

MODELING OF FINANCIAL CRISES: A CRITICAL ANALYSIS OF MODELS LEADING TO THE GLOBAL FINANCIAL CRISIS

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ABSTRACT

The causes of financial crises are multiple but the models of financial crises revolve around four generational models. In this paper, the authors analyzed these models and highlighted the fact that each model was adapted to specific situations to explain the financial crises faced rather than being visionary or systematic in approach. These models suggest crises may develop without significant change in economic fundamentals, since policies usually respond to changes in economy and agents consider these when forming expectations. Therefore, any set of indicators together may not provide an over-all picture but interactions among indicators should be pursued. Common sense and guesswork is used but is not sufficient for representing real behavior. Modeling suggests that stressed or fraudulent companies should be removed to avoid further crises. While the new models handle a wider range of nonlinear behavior, little new work is in fact evident. Apart from a patchwork-like approach of the past, financial or currency crises modeling has not been dealt with systematically. A new way thinking is not emerging suggesting a visionary and dynamic robust mathematical modeling approach is needed with attention to the many possible risks.

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INTRODUCTION

A currency crisis is defined as a situation in which an attack on the currency leads to a sharp depreciation of the currency, a large decline in international reserves, or a combination of the two (Kaminsky, Linzondo and Reinhart, 1998). Many studies have focused on modeling financial crises and the development of early warning systems relying on different techniques (Lestano and Kuper, 2003; Kaminsky et al., 1998; Kaminsky and Reinhart, 1999; Frankel and Rose, 1996; Sachs, Tornell, and Velasco, 1996; Berg and Pattillo, 1999; Eichengreen, Rose, and Wyplosz, 1995). The models have been developed to understand and predict crises such as the recent global financial crisis. Some were tuned to even predict a particular point of time at which a crisis will occur. However, none of these models could predict or explain the current global financial crises. It seems that previous models were insufficient in structure to aid either in understanding or predicting the 2007 global crisis. Some authors state that current dominant theories and econometric models failed to predict the recent crisis (Bezemer, 2009).

The aim of this paper is to critically review models of the past, investigate approaches taken during their development and pointing out reasons why the models failed. Based on mathematical and critical reflective analysis of the literature, new ideas are explored and some insights provided based on history, for the development of new, visionary models. In the remainder of the paper, the authors present a brief literature review followed by a comprehensive analysis of the four generational models of currency and financial crises. This section also includes models related to signal processing and agent analysis. This is followed by a discussion section. The final section provides some concluding comments.

LITERATURE REVIEW

The increase in the number of crises and their impact on the economy has generated a large amount of research into their causes. At the theoretical level, the literature distinguished between four main types (first, second, third and fourth generation) models. The following literature review examines each of these theories in turn.

First generation models (Salant and Henderson, 1978; Krugman, 1979) and its extension models (Flood and Garber 1984; Connolly and Taylor, 1984; Calvo, 1987; Edwards, 1989; Krugman and Rotemberg, 1992) represent the balance-of-payment crises. These models view crises as the unavoidable consequence of macroeconomic policies that vary with the maintenance of a pegged exchange rate. First generation crisis theories represent crises that are mainly due to weakness in economic fundamentals. In these models, there is the assumption that there are two types of exchange rate systems, namely, flexible and pegged exchange rates. Under the flexible system, changes in expectations are reflected in the short run by changes in the exchange rate. Pegged exchange rate regimes are directly reflected by changes in the government's reserves. In first generation crisis models the strength of a fixed exchange rate is established by external fundamentals unconnected to how economic agents behave (Salant and Henderson, 1978; Krugman, 1979; Flood and Garber 1984). Krugman (1979) explained how a standard crisis occurs and suggested that timing of the speculative attack is dependent on a critical official foreign reserve level. Esquivel and Larrain (1998) argued that the original source of problems in Krugman's (1979) model is the excessive creation of domestic credit to either finance deficits or provide assistance to a weak banking system. The first generation models of crises were ultimately driven by ongoing fiscal deficits. However, fiscal amounts were essentially in balance before the Mexican 1994 and the Asian 1997-1998 crashes, and hence the first generation models were inadequate.

Second generation models of financial crises such as Obstfeld (1994) were developed after the collapse of the European Exchange rate Mechanism (ERM) in 1992-1993 and described devaluation as a multiple equilibrium process. In second generation models, crises are attributed either to some deterioration of domestic conditions or to shifts in expectations. The monetary crisis starts either with the worsening of economic fundamentals, or a shift from the expectations to consider endogenous exchange rate policies with optimizing policy makers (Benside & Jeanne, 1997; De Kock & Grilli, 1993; Drazen & Masson, 1994; Obstfeld 1994, 1996, 1997; Ozken & Sunderland, 1995, 1998). These models introduce government decision making and show the possibility of multiple equilibriums (Obstfeld, 1994, 1996). Even if the fundamentals are not bad, currency crises can still occur so long as speculative attacks on currencies are able to drive market participants to believe that policy makers will devalue the currencies; leading to a so called self-fulfilling currency crises. Some research shows that prospective deficits account for currency crises (Burnside et al., 2001; Corsetti et al., 1999; Daniel, 2001; Dupor, 2000). Esquivel & Larrain (1998) identified two key characteristics of second generation models, namely: (i) the government is an active agent and maximizes an objective function and (ii) a circular process exists, leading to multiple equilibriums. The ERM crisis proved that some important fundamentals such as international reserves, domestic credit growth and fiscal deficit, and good economic policies were not enough to protect countries from speculative attacks.

During the mid-1990s, when the economic fundamentals of the affected countries were found to be rather sound, outbreak of the crises continued. A new third generation of theoretical models were then developed that included financial sector indicators derived from aggregate balance sheets of banks. After the failure of two generations of models, two approaches were featured: herd behavior and the moral hazard problem. Under the herd behavior, speculators follow behavior with the assumption that it reflects knowledge sets of others, and that multiple equilibriums are likely to occur (Froot et al., 1992; Krugman, 1997). According to moral hazard, implicit guarantees granted to the financial institutions that are

already ill-regulated and not monitored closely led to over expansion of supply of financial instruments, including derivatives (Mckinnon & Pill, 1996; Krugman, 1998; Kaminsky & Reinhart, 1999). Third generation models focused on contagion effects as a cause of currency crises. Gerlach and Smets (1996) and Kaminsky et al. (1998) presented models in which devaluation by one country led its trading partners to devalue in order to avoid a loss of competitiveness. Calvo & Reinhart (1996) and Eichengreen et al. (1996) discussed the channels for transmission of contagion effect. In the context of contagious currency crises, Masson (1999a, b) explained the distinction between joint exchange market crises as a consequence of a common macroeconomics shock to fundamentals spillovers of one country's crisis on other countries, and fundamentals triggering crises in those countries too. Chang & Velasco (1998) explained currency crises as the byproduct of a bank run. Krugman (1999) argued that two factors had been omitted from formal models: the role of companies' balance sheets in determining their ability to invest, and capital flows in affecting the real exchange rate. The empirical literature in these models uses the ratio of domestic debts dominated foreign currency and the real exchange rate as key factors in predicting crisis, specifically in emerging markets (Calvo et al., 2004, 2006a, 2006b, 2008).

Krugman (2001) conjectured fourth generation crisis modeling that may not be a currency crisis model. Rather it may be a more general financial crisis model in which other asset prices also play the major role. Fourth generation models extend the earlier literature by identifying features of the institutional environment that set the stage for the build-up of macroeconomic imbalances, which subsequently give rise to banking problems. The models also relate to some previous work in which political indicators play a significant role in crisis forecasting (Bussiere & Mulder, 2000). Breuer (2004) referred to a model in which crises are determined by institutional factors. Poor institutional factors appear to be the underlying cause for unsustainable policies, excessive borrowing and lending, hyperinflation, among others. It appears that institutional factors set the conditions for economic outcomes. In contrast, Ghosh (2002) understood the fourth generation as those models in which currency crises are created and accentuated by unexpected financial panic from different players in the market and governments. Bonin & Wachtel (2003) and De Nicolo, et al. (2003) showed that institutional infrastructure affects the level of financial development, depositor trust in the financial system, and the level of credit risk. In the fourth generation models (Agenor & Aizeman, 1999; Alesina et al., 2002; Das et al., 2004), explanatory variables include variables such as politics, trust, ethic, tensions, culture property rights, legal origin, types of governance and quality of financial policies. These variables are important given they have an impact on information and uncertainty, and can affect the efficiency of decision-making. These models highlight the roles of rule of law and contract enforcement, protection of shareholder and creditor rights, regulatory frameworks, and the socioeconomic environment (Buch & De Long, 2008; Das et al., 2004; Demirguc-Kunt & Detragiache, 1998, 2005; Eichengreen & Arteta, 2000; Hutchinson, 2002; Hutchinson & McDill, 1999). The advantage of fourth generational models is that they builds upon forward looking information, contained in market prices.

A number of empirical studies on early warning system (EWS) explained currency crises or twin crises (Berg & Patillo, 1999; Demirguc-Kunt & Detragiache, 1998; Eichengreen et al., 1996; Furnam & Stiglitz, 1998; Gavin & Hausman, 1996; Goldstin et al., 2000; Honohan, 1997; Kaminsky & Reinhart, 1999). There are two main approaches for constructing EWS models: the signals approach and the econometric approach. The signals approach is a non-parametric approach to determine the risk of financial crisis. Here a variable is considered to be issuing a warning signal if it goes beyond a certain threshold level in the "bad" signal. The signals approach was pioneered by Kaminsky & Reinhart (1999) while the econometric approach is a multivariate one that allows testing of statistical significance of explanatory variables. This approach estimates a probability relationship among discrete dependent variables. Eichengreen et al. (1996) exemplified the econometric method for prediction of currency crisis, in which exchange rates played a significant role in predicting the incidence of currency crises.

Agent-based models explain nonlinear behavior when compared to conventional equilibrium models (Krugman, 2001). This type of modeling is not well developed in economics, because of historical choices made to address the complexity of the economy and the importance of human reasoning and adaptability. The agent approach simulates complex and nonlinear behavior that are so far intractable in equilibrium models. The next section presents a mathematical review of four generation models of financial crisis, including signal based early warning systems and agent-based models that are considered as fourth generational models.

FOUR MODELS OF FINANCIAL CRISES

First Generation Models

Mathematical models to study financial crisis originated in the late 70's and the models are popularly known as first generation models. Kouri (1976) first developed monetary equilibrium and stationary state models by an analysis of the short run effects of stock shift, flow shift and central bank intervention in the foreign exchange market on the current account and exchange rate; and the long run effects of the same shifts on the current account and exchange rate. Stock shift refers to an increase in the expected rate of depreciation and flow shift refers to a tax financed increase in government expenditure. On momentary equilibrium in Equation (1), Kouri (1976) obtained the following equilibrium condition for the asset markets as

$$L\left(\eta, Y, \left(\frac{M}{P}\right) + F\right) = \frac{M}{P} \quad (1)$$

where η - expected rate of inflation, Y - domestic output, M – domestic money, F – foreign assets, P – domestic price level, and $L(.)$ – demand function; and the capital flow or current account Equation (2) given as

$$\dot{F} = B(Y, T, F, \eta, M) \quad (2)$$

based on the real trade balance Equation (3);

$$B = Y - C(Y - T, W) - G \quad (3)$$

where T – real taxation, C – private consumption (a function of $Y-T$ and W), W – financial wealth, and G – government expenditure. On the same equilibrium this model provides the realized change in the stock of foreign assets given by Equation (4):

$$\dot{F} = F_{\eta}\dot{\eta} + F_w\dot{W} = F_{\eta}\dot{\eta} + F_w X - F_w \left[\frac{M}{P} \right] \left[\frac{\dot{P}}{P} \right] \quad (4)$$

and the balance of payments Equation (5) given by

$$L_{\eta}\dot{\eta} + L_w\dot{W} = \frac{\dot{M}}{P} \quad (5)$$

where $F_{\eta}\dot{\eta}$ represents the stock shift induced by the change in the expected return on domestic assets; $F_W\dot{W}$ is the flow shift induced by the change in the expected new savings allocated to foreign assets; $X = Y - T - C$, $F_{\eta} = -L_{\eta}$ and $F_W = I - L_W$. On stationary state Kouri (1976) obtained Equation (6), the long run exchange rate path:

$$\ln P(t) = \ln M_0 + mt - \ln \bar{M}^* \tag{6}$$

where m – money stock, \bar{M}^* - real balance and M_0 – a constant.

Kouri (1976) suggested that this model could be extended for rigid wages and unemployment, for changes in relative prices, and for accumulation of real capital.

Salant and Henderson (1978) developed a model to explain the effects of anticipations of government gold policies on the path of gold prices and explained the inability of the standard theory that could be used to explain movements in the gold price. This model generates time paths for the price of gold in anticipation of an auction given by Equation (7):

$$P_t = \frac{\alpha f_{t+1} + (1 - \alpha)P_{t+1}}{1 + i} \tag{7}$$

where auction price was given by $\sum_{x=0}^{\infty} L[f_t(1+i)^x] = \bar{G} + S_t$. The private stock of gold was given by

$S_{t+1} = S_t - L(P_t)$, where f_t – auction price, i – rate of interest, \bar{G} - total stock sold in a single auction, $L(.)$ – demand function, and α - arbitrary constant. Equation (7) indicates that the price expected in period t to prevail one period in the future is equal to the price in period t . From this model the authors discussed a rational speculative attack and explained the market solution to how best to deplete existing reserves when supplies are additionally anticipated at an unknown time.

Following these two models, the classical balance-of-payments crises model was developed by Krugman (1979). It provided the portfolio equilibrium condition as (portfolio balance in Equation (8))

$$\frac{M}{P} = L(\eta) \cdot W \tag{8}$$

where the changes in reserve asset as $\Delta R = \frac{\Delta M}{P}$, where M – domestic money, P – domestic price level, η – expected rate of inflation, W – private wealth, $L(.)$ – demand function, R – reserve of foreign money. Krugman (1979) analyzed the model for flexible and fixed exchange rate in Equation (9). For floating exchange rate, the rate of change of real balance was examined using

$$\dot{m} = \left[g - \eta \left(\frac{m}{F} \right) \right] m \tag{9}$$

$m = \frac{M}{P}$, g is a constant, and the rate of accumulation of foreign money F was given by Equation (10):

$$\dot{F} = Y - G - C(Y - T, m + F) \tag{10}$$

where Y – domestic output, G – government expenditure, C – private consumption (a function of $Y - T$ and $m + F$), T – real taxation. For fixed exchange rate, the government budget constraint was derived in Equation (11):

$$\frac{\dot{M}}{P} + LB - (1 - L)(G - T) = G - T = \left[\frac{M}{P} \right] g \tag{11}$$

where B – trade balance. Due to nonlinearities, Krugman (1979) was unable to solve explicitly a solution for the time of collapse in a fixed exchange rate regime. Later work by Flood and Garber (1984) provided an example of how such a solution is derived in a linear model with or without arbitrary speculative behavior. Krugman (1979) showed how the crises were caused by weak economic fundamentals such as fiscal and monetary policies.

A number of studies extended Krugman’s basic model by exploring the nature of the collapse time of an exchange rate regime and collapse probabilities (Goldberg, 1991; Flood & Garber, 1984), external borrowing and capital controls (Bacchetta, 1990; Dellas & Stockman, 1988; Wyplosz, 1986), and imperfect asset substitutability and sticky prices. These studies provided a qualitative discussion of the causes and developments of the currency crises. Parametric and non-parametric tests were conducted to limit the number of indicators (Eichengreen et al., 1995; Frankel and Rose, 1996; Edwards, 1989; Edwards and Santaella, 1993). Some attempts were made to find variables that determine devaluation. These studies largely compared the pre-crisis behavior variables with non-crisis behavior variables.

Flood and Garber (1984) introduced uncertainty about the domestic policy process in which one-time events could lead authorities to substitute one policy for another, thereby introducing the possibility of self-fulfilling speculative attacks. The authors also adopted the Salant and Henderson (1978) model for collapsing exchange rate regimes. Flood and Garber (1984) constructed two linear examples to study the collapse of a fixed exchange rate regime. The first example was a continuous-time with perfect-foresight model. This model examined the timing of regime collapses either based entirely on market fundamentals; or based in part on arbitrary speculative behavior. This example was a simple realization of Krugman’s (1979) model in which a solution could be derived. The second example was a discrete-time model containing stochastic market fundamentals, which forces the regime collapse. Equations (12-16) show continuous-time model’s principal equations at time t :

(i). Money market equilibrium condition

$$\frac{M(t)}{P(t)} = a_0 - a_1 i(t), \quad a_1 > 0 \tag{12}$$

(i) Money supply equation

$$M(t) = R(t) + D(t) \tag{13}$$

(ii) Domestic credit equation

$$\dot{D}(t) = \mu, \quad \mu > 0 \tag{14}$$

(iii) Purchasing power parity equation

$$P(t) = P^*(t)e(t) \tag{15}$$

(iv) Uncovered interest parity equation

$$i(t) = i^*(t) + \left[\frac{\dot{e}(t)}{e(t)} \right] \tag{16}$$

where $M(t)$ – domestic money, $P(t)$ – domestic price level, $P^*(t)$ – foreign price level, $i(t)$ – domestic interest rate, $i^*(t)$ – foreign interest rate, $R(t)$ – government book value of foreign money holdings, $D(t)$ – domestic credit, $e(t)$ – spot exchange rate and μ – constant rate. The authors derived the time z of the regime collapse using Equation 17:

$$z = \frac{R(0)}{\mu} - \frac{\alpha}{\beta} - A \frac{\beta}{\alpha} \tag{17}$$

and floating exchange rate by Equation (18):

$$e(t) = A \exp\left[\frac{(t-z)\beta}{\alpha}\right] + \frac{\alpha\mu}{\beta^2} + \frac{M(t)}{\beta} \tag{18}$$

where $\alpha = a_1P^*$ and $\beta = a_0P^* - a_1P^*i^*$ (both are constants). Flood and Garber (1984) showed that the fixed exchange system is subject to exactly the same type of dynamic instability problem that may affect a floating system. The discrete-time model's principal equations are same as in continuous-time model except the Domestic credit equation and the uncovered interest parity Equations (19-20) respectively change to:

$$D(t) = D(t-1) + \mu + \varepsilon(t) \tag{19}$$

$$i(t) = i^*(t) + \frac{E[e(t+1)|I(t)] - e(t)}{e(t)} \tag{20}$$

and time t is an integer and $\varepsilon(t)$ represents a random disturbance with zero means, which obeys $\varepsilon(t) = -I/\lambda + \nu(t)$, where $\nu(t)$ is distributed exponentially with an unconditional probability density function. The authors obtained the expected exchange rate conditional on the information set $I(t)$ using Equations (21-22):

$$E[e(t+1)|I(t)] = \frac{\alpha\mu}{\beta^2} - \frac{D(t) + \mu}{\alpha} \quad \text{when } K(t) < 0 \tag{21}$$

$$E[e(t+1)|I(t)] = \frac{\pi(t)}{\beta\lambda} + \bar{e} \quad \text{when } K(t) \geq 0 \tag{22}$$

where $K(t) = \beta \bar{e} - \frac{\alpha\mu}{\beta} - D(t) - \mu + \frac{1}{\lambda}$, $\pi(t)$ – probability evaluated at time t that a collapse will occur at time $t + 1$ and \bar{e} – fixed exchange rate. This model produces the forward discount during the fixed-rate system. However, the result is not attributable to the possibility that unusual, large random disturbances may impinge on the system. In the analysis of the discrete-time uncertainty model the authors ignored the possibility that the country may devalue its currency when a crisis seems imminent.

Agenor et al. (1991) and Blackburn and Sola (1993) reviewed the first-generation models and argued that the main contribution is the identification of the tension between domestic fiscal policy and the fixed

exchange rate regime. In the first generation models the main indicators are fiscal deficit/GDP, real money balance, *MI* balance surplus. However, the models are lacking in two aspects. First, the models require agents to suddenly increase their estimates of the likelihood of devaluation; and second, they do not explain why the currency crises spread to other countries. Basically, within the framework, it is difficult to understand why the government on the one hand tries to keep the exchange rate fixed, while on the other hand, conduct a policy which the government knows may ultimately lead to a currency crisis. In general, unpredictable currency crises are not in accordance with the implication of a speculative attack with a probability one event in first generation models.

Second Generation Models

Second generation models appeared in the mid of 80's and were designed to capture the characteristics of the speculative attacks in currency crisis. Second generation models are also referred to as 'endogenous policy' models. Obstfeld (1986) developed a basic second generation model that suggested when and if an attack occurs, governments simply shift policy in an assumed but different direction (considered as one of the limitations of this model). This model included an expectation difference Equation (23) involving floating rate evolution given by:

$$-\beta E_t[\bar{S}_{t+1}] + (\alpha + \beta)\bar{S}_t = \bar{R} + D_t \quad (23)$$

and the saddle-path solution for floating rate \bar{S}_T at a time T given by Equation (24):

$$S_T = \alpha^{-1}(\bar{R} + \bar{D}) + [\alpha + \beta(1 - \rho)]^{-1}v_T \quad (24)$$

where \bar{R} - lower bound on central bank reserves, $E_t[\cdot]$ - an expectation conditional on time t , D_t - domestic credit such that $D_t = \bar{D} + v_T$, v_T - random disturbance with zero mean, α, β - constants. These models focus on the relationship between expectations and outcomes, in which expectations affect the policy decisions. Obstfeld (1986) also provided several examples of multiple equilibrium and self-fulfilling attacks on foreign exchange markets in the context of bank runs, bubbles and extrinsic uncertainty.

In fact, Obstfeld (1994) is an important representative of the second generation model. Obstfeld provides two self-fulfilling currency crisis models, in which the crisis and realignment of exchange rates result from interaction between rational private agents and a policymaker with precise objectives. The models are of single currency attack but consider endogenous exchange rate policies with optimizing policy makers. The policymaker may devalue the currency out of a desire to offset external shocks to the economy. The first and second generational models suggest the possibility of the existence of multiple equilibria since speculative anticipation depend on conjecture government responses; which in turn depend on how price changes, themselves powered by expectations, affect the government's economic and political positions. This implies that crises need not have occurred, but do occur because market participants expect them to occur. Obstfeld described a variety of circumstances in which an optimizing government wishing to peg the exchange rate will be forced to abandon that commitment by a self-fulfilling attack. In these models, the cost function of the government is determined and the variables are the tax rate and devaluation. The loss function (£) of the government is defined in Equation (25):

$$\pounds = \frac{1}{2}\tau^2 + \frac{\chi}{2}\delta^2 + cZ \quad (Z = 1 \text{ if } \delta \neq 0, Z = 0 \text{ otherwise}) \quad (25)$$

where τ is the tax rate, δ is the depreciation rate, χ is the weight placed on depreciation relative to other taxes, and c is the fixed cost. The author provided the role of foreign currency public debt in his model, but the impact of private foreign currency debt has not been analyzed. Obstfeld (1994) provided some examples of values of the variables in the model. For high interest rates, it is also possible to show that the model can have no solution; that is there is no equilibrium. Obstfeld (1994) focused on short-term government debt in generating self-fulfilling crisis without endogenizing the choice of maturity. The author provided the theoretical surveys of EMS crisis and of aspects of other crises. In first generation models the suddenness of currency crises did not mean that their timing was arbitrary, on the contrary, Obstfeld argued that the timing of crisis was indeed arbitrary.

Jeanne and Masson (2000) used Markov switching regime model to analyze the speculation against the French franc in 1987-1993 and argued that the devaluation expectations were influenced by sunspots. Jeanne and Masson developed currency crises models with a non-linear relationship between devaluation expectation and economic fundamentals that produce multiple equilibria. From the results, it is clear that performance of the model improves significantly once sunspots are introduced to influence devaluation expectations by means of a Markov process approach. Jeanne and Masson provided a mean shifted model to study how fundamentals such as the unemployment rate, trade balance and real effective exchange rate, affect the devaluation probability of the French franc conditional on switching between multiple equilibria. Under the fundamental-based equilibrium the devaluation probability at time t is defined in Equation (26):

$$\pi_t = \Pr ob[\phi_{t+1} < \phi^{*e} / \phi_t] = F(\phi_t, \phi^{*e}) \tag{26}$$

where ϕ_t is a variable reflecting the exogenous economic fundamentals at time t and ϕ^{*e} is the level of the fundamental under which speculators expect the policymaker to devalue. The authors defined the devaluation probability under the sunspot equilibrium jointly on the state and the fundamental variable, using Equation (27):

$$\pi_t = \sum_{\rho=1}^n \theta(\rho_t, \rho) F(\phi_t, \phi_{\rho}^*) \tag{27}$$

where $\theta(i, j)$ ($1 \leq i, j \leq n$) is the transition matrix and ρ_t is the state of the economy at time t . Under the Markov switching regime the devaluation probability is defined in Equation (28):

$$\pi_t = \gamma_{s_t} + \beta' x_t + \nu_t, \quad s_t = 1, 2, \dots, n \tag{28}$$

where γ_s is a constant that depends on the state, $\beta = (\beta_1, \dots, \beta_k)'$ is a vector of coefficients and ν_t is an independent and identically distributed shock.

Jeanne and Masson (2000) used interest rate differentials as a proxy for market expectations to study the speculative attack. The authors showed that the statistical significance of the coefficients on the macro fundamentals and time is much stronger when the relationship is allowed to include a different constant term in two regimes than in a single regime model. The two regime model successfully captures several periods of turmoil, while the single regime model yields a smooth, curved, downward trend in the interest differential. However, testing a single regime versus the alternative of two regimes is not that straightforward, since some of the parameters are not defined under the null hypothesis. Jeanne and

Masson showed that the Markov regime switching models do a better job in describing the speculative attack on the French franc than the simple linear models.

Tamgac (2011) analyzed the role of fundamentals and self-fulfilling expectations in the crisis episodes of Turkey in 1994 and 2000-2001. The author followed a similar approach to Jeanne and Masson (2000) and used a Markov regime switching framework to test the existence of self-fulfilling expectations. Tamgac (2011) estimated the pure fundamentals based model by Ordinary Least Squares (OLS) and then estimated the model for multiple equilibria via self-fulfilling expectations using a Markov switching model. Abiad (2003) provided a survey on the empirical crises literature that showed a Markov switching estimation procedure performs better than probit and signaling models as an early warning system for currency crisis. The devaluation probability at time t is given by Equation (29):

$$\pi_t = a_{s_t} + b_1x_{1,t} + b_2x_{2,t} + b_3x_{3,t} + \dots + \nu_t \tag{29}$$

where $x_{i,t}$ are the fundamental variables that affect the probability of a crisis at time t , b_i is the coefficient of explanatory variable i that will be estimated and ν_t is the normally distributed error term with variance σ_ν^2 . The value of the constant term a_{s_t} depends on the state s_t ; with $s_t = 0$ or 1 - two regimes in the economy. Regime “0” is the tranquil regime (low state or no crisis state), during which the probability of devaluation is low, whereas regime “1” is called taut regime (high state or crisis state) represents a time of high economic tensions and reflects periods during which the devaluation probability is considerably higher for the same level of fundamentals. The dependent variable provided an estimate of the devaluation probability π_t . The author used the Speculative Pressure Index (SPI) to proxy for the devaluation probability. The method is labeled an ad hoc method to measure exchange market pressure, and is based on the earlier work of Girton and Roper (1977) but first introduced by Eichengreen et al. (1994) for the identification of crises. The SPI is calculated as the weighted average of the monthly percentage changes in the real effective exchange rate (Δe) and international reserves (ΔR) and monthly change of the interest rate differential ($\Delta(i-i^*) = \Delta i$) as noted in Equation (30):

$$SPI = \left(\frac{1}{\sigma_e} \right) \left(\frac{\Delta e}{e_{t-1}} \right) - \left(\frac{1}{\sigma_R} \right) \left(\frac{\Delta R}{R_{t-1}} \right) + \left(\frac{1}{\sigma_i} \right) \Delta i \tag{30}$$

The weights are inversely related to the standard deviation of each of the three variable, σ_e , σ_R , σ_i - the standard deviations of the exchange rate, international reserves and the interest rate differential over the same period respectively. The author inferred the timing of the crisis from the spikes of the *SPI* and the crisis dummy is construed from the *SPI* based on a threshold level of mean plus two standard deviations.

Tamgac (2011) considered a set of crisis indicators that included general macroeconomic variables, indicators related with the real sector, the financial sector, government, and political and institutional variables, which might have influenced the Turkish crisis. Under OLS estimation the author estimated the devaluation probability without multiple equilibria. Here the variables except the current account to GDP ratio and export growth have the expected signs. The significant variables are: the deviation of real exchange rate from trend, annualized growth rate of M2 to reserves ratio, trade balance, growth rate of the ratio of bank deposits to M2 and ratio of short term debt to reserves. The OLS model was a poor performer as it gave a false crisis signal in 1990.

The CTP-Markov switching model estimation of probabilities correctly picked two crises in 1994 and 2000-2001. During both crises the economy had switched to a high devaluation expectations state. The switch of the economy to a high devaluation expectations state during both crises shows that the agents’

expectations for devaluation had significant contribution to the occurrence of the crisis. Hence self-fulfilling expectations played a role in the Turkish crisis.

In TVTP-Markov switching model estimation, the transition probabilities are defined as a function of the exogenous variables. This model also correctly picked the two crises in 1994 and 2000-2001 but it provided an incorrect crisis signal in 1998. It seemed that the CTP model did a better job in predicting the occurrence of crises. Both CTP and TVTP models show that besides the deteriorating fundamentals, agents' devaluations expectations played a part in the Turkish crises.

Flood and Marion (1998) and Rangvid (2001) reviewed the second-generation models and concluded that speculative attacks are unrelated to economic fundamentals. The second generation models suggest how a government should behave in periods leading to currency convulsion and some of the models explained the relationship between economic fundamentals and speculative attack period. These models explained self-fulfilling currency crises. The devaluation in one country affects the price level or the currency account by reduction of exports in a neighboring country. Since the crises are self-fulfilling, these expectations increase the likelihood of devaluation.

The second generation models focus on short run, multiple equilibriums, government policies, and largely depend on speculator expectations. In these models the main indicators were export, import, real exchange rate, terms of trade, production, real interest rate. However, these models did not survey the Asia currency crisis. The Asia crisis was neither a problem brought on by fiscal deficits (as in first generation models) nor as one brought on by macroeconomic temptation (as in second generation models); but as a problem brought on by financial excess and then financial collapse (Krugman 1998).

Third Generation Models

Third generation models appeared after the 1997 financial crisis of Asia. These models explained how banking financial system interact with currency crises and considered real effects of crises on the economy. The Asian crisis seems to have differed from the Latin American crisis of 1980. The currency crisis included failures of financial institution, bank runs, and bankruptcies of many firms with a result of severe real down turn (Krugman 1998).

Braggion, Christiano and Roldos (2005) focused on the response to an increase in interest rates before and at the moment of financial crisis and reductions in them after crisis. The authors characterized a financial crisis as a shock in which collateral constraints unexpectedly bind and were expected to remain in place permanently. They noted that collateral constraints were increased during the Asian financial crisis because collateral was widely used in emerging markets. The authors compared the dynamic behavior of the variables with data drawn from the Asian crisis economies. Braggion et al. developed a model that provided the response in terms of maximizing welfare; that is to raise interest rates and then reduce them sharply. Braggion et al. explained how frictions in the model contributed to the optimal monetary policy outcome by an example. In this dynamic, monetary model, the traded and non-traded intermediate goods were produced as given in Equation (31):

$$y^T = C^T + i^* r \quad \text{and} \quad y^N = C^N \tag{31}$$

where y^T , y^N - gross amount of traded goods and non-traded goods respectively, C - consumption, i^* - gross rate of interest in traded good terms, and r - amount borrowed from abroad. The authors maximize the profits based on Equation (32):

$$\dot{\phi} = p^N y^N + y^T - q(K - K_0) - \omega(1 + \tau)\ell - i^* r \quad (32)$$

were p – price of consumption good, q – price of capital, ω - wage rate, ℓ – labor, τ - tax on labor, K - actual capital used in production, K_0 - initial endowment of capital of the firm. The authors showed that financial frictions could actually reverse the sign of the effect of a monetary action. However, this model doesn't focus on the currency problem and does not possess multiple equilibriums. Moreover, the initial rise in interest rates is not a consequence of monetary policy actions but the outcome of the activation of credit constraints - the increase in the value of the capital stock in the traded and non-traded sectors.

Schneider and Tornell (2004) analyzed the impact of implicit guarantees on dynamics of financial crisis. The authors described how interactions of contract enforceability problems and systemic bailout guarantees generate financial fragility and boom-bust episodes. It was also noted that the balance of payment crises are preceded by lending booms and real appreciation; with self-fulfilling crises and balance sheet effects. The analysis was based on two assumptions: asymmetry in financing opportunities across tradable and non-tradable sectors and systemic bailout guarantees. The features of this model are: excessive risk taking and credit constraints arise simultaneously in equilibrium; both credit risk and real exchange rate risk arise endogenously. Schneider and Tornell analyzed distortions in an explicit microeconomic setting and showed that such interaction is non-trivial. However, there are no linkages between skewness and growth because only one crisis occurs in equilibrium and there is no welfare analysis.

In third generational models, policies are not pre-determined but respond to change in economy and economic agents take this relationship into account in forming their expectations. The models focus on financial excesses and how monetary policy can impact the currency crises. The model attempt to explain causes of crises spread across other countries. The main indicators in the third models include domestic credit/GDP, M2/international reserves, M2 multiplier, stock prices, bank deposits and, banking crises. Third generation models may be characterized as emphasizing the capital account, whereas the first two generation of models focus on the current account.

Fourth Generation Models

Krugman (2001) conjectured about a future fourth-generation crisis model which may not be a currency crisis model, but a more general crisis model in which asset prices other than the exchange rate play the major role. Breuer (2004) defined fourth-generation (institutional) models as a model that determines important economic outcomes such as ethic tension, politics (voting, checks, and, balances, etc.), civil order including rule of law, trust, culture, social norms, property rights, legal origin and types of governance, be it over the financial sector or the trade sector. In these models, economic and financial rules and regulations, shareholder rights, transparency and supervision over the financial system, and government distortions are emphasized. Breuer (2004) highlighted the parallels to be found in developing literatures on currency crises and banking crises. Breuer (2004) offered more questions related to institutions and financial system for further research and it seems that such models are still under investigation or development. Overall much less work is evident in the fourth generational models but some signal processing and agent based models are considered fourth generational and are reviewed.

Signal processing – Early warning systems- Kaminsky et al. (1998) reviewed the empirical literature examining methodologies and variables used to estimate the probability of a crisis. The authors suggested a specific early warning system for currency crises in the context of a signals approach. Kaminsky et al. highlighted variables that determine indicators useful in predicting crises. The authors reviewed a large variety of indicators and grouped them into six categories 1.) the external sector (capital account, external

debt profile and current account international variables); (2) the financial sector (financial liberalization and other financial variables); (3) the real sector (real GDP growth, the output gap, employment/unemployment, wages, and changes in stock prices); (4) the public finances (fiscal variables); (5) institutional and structural variables; and (6) political variables.

Fifteen indicators were chosen using theoretical considerations and availability of information on a monthly basis. Each of the indicators was compared one at a time with a crisis index. The indicators apparently behave differently close to the border of crises. Here the probability of a crisis is defined by higher indicator signals. Vulnerability to crisis is signaled when the indicator variable deviates from its usual behavior. The period of target is 24 months. The model estimated an optimal threshold value for each country and maximized the correct signals while minimizing the false signals.

Kaminsky and Reinhart (1999) used a non-parametric approach to find variables and compared the behavior of such variables in pre-existing crises. This model was examined to study the behavior of the variables around the time of balance-of-payment crises, banking crises, and twin crises. A single composite indicator is expressed as a weighted sum of the indicators, where the weights are defined by the inverse of its noise-to-signal ratio. In many emerging economies the indicator performed comfortably well in the case of some currency crises.

Kaminsky (2000) described a method for finding the degree of distress of the economy using the methodology of leading indicators. The author developed a warning system based on the empirical regularities from a sample of 20 countries; examining 76 currency crises and 26 banking crises. The information from each variable is combined, using each variables forecasting track record to produce a composite measure of the probability of a crisis. This model proposes four different composite leading indicators and evaluates them in terms of forecasting accuracy and calibration. The author constructed conditional probabilities for both currency and banking crises for each indicator of fragility; and constructed four sets of probability forecasts of banking and currency crises based on Equation (33):

$$\pi(\psi_{t,t+h} | I_i^k < I_t^k < I_j^k) = \frac{\text{months with } I_i^k < I_t^k < I_j^k \text{ and a crisis with } h \text{ months}}{\text{months with } I_i^k < I_t^k < I_j^k} \quad (33)$$

where π denotes probability, $\psi_{t,t+h}$ is the occurrence of a crisis in the interval $[t, t+h]$ and I_t^k are four different composite leading indicators with $k = 1, 2, 3, 4$.

Analysis of the model led to two main results: first, in the midst of multiple economic problems, no crisis occurred following a unique bad shock; and second, the best composite leading indicator is the one that accounts for the forecasting track record of the individual leading indicators.

Edison (2003) extended the early warning systems by adding more countries and indicator variables compared to those used by Kaminsky et al. (1998) and Kaminsky and Reinhart (1999). Edison (2003) approached the benchmark model on different indicators and evaluated the in-sample performance and out-of-sample probability indicators of a crisis. The author defined a crisis as an event where the exchange market pressure index rises above an extreme value as shown in Equation (34):

$$\text{Crisis} = 1 \text{ if } emp_t > 2.5 \sigma_{emp} + \mu_{emp}; = 0 \text{ otherwise} \quad (34)$$

where emp_t is the exchange market pressure index at time t , σ_{emp} and μ_{emp} are the sample standard deviation and sample mean of exchange market pressure respectively. Again, the probability of future

crisis is defined as in Equation (33). Edison attempted to take account of signals in overlapping crises windows.

Liu and Lindholm (2006) used a fuzzy (c-means based fuzzy clustering) method to find important economic indicators for the prediction of crisis at the time of crisis as well as pre and post crisis. This paper analyzes the Finnish currency crisis in 1992 using the fuzzy c-means method. In this clustering analysis a collection of variables were analyzed together, but how the variables interacted with each other was not explicitly shown. The important indicators of financial crisis identified are: (1) current account as a percentage of GDP; (2) increase in net foreign debt as a percentage of GDP; (3) foreign exchange reserves as percentage of imports; (4) deviation of the exchange rate from its PPP equilibrium level; and (5) growth rate decline i.e., GDP decline. Liu and Lindholm (2006) discussed the economic theoretical framework for the assessment of early warning signals of financial crises. The selection of early warning indicators was based on the portfolio balance model was first introduced by Kouri (1976).

Agent based models- Clearly, the financial markets are complex systems and involve human activities and behavior. Therefore, there is a need to understand the behavior of the whole economic system in a simplistic manner. One way to understand human behavior better is by using agent analysis. Agent-based modeling appears to be one of the better ways to explain the behavior of the economic systems, since it does not assume that the economy can achieve a settled equilibrium. Moreover, it uses a bottom-up approach that assigns behavioral rules to each agent.

Farmer and Foley (2009) made a strong case for the use of agent-based models in economics. The authors suggested that agent-based models are capable of generating complex dynamics even with simple behavioral rules. In fact, the use of rules can give rise to emergent properties that could not possibly be deduced by examining the rules themselves.

A recent example of an agent-based model that deals specifically with the financial crisis was suggested by Thurner, Farmer and Geanakoplos (2009). Thurner et al. investigated the effects of use of leverage and margin calls on the stability of the market. In this model, traders had a choice between owning a single asset such as stock or a commodity and owning cash. There were two types of traders, noise traders and funds. The noise traders buy and sell nearly at random, with a slight bias that made the price weakly mean-revert around a perceived fundamental value V . The funds traders use a strategy that exploits mispricing by taking a long position when the price is below V , but otherwise staying out of the market. In addition, there is a representative investor who either invests in a fund or holds cash. The funds in this model are value investors, who base their demand on a mispricing signal $m(t) = V - p(t)$, where $p(t)$ is the price of asset at a time t . Thurner et al. showed that when individual lenders seek to control risk through adjusting leverage, they may collectively amplify risk. The authors concluded that this mechanism comes into play with other risk control mechanisms, such as stop-loss orders and derivatives; whenever they generate buying or selling in the same direction as price movement.

Another example an of agent-based model was developed by Korobeinikov (2009) who considered an economy as a population of interacting economic agents of size N dividing the population into two subpopulations; namely the healthy subpopulation of size $x(t)$, and the activated or infected subpopulation of size $y(t)$. Here the activated or infected units could activate (infect) healthy units by failing to fulfill their financial obligations. The model described using Equations (35-36) explain the dynamics of the system:

$$\dot{x} = -\beta xy^\alpha \tag{35}$$

$$\dot{y} = \beta xy^\alpha - \frac{y}{\varphi} \quad (36)$$

where α - number of activated units contact with healthy units, β - positive activation rate coefficient and, φ - an average time duration in which an activated units was affecting the others and then the units removed from the population and didn't participate in further events. The behavior of this model is defined by the three parameters α , β and, φ ; where β and φ defined by $\xi = \beta\varphi$. The parameter α is viewed as a mean value for a large population and the activation rate coefficient β reflects efficiency of an economy. This model provides a general idea of what can be done to avoid a crisis and explains how one can reduce the length of infection time - η such that the crisis can slow down and reduce its consequence. This model clearly indicates how "dangerous" fraudulent companies could exist in reality, and indeed how important it is to detect and remove them in time.

DISCUSSION

Financial crises are usually described as failures of financial institutions or sharp falls in asset prices. Currency crises played a large role in recent economic turmoil and since the late 1970s have been a major subject of academic study. In this review financial crisis models are categorized as first, second, third and fourth-generation models. First-generation models of currency crises are based on macroeconomic fundamentals and speculations. They focus on long run, unique equilibrium, fiscal deficits and monetary policies. The models were developed in response to the sovereign debt crisis of Latin America in 1980s. The models explain currency crises by poor domestic macroeconomic conditions such as budget deficit, hyperinflation, and current account deficit (Agenor et al., 1991; Blackburn and Sola 1993). Also, they emphasize the relationship between speculation attack in foreign exchange market and macroeconomic variables. First-generation models begin with a fixed rate regime but external macroeconomic conditions can set the stage for a crisis as in Dooley (1997). These models showed how fundamentally inconsistent domestic policies lead an economy inevitably toward a currency crisis. The models did not focus on predicting whether or not the currency will collapse but rather on the timing of a speculative attack on the currency. From the literature of first generation models it is difficult to understand why governments keep exchange rates fixed and retain a policy the government knows will ultimately lead to a currency crisis.

Second-generation models of currency and banking crises introduce speculation based on self-fulfilling expectations that need not be tied to fundamentals. These models were developed in response to the European Exchange Rate Mechanism (ERM) crisis (1992-1993) and Mexican crisis (1994-1995). Second-generation models emphasize that speculative attacks can occur in the absence of poor macroeconomic fundamentals but also explain herding behavior, information cascades, and contagion (Calvo and Reinhart, 1996). The models focus on short run, multiple equilibriums, government policies and speculations expectations. Second generation models explain the relationship between economic fundamentals and a speculative attack period. These models view currency crisis not as a result of bad policy but a shift in expectation. The model is called self-fulfilling. Second-generation models showed how a spontaneous speculative attack on a currency can cause a crisis, even if fiscal and monetary policies are consistent. Essentially, the literature suggests that crises are not affected by the position of the fundamentals. Instead, they may simply occur as a consequence of pure speculation against the currency. However, these second models are not necessarily mutually exclusive with first-generation models. In fact, the second-generation models analyze the market decision-making behind the drain of international reserves initially modeled by the first-generation models. These models did not attempt to review the Asia currency crisis, which involved great financial excess and then a financial collapse.

The causes of speculative attacks on Asian currencies appeared to be different from those explained in the first and second-generation models. Therefore, economists came up with third-generation models to explain currency crisis. The Asian crisis (1997-1998) motivated the development of third-generation models. Third-generation models emphasized incentives and opportunities that invite lending and borrowing for overly risky or unproductive projects. Thus, they explicitly making a connection between banking and international currency markets. The models focused on the role of foreign currency denominated debt and its adverse balance sheet effects. The models explained the relationship between financial fragility and currency crisis. In third generation models, macroeconomic fundamentals were strong in the context of high annual growth rates, a low inflation rate and budget deficits, strong capital inflows and manageable current account deficits. Moral-hazard-driven investments leads to an excessive buildup of external debt and then to a collapse; (ii) bank-run; and also (iii) balance-sheet implications of currency depreciation.

Krugman (2001) proposed a fourth-generation crisis model, which was similar to the third-generation model, except that the new models considered asset prices other than the exchange rate. These are more general financial crisis models where other asset prices play the starring role. Breuer (2004) considered currency and banking crises, the author called fourth-generation models, as the role of institutional factors. For example, the fourth-generation models emphasized economic and financial rules and regulations, shareholder rights, transparency and supervision over the financial system, and government distortions. The models also included legal variables such as legal origin, shareholder protection property rights, and enforcement of contracts. Moreover, the models also considered political variables such as democracy and political instability and sociological variables such as corruption, trust, culture, and ethnicity. Yet very few models of this nature have been developed as yet and thus are not readily available for an in depth review. The signal processing and agent based approaches have been considered in this set but were reviewed separately within the section.

Agent-based simulations can handle a far wider range of nonlinear behavior than conventional equilibrium models. Farmer and Foley (2009) stated that this type of modeling was not well developed in economics, because of historical choices made to address the complexity of the economy rather than the importance of human reasoning and adaptability. Such models do not rely on the assumption that the economy will move towards a predetermined equilibrium state, as other models. The agent approach simulates complex and nonlinear behavior that is so far intractable in equilibrium models. A summary of all four generation models highlighting main variables, feature and issues is presented in Table 1.

Table 1: A summary of the four generational models with authors, variables, main features and issues

Generation Models	Pioneers	Main Variables	Important Features	Issues
First (1978)-defined as those in which speculation is determined solely by the fundamentals	Salant, S., Henderson, D., Kouri, P.J.K., Krugman, P.	Fiscal deficit/GDP, real money balance, M1 balance surplus, government consumption/GDP, credit growth, growth in M2 trade account balance, evolution of real exchange rate, capital account,	It focus on long run, unique equilibrium, fiscal deficits and monetary policies. Crises arise as a result of an inconsistency between an excessive public sector deficit that becomes monetized and the exchange rate system. Abandonment of a fixed exchange rate regime is largely due to unsustainable credit expansion and unsound economic fundamentals. A country with weak economic fundamentals is more vulnerable to	These models require agents to increase their estimates of the likelihood of devaluation. It doesn't explain why the currency crises spread to other countries. From the literature of first generation models it is difficult to understand why the government tries to keep the exchange rate

<p>Second (1986)- defined as those in which it can be self-fulfilling</p>	<p>Obstfeld, Ecichengreen, B., Rose, A., Wyplosz, C., Jeane, O., Masson, P.</p>	<p>Export, import, real exchange rate, terms of trade, production, real interest rate,</p>	<p>speculative attack. It emphasizes the relationship between speculation attack in foreign exchange market and macroeconomic variables. It focus on short run, multiple equilibrium, government policies and speculations expectations. Explains the relationship between economic fundamentals and speculative attack period. The government is an active agent that maximizes an objective function. Circular process exists, leading to multiple equilibrium. Suggests that crises are not affected by the position of the fundamentals. Instead, they may simply occur as a consequence of pure speculation against the currency. Self-fulfilling speculative attacks brought about by the government's time inconsistent policy goals appear to be the main cause of crisis.</p>	<p>fixed and conducts a policy which the government knows will ultimately lead to a currency crisis. The shift from one equilibrium to another is unexplained. Economists described only quite lightly the role of financial markets in the run-up crises. It did not attempt to review the Asia currency crisis, which was financial excess and then financial collapse.</p>
<p>Third (1998)- defined as in which it can be linkage between banking and currency crises and the contagion of crises</p>	<p>Krugman, P., Mckinnon, R.I., Pill, H., Corsetti, G., Pesenti, P., Roubini, N., Bhattacharya, A., Claessens, S., Ghosh, S., Hernandez, L., Alba, P.</p>	<p>Domestic credit/GDP, M2/international reserves, M2 multiplier, stock prices, bank deposits.</p>	<p>Explains relationship between financial fragility and currency crisis. Focus on the role of foreign currency denominated debt and its adverse balance sheet effects. Explains fundamentals driven, self- fulfilling and banking sector to analyze the Asian crisis. Suggests asset market prices may be useful leading indicators of crisis. Emphasizes macroeconomic analysis scope of exchange rate mechanism monetary policy, fiscal policy, and public policy. Focus on financial intermediaries, change in asset prices.</p>	<p>Solutions to currency crises are possible to appear too radical to be executed in practice and measures are to fail.</p>
<p>Fourth(2001)- defined as in which it can explains asset prices other than the exchange rate and social factors play main role.</p>	<p>Krugman, P.</p>	<p>Asset prices, ethic tension, politics, civil order including rule of law, trust, culture, social norms, property rights, legal origin and types of governance</p>	<p>Analyzes investments affected by moral hazard, bankruptcy, and balance-sheet implications of currency depreciation. Emphasizes economic and financial rules and regulations, shareholder rights, transparency and supervision over the financial system, and government distortions. Explains relationship between financial institutions and financial systems. It builds upon forward looking information contained in market prices.</p>	<p>Its reliance on market prices derived from liquid markets, which limits its applicability when such markets do not exist.</p>

This table presents a summary of the four generational models with authors and main variables. The table also shows important features of the models and related critical issues noted.

CONCLUDING COMMENTS

The aim of this paper was to review currency and financial crisis models by analyzing the nature of the models and their development over time in an attempt to understand why the 2007 financial crisis was not predicted by previous models. The models were critically reviewed and a number of underlying issues were highlighted. The analysis of the models led to a better understanding of the approaches undertaken in their development, and this in turn helped understand reasons why the models may have failed to capture crises in the modern financial system. The causes for financial crises are multiple but the models of financial crises revolve around four generational models. The recent financial crisis has challenged assumptions on which previous regulatory approaches were largely built, particularly the theory of rational and self-correcting markets. It is difficult to understand governments considering fixed exchange rates knowing the policy will ultimately lead to currency crisis. It seems crises occur because market participants expect them to materialize but the Asia crisis was neither due to fiscal deficits, as in first generation models, nor based on macroeconomic temptation, as in second generation models. Rather they were driven by simple financial excess followed by financial collapse. Some recent models suggest crises may develop without significant change in economic fundamentals.

More specifically, the analysis highlighted the fact that each model was adapted to specific situations to explain the financial crises faced rather than being visionary or systematic in approach in four generation models. The crises may develop without significant change in economic fundamentals, since policies usually respond to changes in the economy and agents consider these when forming expectations. Therefore, any set of indicators together may not provide an over-all picture of the system but certainly interactions among indicators should be pursued. Common sense and guesswork as used in rules based models may not be sufficient for representing real behavior. Agent based modeling suggests that stressed or fraudulent companies should be removed to avoid further crises.

In sum, it seems that any set of indicators together do not provide an over-all picture but correlations among indicators should be pursued. While the new models handle a wider range of nonlinear behavior, little new work is evident in this area. From this analysis it is clear that a patchwork-like approach has been used previously with after the event assessments of models. Also, there is little evidence of a longer term vision and therefore financial crises modeling has not been dealt with by researchers with any level of visionary approach. There is also little or no evidence of a new way thinking presently emerging suggesting a more complex dynamically based and robust mathematical modeling approach should be pursued.

Clearly, there is a need to do more research and in depth analysis of crisis modeling more generally and indeed financial crisis modeling in particular. The models analyzed in this paper could do with more in depth real data analysis. Such a process could have helped the authors understand other implications of the models. This issue will be examined in future research.

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