over a 10 year period
numperiods=10;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
rate=((mean(Libormonthly)+spread)/100);

  %the initial value is in dollars
presentvalue=internationaldebt;
[Principal, Interest, Balance, Payment] = amortize(rate,numperiods,
presentvalue);
pinternationaldebt=Payment;
pinternationaldebtbaht=e*Payment;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
numperiods=7;
rate=(10.75/100)/100;
%the initial value is in dollars
presentvalue=domfixinterdebt;
[Principal, Interest, Balance, Payment] = amortize(rate,numperiods,
presentvalue);
pdomfixinterdebt=Payment;
pdomfixinterdebtbaht=(1/initialexchangerate)*Payment;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
numperiods=5;
rate=(mean(VI)/100)/100;
%the initial value is in dollars
presentvalue=domvarinterdebt;
[Principal, Interest, Balance, Payment] = amortize(rate,numperiods,
presentvalue);
pdomvarinterdebt=Payment;
pdomvarinterdebtbaht=(1/initialexchangerate)*Payment;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
networthdollar=govbudget-pinternationaldebt-pdomfixinterdebt-
pdomvarinterdebt;
networthbaht=govbudgetbaht-pdomfixinterdebtbaht-pdomvarinterdebtbaht-
pinternationaldebtbaht;
t=1;
steps=253;


str='Please enter the  ';
replications=input([str, 'the number of replications: ']);

datamatrix2=horzcat(exchrate,CPI,Libormonthly,VI);
c=corr(datamatrix2);


str='This part of the program creates the correlated random variables'
OX=correlaterv(exchrate,CPI,Libormonthly,VI);
```

```
rmatrx1=randn(replications,steps);
rmatrx2=randn(replications,steps);
rmatrx3=randn(replications,steps);
rmatrx4=randn(replications,steps);
corrmatrx1=rmatrx1;
corrmatrx2=OX(2,1)*rmatrx1+OX(2,2)*rmatrx2;
corrmatrx3=OX(3,1)*rmatrx1+OX(3,2)*rmatrx2+OX(3,3)*rmatrx3;
corrmatrx4=OX(4,1)*rmatrx1+OX(4,2)*rmatrx2+OX(4,3)*rmatrx3+OX(4,4)*rmat
rx4;

epaths=assetpathsexchrate(t,steps,replications,exchrate,corrmatrx1);
maxexchangerate=max(epaths(:,253))
minexchangerate=min(epaths(:,253))
standarddeviationexchangeratepaths=std(epaths(:,253))
exchangrate=mean(epaths(:,253))
cpipaths=assetpathscpi(t,steps,replications,CPI,corrmatrx2);

sampleepath=epaths(1,253);

n=12;
t=1;
MLE_Vasicek;

parameters=tetas;
l=0;

y=0;

%for j=1:2



initialinterest=Libordaily(1);
corrandv=corrmatrx3(:,1);




for k=1:steps
corrandv=corrmatrx3(:,k);
initialinterest=Libordaily(1);
VIstoch=stochvasint(t,n,initialinterest,parameters,corrandv);
liborinterestrate(k)=VIstoch(12)+10;
returnoninternationaldebt(k)=exp(-
((liborinterestrate(k))/100))*pinternationaldebt;
trate=mean(Libormonthly+spread)/100;
returnondomesticdebt(k)=exp(-
mean(Libormonthly+spread)/100)*pdomfixinterdebt;
returnondomesticdebtbaht(k)=exp(-
mean(Libormonthly+spread)/100)*pdomfixinterdebtbaht;
Virrate(k)=VIstoch(12)/100+(spread+10)/100;

returnondomesticdebtvar(k)=exp(-Virrate(k))*pdomvarinterdebt;
returnondomesticdebtvarbaht(k)=exp(-Virrate(k))*pdomvarinterdebtbaht;
end
```

```
datamatrixfordebt=horzcat(returnondomesticdebt',returnondomesticdebtvar
',returnoninternationaldebt');
irrate=Virrate';
lenirrate=length(Virrate);



avelibor=mean(irrate);
pvint=(avelibor);

discountrate=10.75/100;
npvgov=pvvar(govbudget,discountrate);

%npvgov=pvvar(difgovcliab,discountrate)

npvgovbaht=(1/initialexchangerate)*npvgov;

%npvgovbaht=(1/initialexchangerate)*npvgov

    s=length(returnondomesticdebt);
    npvgov1=npvgov*ones(s,1);
    npvgov2=npvgovbaht*ones(s,1);

    dollarcliab=dollarcliab*ones(s,1);

    cliab=cliab*ones(s,1);

    BaseVaRGovSector=npvgov1-sort(returnoninternationaldebt)';
    vbmin=min(BaseVaRGovSector)
    vbmax=max(BaseVaRGovSector)
    vbmean=mean(BaseVaRGovSector)
    vbstandard=std(BaseVaRGovSector)
    BVaRquantiles = quantile(BaseVaRGovSector,[.01 .05 .50 .75 .975
.99])
    VaRGovSector=npvgov1-sort(returnondomesticdebt)'-
sort(returnondomesticdebtvar)'-sort(returnoninternationaldebt)';
    vmin=min(VaRGovSector)
    vmax=max(VaRGovSector)
    vmean=mean(VaRGovSector)
    vstandard=std(VaRGovSector)
    VaRquantiles = quantile(VaRGovSector,[.01 .05 .50 .75 .975 .99])

    CVaRGovSector=npvgov1-dollarcliab-sort(returnondomesticdebt)'-
sort(returnondomesticdebtvar)'-sort(returnoninternationaldebt)';
    vcmin=min(CVaRGovSector)
    vcmax=max(CVaRGovSector)
    vcmean=mean(CVaRGovSector)
    vcstandard=std(CVaRGovSector)
    VaRCquantiles = quantile(CVaRGovSector,[.01 .05 .50 .75 .975 .99])

  %     for j=1:length(VaRGovSector)
  %     VaRGovSector1(y+j)=VaRGovSector(j);

   %    end
```

```
   %      l=l+1;
   %      y=253*l;


   %      y1=0
   %      for v=1:12
   %         VaRGovSectorbaht=npvgov2-returnondomesticdebtbaht'-
returnondomesticdebtvarbaht'-
(epaths(v,253)+10).*returnoninternationaldebt'
   %      for j=1:length(VaRGovSectorbaht)
   %          VaRGovSector2(y1+j)=VaRGovSectorbaht(j);
   %      end
   %          y1=253*v;
   %      end



[l1 l2]=size(epaths);


returnoninternationaldebtbaht2=max(epaths(:,l2))*returnoninternationald
ebt;

BaseVaRGovSectorbaht=npvgov2-sort(returnoninternationaldebtbaht2)';

VaRGovSectorbaht=npvgov2-sort(returnondomesticdebtvarbaht)'-
sort(returnondomesticdebtbaht)'-sort(returnoninternationaldebtbaht2)';


 vbbahtmin=min(BaseVaRGovSectorbaht)
 vbbahtmax=max(BaseVaRGovSectorbaht)
 vbbahtstandard=std(BaseVaRGovSectorbaht)
 vbbahtmean=mean(BaseVaRGovSectorbaht)
 BaseVaRbahtquantiles = quantile(BaseVaRGovSectorbaht,[ .01 .05 .25 .50
.75 .975 .99])



 vbahtmin=min(VaRGovSectorbaht)
 vbahtmax=max(VaRGovSectorbaht)
 vbahtstandard=std(VaRGovSectorbaht)
 vbahtmean=mean(VaRGovSectorbaht)
 VaRbahtquantiles = quantile(VaRGovSectorbaht,[ .01 .05 .25 .50 .75
.975 .99])


 CVaRGovSectorbaht=npvgov2-cliab-sort(returnondomesticdebtvarbaht)'-
sort(returnondomesticdebtbaht)'-sort(returnoninternationaldebtbaht2)';
 vcbahtmin=min(CVaRGovSectorbaht)
 vcbahtmax=max(CVaRGovSectorbaht)
 vcbahtstandard=std(CVaRGovSectorbaht)
 vcbahtmean=mean(CVaRGovSectorbaht)
 CVaRbahtquantiles = quantile(CVaRGovSectorbaht,[ .01 .05 .25 .50 .75
.975 .99])
```

```
N=1+3.3*log(length(VaRGovSectorbaht));
   hist(VaRGovSectorbaht,N);
```

```
%historical value at risk

Setindex=xlsread('ThaiPriceindex')
Snot=Setindex;
m=102
stocks=Setindex(1:m,:)

initial_portfolio_value=100*stocks(m)



Sm=stocks(m)

scenarios=stocks(2:m,:)./stocks(1:m-1,:)

histval=Sm.*scenarios

final_portfolio_value=100*histval;
Value_at_Risk=(final_portfolio_value'-initial_portfolio_value.*ones(m-
1,1)')'

[n,x]=hist(Value_at_Risk)

bar(x,n)
hist(Value_at_Risk,x)
y=quantile(Value_at_Risk,.05)

initialstockvalue=stocks(m)
```

```
%Variance Covariance method
Setindex=xlsread('ThaiPriceindex')
Snot=Setindex;
m=66
stocks=Setindex(1:m,:)
initial_portfolio_value=100*stocks(m)

scenarios=stocks(2:m,:)./stocks(1:m-1,:)
sreturns=log(scenarios)
volitility=std(sreturns)/sqrt(m)

tau=1

Value_at_Risk_VCov=1.65*volitility*initial_portfolio_value*sqrt(tau)
```

```
%MonteCarloValue
Setindex=xlsread('ThaiPriceindex')

m=102
stocks=Setindex(1:m,:)
SO=Setindex(1,:)
initial_portfolio_value=100*mean(stocks)

stockreturns=log(stocks(2:m,:)./stocks(1:m-1,:))
mu=mean(stockreturns);
dailyvolatility=std(stockreturns);
sigma=sqrt(m)*dailyvolatility;
NSteps=m;
str='Please enter '
NRepl=input([str, 'the number of replications: ']);
T=1

MC_Value=MAssetPaths(SO, mu, sigma, T, NSteps,
NRepl,initial_portfolio_value)'

[n,x]=hist(MC_Value)

bar(x,n)
hist(MC_Value,x)
y=quantile(MC_Value,.05)

N=2*(1+3.3*log(length(MC_Value)))
hist(MC_Value,N)
```

```
%this is a stochastic vasicek interest rate model

function r=stochvasint(t,n,initialinterest,parameters,corrandv);

B=parameters(2);
mu=parameters(1);
sig=parameters(3);
T=t;
N=n;
dt=T/N;

intrrate(1)=initialinterest;
for j=1:n;
intrrate(j+1)=intrrate(j)*(1-B*dt)+B*mu*dt+sig*corrandv(j)*sqrt(dt);
end

r=intrrate;
```

```
%Program for ML estimation of Vasicek Model
%source for this code is [1.] in bibliography

initial=[0.2623 -0.0232 0.1];
options=optimset('maxfunevals',580,'maxiter',7000);
[tetas,fval,exitflag]=fminsearch(@likelim4,initial,options)
tetas;
estimparam=tetas;

%likelihood function for Vasicek Model

function x=likelim4(param)

r=xlsread('liborrate96');
alfa=param(1);
beta=param(2);
sigma=param(3);
nn=size(r);
n=nn(1,1);
v=zeros(n,1);

for i=2:n,
    v(i)=.5*log(sigma^2)+.5*((r(i)-r(i-1)-alfa-beta*r(i-1))/(sigma))^2;
end
x=sum(v);
end
```

```
%Scenarios
Setindex=xlsread('ThaiPriceindex')
Snot=Setindex;
m=102
stocks=Setindex(1:m,:)
initial_portfolio_value=100*stocks(m)

mscenarios=stocks(2:m,:)./stocks(1:m-1,:)
```

Correlated Random Variables

```
%this function generates correlated random variables

function crelaterv=correlaterv(exchrate,CPI,Libormonthly,VI)

datamatrix1=horzcat(exchrate,CPI,Libormonthly,VI);
c=corr(datamatrix1);
crelaterv=chol(c)';
end


%AssetPaths.m
Source for this code is [12] pg.319
function SPaths=AssetPaths2(SO,mu,sigma,T,NSteps,NRepl);
dt=T/NSteps;
nudt=(mu-0.5*sigma^2)*dt;
sidt=sigma*sqrt(dt);
Increments=nudt+sidt*randn(NRepl,NSteps)
LogPaths=cumsum([log(SO)*ones(NRepl,1),Increments],2);
SPaths=exp(LogPaths);
```

Appendix C

Full Scenario Table

Days	Historical Prices	Scenario	Scenarios	Possible future prices
1	100			
2	114.614	1	1.1461	624.9798
3	134.28	2	1.1716	638.8852
4	139.208	3	1.0367	565.3229
5	152.589	4	1.0961	597.7143
6	154.815	5	1.0146	553.2715
7	164.924	6	1.0653	580.9187
8	168.617	7	1.0224	557.5249
9	160.453	8	0.9516	518.917
10	163.322	9	1.0179	555.071
11	156.612	10	0.9589	522.8978
12	146.022	11	0.9324	508.447
13	141.564	12	0.9695	528.678
14	156.826	13	1.1078	604.0944
15	155.503	14	0.9916	540.7294
16	153.136	15	0.9848	537.0213
17	173.866	16	1.1354	619.145
18	188.052	17	1.0816	589.8073
19	201.55	18	1.0718	584.4633
20	204.311	19	1.0137	552.7807
21	223.087	20	1.0919	595.424
22	225.61	21	1.0113	551.472
23	231.772	22	1.0273	560.197
24	264.23	23	1.14	621.6534
25	291.734	24	1.1041	602.0768
26	283.734	25	0.9726	530.3685
27	265.784	26	0.9367	510.7919
28	274.831	27	1.034	563.8505
29	275.215	28	1.0014	546.0734
30	318.381	29	1.1568	630.8146
31	335.596	30	1.0541	574.8113
32	358.066	31	1.067	581.8458
33	282.555	32	0.7891	430.3041
34	211.115	33	0.7472	407.4556
35	211.17	34	1.0003	545.4736
36	182.251	35	0.8631	470.6571
37	204.971	36	1.1247	613.3102
38	226.096	37	1.1031	601.5315
39	263.203	38	1.1641	634.7954
40	286.479	39	1.0884	593.5154
41	283.831	40	0.9908	540.2931
42	256.629	41	0.9042	493.0693
43	242.62	42	0.9454	515.5361
44	234.993	43	0.9686	528.1873
45	230.112	44	0.9792	533.9676

46	218.467	45	0.9494	517.7173
47	209.744	46	0.9601	523.5521
48	222.445	47	1.0606	578.3558
49	241.98	48	1.0878	593.1882
50	262.629	49	1.0853	591.8249
51	263.562	50	1.0036	547.2731
52	278.864	51	1.0581	576.9925
53	258.043	52	0.9253	504.5753
54	241.107	53	0.9344	509.5377
55	260.491	54	1.0804	589.1529
56	256.666	55	0.9853	537.2939
57	262.056	56	1.021	556.7615
58	295.76	57	1.1286	615.4369
59	327.336	58	1.1068	603.5491
60	309.52	59	0.9456	515.6451
61	315.578	60	1.0196	555.9981
62	353.77	61	1.121	611.2925
63	348.408	62	0.9848	537.0213
64	320.865	63	0.9209	502.176
65	330.14	64	1.0289	561.0695
66	320.942	65	0.9721	530.0959
67	333.783	66	1.04	567.1224
68	344.754	67	1.0329	563.2507
69	354.117	68	1.0272	560.1424
70	361.645	69	1.0213	556.9251
71	467.918	70	1.2939	705.5766
72	485.976	71	1.0386	566.359
73	624.333	72	1.2847	700.5598
74	563.181	73	0.9021	491.9242
75	510.505	74	0.9065	494.3235
76	466.478	75	0.9138	498.3043
77	482.17	76	1.0336	563.6324
78	525.595	77	1.0901	594.4424
79	508.447	78	0.9674	527.5329
80	562.875	79	1.107	603.6582
81	621.3	80	1.1038	601.9132
82	595.295	81	0.9581	522.4615
83	621.654	82	1.0443	569.4672
84	552.647	83	0.889	484.7806
85	554.749	84	1.0038	547.3822
86	489.038	85	0.8815	480.6908
87	521.476	86	1.0663	581.4641
88	494.617	87	0.9485	517.2265
89	497.014	88	1.0048	547.9275
90	578.137	89	1.1632	634.3046
91	573.1	90	0.9913	540.5658
92	562.969	91	0.9823	535.658
93	531.685	92	0.9444	514.9908
94	528.466	93	0.9939	541.9836
95	519.665	94	0.9833	536.2033

96	488.353	95	0.9397	512.4278
97	523.335	96	1.0716	584.3542
98	571.307	97	1.0917	595.3149
99	538.463	98	0.9425	513.9547
100	526.972	99	0.9787	533.6949
101	536.637	100	1.0183	555.2892
102	545.341	101	1.0162	554.144