Measuring the Probability of Crises in the Turkish Economy

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ABSTRACT

The goal of this paper is to utilize an early warning system in order to measure the predicted probability of crises on the Turkish economy. It is not an attempt to formulate or test specific theories, but rather to measure the effect of probability of crisis on a proxy to the level of economic activity. This study looks Turkish economy over the period of 1999-2004. The motivation of combining early warning systems methodology and cost of crises analysis lies in its evaluation patterns of selected variables in tranquil, crisis and recovery periods. Using probability of crises instead of dates of crises enables one to capture the effects of vulnerability of the economy at each observation of the time interval analyzed. Since the system of the equations in this paper consists of time-varying parameters and an unobserved variable, a non-linear state space model is employed. Due to the non-linear characteristic of the model, the Extended Kalman Filter is utilized. The results indicate that both the derived "crisis" measure and the estimated parameters are meaningful and can successfully explain the path that the Turkish economy had followed between 1999-2003 period. Especially, the estimated "crisis" series show that the optimistic attitude of the agents in the economy right at the beginning of the exchange rate based stabilization program was misleading and the macroeconomic dynamics actually worsened. The estimated parameters also suggest that overvalued domestic currency, current account deficit and the increase in the default risk increase the likelihood of having an economic crisis in the economy. These results suggest that the estimation methodology introduced in this paper can also be applied to other emerging market economies as well.

I. Introduction

Crisis is a prominent problem is one of the dominant macroeconomic phenomenon of our age. The recent crises of 2000 and 2001 in Turkey and previously the Asian crises were the latest in a series of currency crises that at various times in the post-Bretton Woods period have engulfed emerging market economies and industrial countries alike. The increased frequency of crises channeled the academic research into a surge of explicating the common elements of those crises and creating early warning systems as instruments to avoid currency crises by predicting the timing of the crises. Although it is difficult to fit the characteristics of crises into a single mold, some common features nonetheless stand out from the analysis of the behavior of various macroeconomic and financial variables. Generally, overvalued exchange rate, growing current account deficit and domestic credit expansion are observed prior to a crisis. Previously, the literature was shallow in its empirical side since the dataset and time period employed was narrow so as to come up with robust results in predicting the crises of in-sample and out-sample countries. However, recent usage of monthly data for more countries and longer periods and improved econometric techniques reinvigorated the literature on early warning systems and give rise to the construction of new models with high predictive power. In addition, many restrictive assumptions prevailing in previous studies include strict purchasing power parity (PPP), interest rate parity parity, and the unresponsiveness of the demand for real balances to currency substitution motives. But, a richer specification of the forces contributing to crises can be modeled in recent studies.

Along with the early warning systems, observation of increased frequency of crises necessitated deeper research for costs of crises. Magnitudes of contraction/expansion of economies following crises for short and long-term are still being questioned. Currency crises can be very costly in terms of fiscal and quasi-fiscal costs of restructuring the financial sector and more broadly in terms of the effects on economic activity of the inability of financial markets to function effectively. The output effects of a currency crisis may depend on a large number of factors: conditions prevailing in the real, external, financial sectors; fiscal and monetary policies implemented during the period; and structural characteristics of the economy. Debt overhangs and capital reversals are two of the main causes of significant distortions experienced in the period of crises. Debt overhangs during crisis can conduce to hinder aggregate investment and economic activity and since most of the developing countries' external debt is denominated in foreign currencies, they are particularly vulnerable to this effect, which may be one of the reasons of observing the negative effect of an increase in probability of crisis on output sample (Calvo (1998) and Mishkin (1999)). The reversal of

capital inflows can increase the incidence of non-performing loans and cutting the credit underlying the longer-mature projects can reduce the productive activity (Calvo (1998) and Calvo and Reinhart (1999)). Moreover, Rodrick and Velasco (1999) has highlighted that the capital flow reversal that creates difficulties in rolling over short term debt can also shrink the level of economic activity by squeezing the liquidity available within the economy.

Moreover, the weakness of the banking sector during the crisis can magnify the disrupting effect of devaluation on the balance sheets of productive firms by giving rise to a "credit crunch". Mishkin (1999) claims that such a contraction in credit brought about by banking sector problems aggravates the crisis in emerging markets and the reduction in economic activity. It is also argued that the liberalization of the external capital account without taking regularity and strengthening actions becomes a source of external vulnerability and thus a severe cause of reduction in the growth of the economy (Furman and Stiglitz (1999) and the World Bank's Global Economic Prospects (1997/98).

Another issue to be taken into account is the effects of crises on trade. The trade-growth literature emphasized that growth in export could serve as an engine of output growth because crises alter the trade flow with abrupt changes in exchange rate (commonly a devaluation). In theory, a real devaluation is expected to increase the competitiveness of exports of the country (Glick and Rose (1999). However, if the competitors of the country undertake a similar devaluation, the expected expansion would not be realized. The so-called "beggar-thy-neighbor" effect will prevent the economy from expanding its exports and will cause a contraction.

On the other hand, when the country experiences a speculative attack, government needs to make a tradeoff between output and inflation. When capital starts to flee from the country, government needs to choose between a contraction in real demand and depreciation. Generating a recession and reducing absorption would pull down output and letting the exchange rate to depreciate would inflict loss on international investors and reduce the magnitude of required transfer of resources. Hence, costs of inflation during the crisis periods depend on the actions undertaken by the government. Another study claims that prices respond positively to ant deviation of real output from trend (Christiana Romer (1996)). Therefore, a bigger magnitude of change in growth of output during crisis increases the probability of a rise in inflation.

The goal of this paper is to utilize an early warning system in order to measure the impact of the predicted probability of crises on the economy. It is not an attempt to formulate or test specific theories, but rather to measure the effect of probability of crisis on a proxy to

the level of economic activity. This study looks at a sample of emerging market economies over the period of 1980-2004. But the Turkish economy is taken as our main case study. The attempt of this text is to deduce generalized hypotheses on costs of probability of a crisis on financially open developing countries by merging early warning system methodology and cost of crises analysis. The motivation of combining early warning systems methodology and cost of crises analysis lies in its evaluation patterns of selected variables in tranquil, crisis and recovery periods. Using probability of crises instead of dates of crises enables one to capture the effects of vulnerability of the economy at each observation of the time interval analyzed.

This paper contributes literature in various ways. First, it is apparent that those two concepts, early warning systems and costs of crises, are examined separately in most of the works done. In this paper, however, they will be combined and elaborated together in assessing the effects of crises on the economy. Although, the main theme is to consider the effects of crises on the economy, new values of probability of crises are developed touching upon many cornerstone studies in this area. Until now, costs of crises are examined by using dates of crises as a binary variable in regressions or by setting event analysis frameworks. Unlike the previous cost of crises literature, this study evaluates the effects of crises for any period using the probability values. They indicate that the susceptibility of the economy to crises by constructing and attributing probability values for each period.

Since the aim of the paper is to come up with a measure of the probability of a crisis, which is, in fact, an unobserved variable, the standard econometrics tools will not be appropriate to employ. Instead, one has to work within a state space model, where the probability measure is treated as being unobserved. In this case, the celebrated Kalman filter by Kalman (1960) emerges as the optimal estimation method. However, when the unobserved variable is to be estimated together with the parameters of the system, which determine the relationship between the macroeconomic variables, then the estimation algorithm should be modified. The contemporaneous estimation of the unobserved variable and the system parameters gives the problem at hand a non-linear characteristic. In this case, extended Kalman filter should be employed in this non-linear setup (for ails of the algorithm, the reader is referred to Chen (1993).

There is another major advantage of employing the extended Kalman filter in the analysis. The algorithm makes it possible to obtain a time series for ‘probability of crisis’ as well as time-varying parameter estimates. In such a case, the highly volatile nature of the emerging market economies and the unstable relation between the macroeconomic variables can be nicely captured. For example, the Turkish economy in the last fifteen years exhibits

different exchange rate regimes and monetary policy framework. Therefore, it will impose a strong restriction to the system if the parameters in the system are assumed stay intact over time. However, with the methodology employed in this analysis, it will also be possible to identify these differing macroeconomic relationships between the variables of the model. Thus, the paper contributes to methodological issues by employing the probability of crisis estimated by extended Kalman filter model.

At the end of the estimation of the system of equations, there will be two sets of results. First, we will be able to derive a time series of crisis probability. By doing so, we will be able to assess how the probability of crisis evolved over time and whether the model is capable of predicting the financial crisis that the Turkish economy had experienced in the last decade. Second, and importantly, we will be able to track down the time-varying effects of several macroeconomic variables on the crisis probability. Such an exercise will enable us to obtain a crisis indicator. In other words, by examining the time path of some of the relevant macroeconomic variables and the estimated parameters, we will be able to predict a possible financial crisis. Taking into account the financial crisis in February 2001, we expect that the over-valued Turkish lira and the resulting current account deficit may be two good indicators. Also, the EMBI spread, which shows the risk taking incentives of the foreign investors, can be another variable that may provide further information.

The rest of the paper is organized as follows. Section II gives the summary of the literature review on cost and probability of crisis. Section III gives the discussion about the Turkish economy. Section IV presents the model and the estimation procedure. Section V provides the results of the model application and analyzes the results. Section VI concludes and some technical details are collected in the appendix.

II. Literature Review on Cost and Probability Crisis

Before 90s, currency crises were thought to have a significant predictable component, as was captured in a series of first- generation models which assert that a fixed exchange rate policy combined with excessively expansionary pre-crisis fundamentals push the economy into crisis, with the private sector trying to profit from dismantling the inconsistent policies (Salant and Henderson (1978); Krugman (1979)). In these models unsustainable money financed fiscal deficits lead to a persistent loss of international reserves leaving the exchange rate regime exposed to speculative attacks. The experiences of 1970s and 1980s support the predictions of first generation models (Flood and Marion (1999)). However, the currency

crises experienced in Europe (EMS collapses) in spite of the sound macroeconomic fundamentals challenged this view.

More recently, the literature on capital inflows and capital inflow problems has suggested another potential source of instability (see, e.g. Montiel and Reinhart (1997). Sudden reversals of capital flows may cause liquidity crises as happened in debt crises of 1982, the Mexican crisis in 1994 and the Asian crises in 1997-98. Thus, the liberalization of capital account transactions by allowing this type of short term capital flows may contribute to the instability of the flow of reserves and inability of the country to the peg the domestic currency.

Recent work on currency crises has focused in a broader set of indicators (see, e.g. Kaminsky (1999); Aziz et al. (2000)). Especially after the currency crises of 1990s, which resulted in devastating economic, social and political effects, economists have had a renewed interest in understanding underlying elements. Especially, the contagion aspect of financial crises alarmed international organizations and private sector institutions and led them to spend intensive effort to develop models detecting the possibility of crises. Those models focus primarily on currency crises. Even though the ultimate causes of currency crises cannot be the same for each individual country and hence can be reveled best by country specific analyses, it might be possible to identify a common pattern in the development of crises and delineate common symptoms and leading indicators of numerous crises experienced. In addition to inferring common indicators of crises, aforementioned authors also try to construct methods that could assist in predicting the exact timing of currency crises or a specific time horizon that a country becomes highly vulnerable and exposed to attacks.

Up to now, there has been several models built such as Kaminsky, Lizando and Reinhart's (1998) leading indicators approach, Frankel and Rose's (1995) probit regression model, Sachs, Tornell and Velasco's (1996) weak fundamentals approach, the Developing Country Studies Division model of Berg and Pattillo (1998), Policy Development and Review model of Mulder, Perrelli and Rocha (2002) and the model of Bussiere and Fratzscher (2002). In addition to those there are some other private studies can be presented. For example, Goldberg (1994) predicts ex ante probabilities of currency crises and sizes of expected devaluations month by month for Mexico between 1980 and 1986. Also, Tillmann (2004) tests the impact of the distribution of information on the probability of currency crises within a Markov-switching framework. Moreover, Oka (2003) attempts to predict the incidence of arrears to the International Monetary Fund (IMF) by modifying and applying two of the major early warning systems for currency crises: the "signals" approach proposed by Kaminsky,

Lizondo, and Reinhart (1997) and the probit-based alternative developed by Berg and Pattillo (1998). The results, based on both in-sample and out-of-sample tests, appear encouraging. The models could be useful tools for identifying countries at high risk of incurring arrears to the IMF. In addition, Wirjanto (1999) shows the empirical indicators of currency crises in East Asia. His paper is concerned with identifying useful indicators of the probability of currency crises in Indonesia, Malaysia, the Philippines, South Korea and Thailand over a period of 22 years, where a currency crisis is defined as a large and infrequent devaluation of a local currency. The leading crisis indicators include international and domestic factors; but they are dominated by the leading indicators from the financial sector, such as the ratio of short-term debt to foreign reserves, the ratio of M2 to foreign reserves, and the indicator representing a regional contagion effect.

Disyatat (2004) shows that countries with higher degrees of financial market imperfection and/or a banking sector whose balance sheets are weak, in terms of having low net worth and high foreign currency exposure, are much more likely to suffer a contraction in the wake of a currency crisis. Similarly, Gale and Hellwig (1985), Williamson (1987), Bernanke and Gertler (1989), Agenor and Aizenman (1987), and Holmstrom and Tirole (1997) by introducing credit market imperfections in a setting where firms are critically dependent on bank credit for their operations. Alternatively, Chang and Velasco (1998) analyzed the interaction between financial intermediaries and currency crises in a model that builds on the 'bunk run' framework of Diamond and Dybvig (1998). A crisis occurs when there is a self-fulfilling depositor panic which results in the collapse of the whole banking sector as well as the liquidation of real investments.

As the theoretical literature differs in its explanations of costs of crises, there are two opposing views on the effects of a currency crisis in empirical literature. The traditional view is that, with price and wage rigidities, a sharp nominal devaluation would produce a real depreciation in the short run, increase exports and stimulate employment and output. By contrast, an alternative view is that sharp devaluation could have contractionary effect, working through such channels as a wealth effect on aggregate demand, higher production costs, disruption in credit markets, or a sudden cessation in capital inflows limiting imported capital goods (Moreno (1999)). In addition to the discussion about the sign of the effect, views about the persistency of the effects of currency crises, in other factors that cause the difference in sign or persistency of the effects of currency crises also vary. Furthermore, the empirical literature differs in the samples used (such as studies that focus on single crisis episodes such as Mexican crisis or Asian crisis- e.g. Calvo and Mendoza (1996); Lane and

Phillips (1999); Calvo and Reinhart (1999) – and studies that analyze output developments in broader sample countries – e.g. Milesi-Ferretti and Razin (1998 and 1999), Aziz et al. (2000), Bordo et al. (2001), Barro (2001), Gupta et al. (2000), Hutchison (2001) and Hutchison and Neuberger (2001a, b)). In the proceeding part several different studies and views will be overviewed and assessed.

Cerra and Saxena (2003) examine whether a recession following a crisis permanently lowers the level of output. They investigate the extent to which output has recovered in the aftermath of the Asian crisis. It is found out that while growth recovered fairly quickly after the crisis, there is evidence of permanent losses in the levels of output in all of the countries studied. However, Barro (2001) does not detect a persistent adverse influence of currency and banking crises on long-run economic growth. Alternatively, Hutchison and Neuberger (2001) find out that currency and balance of payments crises reduce output by about 5-8 percent over a two-three year period. Typically, growth tends to return to trend by the third year following the crisis. Greene (2002) examines whether capital outflows may have contributed to output declines during the Asian crises by reducing the financing available for domestic investment. The results shows a positive, short-term relationship between net capital inflows and investment during the period before 1997 in five Asian countries once real net capital flows are netted out from real flows of private bank credit. Aziz et al. (2000), comparing GDP growth after a crisis with trend GDP growth, assert that, for approximately 40 percent of crises output growth returned to trend in a little more than 1.5 years time. It is also estimated that the average recovery time is shorter than in industrial countries, although the cumulative output loss on average is larger. Gupta et al. (2001) discuss whether currency crises are necessarily contractionary. They find that more than 40 percent of the 195 crisis episodes across 91 countries have been expansionary band reject the notion that output severity of crises has risen over time.

III. Turkish Economy: 1999-2004

The East Asia and Russian crises of 1997-98 and the two devastating earthquakes of 1999 had a negative impact on the Turkish economy and the banking .Turkey adopted a comprehensive disinflation program at the beginning of 2000. The main aims of the program were tight fiscal and monetary policies, structural reforms and the use of a pre-determined exchange rate path as a nominal anchor. The disinflation program had a major impact on banks' balance sheets. First, with the initial sharp decline in market interest rates and the expectation of a further drop in these rates, the banks reduced deposit and lending rates. The

banks also increased their exposure to fixed rate treasury securities during this period. In addition, the pre-announced exchange rate path and the real appreciation of the Turkish lira meant a lower cost of funding for foreign currency liabilities. As a result, a number of banks borrowed in short-term foreign currency terms and lent in Turkish lira for longer terms. This led to a sharp increase in maturity mismatch and a foreign currency open position in the private banks.

The composition of the asset structure of the banking sector changed significantly during 2000 with an increase in the share of loans and a decline in liquid assets. As a result of these changes, the exposure of the banking sector to liquidity, interest rate and exchange rate risks increased during 2000. At the end of 2000, the Turkish Banking System was considerably affected by the increasing interest, exchange rate, and credit risks because of the short term- maturity structure of financial resources used in the sector, open positions, and increasing credits.

The outflow of foreign funds from Turkey and the sharp increase in T-bill rates led to financing difficulties by some private and state banks. The subsequent November 2000 crisis led to a significant erosion of the capital base of the banking sector and revealed the fragility of the system. The loss of credibility of the exchange rate regime and finally the abolition of the exchange rate peg in February 2001 further hit the already weak banking sector. Central Bank was forced to quit the exchange rate peg and started to implement floating exchange rate regime.

The government adopted a new program “Transition to a Strong Economy” in order to eliminate the confidence and financial crisis. The strategy is strongly based on market-orientation and openness to the world economy. This program intended for a structural transformation in the economy and therefore placed heavy emphasis on the implementation of the key structural reforms in public finance and banking sector as well as on the implementation of prudent fiscal and monetary policies with a view to place the Turkish economy on a sustainable growth path. The Central Bank has been implementing implicit inflation targeting as the monetary policy framework since May 200 and has been using overnight interest rates as the policy instrument in a forward-looking manner to achieve the inflation targets, jointly set by the Government. Furthermore, control over the overnight rates has been strengthened with the floating exchange rate regime and short-term interest rates became the main policy instrument of the monetary program.

Following the adoption of floating exchange rate regime, Central Bank was successful in bringing down the inflation. The year-end inflation in 2002 was 29,7 percent, below the year-end target of 35 percent and it was 18,4 percent in 2003, below the target of 20 percent, which was a historic low in the last 20 years.

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III. The Model

It is important to briefly introduce the equations in the system and explain the economic meaning behind each equation.

$$D_{t+1} = \gamma_{0,t} D_t + \gamma_{1,t} PSBR_t + \gamma_{2,t} DEPR_t + \varepsilon_{1,t} \qquad (1)$$

$$\left(\frac{1+R_t}{1+DEPR_t}\right)_{t+1} = \alpha_{0,t}\left(\frac{1+R_t}{1+DEPR_t}\right)_t + \alpha_{1,t} D_t + \alpha_{2,t} EMBI_t + \varepsilon_{2,t} \qquad (2)$$

$$MIS_{t+1} = \beta_{0,t} MIS_t + \beta_{1,t}\left(\frac{1+R_t}{1+DEPR_t}\right)_t + \varepsilon_{3,t} \qquad (3)$$

$$CA_{t+1} = \psi_{0,t} CA_t + \psi_{1,t} RER_t + \psi_{2,t} Y_t + \varepsilon_{4,t} \qquad (4)$$

$$\Pr_{t+1} = \phi_{o,t} \Pr_t + \phi_{1,t} CA_t + \phi_{2,t}\left(\frac{1+R_t}{1+DEPR_t}\right)_t + \phi_{3,t} MIS_t + \phi_{4,t} EMBI_t + \varepsilon_{5,t} \qquad (5)$$

where D_t is the domestic debt to GDP ratio, $PSBR_t$ is the public sector borrowing requirement, $DEPR_t$ is the depreciation rate of the domestic currency (TL/USD), the ratio of $(1+R_t)/(1+DEPR_t)$ is defined as monetary spread where R_t is the Central Bank's interbank interest rate, $EMBI_t$ is the emerging market bond index, MIS_t is the exchange rate misalignment which is defined as deviation of real exchange rate from its long run trend, CA_t,

is the current account deficit ratio to GDP, RER_t is the real exchange rate, Y_t is the nominal GDP and Pr_t is the unobserved risk premium[1].

The first equation attempts to summarize the debt dynamics of the Turkish economy: It states that the domestic debt to GDP ratio of the economy depends on its own lag, public sector borrowing requirement and the depreciation rate. While an increase in the public sector borrowing requirement raises the current period debt burden, the depreciation of currency increases the debt burden of the foreign exchange denominated debt. Therefore, these two factors negatively affect the debt stock to GDP ratio.

The spread between the Central Bank's interbank interest rate and the depreciation rate of the domestic currency is used as an indicator of the monetary policy where the monetary spread defined as $(1+R_t)/(1+DEPR_t)$ (Berument, 2001). The second equation states that the monetary spread depends on its own lag, the domestic debt to GDP ratio of the economy and EMBI spread. We expect that an increase in the domestic debt to GDP ratio of the economy and EMBI raises the monetary spread.

The third equation shows that the misalignment depends on its own lag and the monetary spread. We expect a rise in the monetary spread will increase the misalignment.
The fourth equation summarizes the current account dynamics of the Turkish economy simply: It states that the current account deficit to GDP ratio of the economy depends on its own lag, real exchange rate and nominal output. While an increase in the real exchange rate raises the current account deficit and increasing of output raises the current account to GDP ratio of the economy. As a result, real exchange rate affects the current account to GDP ratio negatively, but output affects it positively. In other words, appreciation of the exchange rate and positive output are expected to generate a current account deficit.

The last equation shows that the possible components of the risk premium associated with the monetary fundamentals. It is assumed that, the risk premium affected by its own lag, the current account to GDP ratio of the economy, monetary spread, misalignment, EMBI spread. Current account is of the main foot of external sector, and deterioration in current account is a part of currency crisis. If a current account deficit is accompanied by a real exchange rate appreciation, then the probability of currency crises is increased (Corsetti, Pesenti and Roubini (1999)). Also, we expect that monetary spread, misalignment, EMBI spread will also increase the probability of currency crises.

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[1] The data are obtained from the Research Department of the Central Bank of the Republic of Turkey. The Time period is 1999:01-2003:12.

IV. Estimation Procedure:

This part introduces the state space representation of the model and the non-linearity, which necessitates the employment of extended Kalman Filter.

A linear state space form will have the following state and observation equations:

$$x_{t+1} = \Phi x_t + \Psi K_t + G w_t \quad (6)$$

$$y_t = H x_t + v_t \quad (7)$$

In the linear form, the matrices Φ, Ψ do not vary over time. Then, both the state variables and the parameters are estimated via standard Kalman filter. However, as the state space representation of the model in the appendix shows, these matrices are time dependent since they include time varying parameters to be estimated. Therefore, our state space model should be presented as:

$$x_{t+1} = f_t(x_t) + k_t(z_t) + M_t(x_t)\zeta_t \quad (8)$$

$$y_t = g_t(x_t) + \eta_t \quad (9)$$

The above form is an example for a non-linear state space model, where f_t, k_t and g_t are vector-valued functions, ζ_t and η_t are uncorrelated zero mean white noise sequences with covariance matrix Q_t and R_t, respectively. Note that both the time-varying parameter vector, f_t and the state vector, x_t, are presented in the state equation together in multiplicative form. Since both the state variables and the parameters are to be estimated simultaneously, the state equation will have a non-linear feature. The extended Kalman filter (EKF) is one of the most popular estimation techniques largely investigated for state estimation of such nonlinear systems. It consists of using the standard Kalman filter equations to the first-order approximation of the nonlinear model about the last estimate.

Applying EKF:

$\Omega_t = \begin{bmatrix} \alpha_{0,t}, \alpha_{1,t}, \beta_{o,t}, \beta_{1,t}, \gamma_{0,t}, \gamma_{1,t}, \gamma_{2,t}, \varphi_{0,t}, \varphi_{1,t}, \theta_{0,t}, \theta_{1,t}, \theta_{2,t}, \\ \partial_{0,t}, \partial_{1,t}, \partial_{2,t}, \mu_{0,t}, \mu_{1,t}, \mu_{2,t}, \phi_{0,t}, \phi_{1,t}, \phi_{2,t}, \phi_{3,t}, \phi_{4,t} \end{bmatrix}$ is the parameter vector to be estimated.

Then equation (6) and (7) should be treated as $\Phi_t(\Omega t)$, $\Psi t(\Omega_t)$, $G_t(\Omega_t)$, $H_t(\Omega_t)$, which are all functions of the parameter vector, Ω_t. In this case, the model becomes:

$$x_{t+1} = \Phi(\Omega_t)x_t + \Psi(\Omega_t)K_t + G_t(\Omega_t)wt \quad (10)$$

$$y_t = H_t(\Omega_t)x_t + v_t \quad (11)$$

It can be seen that equations (10) and (11) are in the non-linear form described by equations (8) and (9). Next, we have to specify a time series process for the parameters. Let the parameters follow random walk:

$$\Omega_{t+1} = \Omega_t + \zeta_t$$

Where ζ_t is any zero-mean white noise sequence uncorrelated with v_t and with preassigned positive definite variances $Var(\zeta_t) = S_t$. If we treat the above equations as the new state vector and combine them, the new state space model becomes:

$$\begin{bmatrix} x_{t+1} \\ \Omega_{t+1} \end{bmatrix} = \begin{bmatrix} \Phi_t(\Omega_t)x_t \\ \Omega_t \end{bmatrix} + \begin{bmatrix} \Psi_t(\Omega_t)K_t + G_t(\Omega_t)\omega_t \\ \varsigma_t \end{bmatrix} \quad (13)$$

$$y_t = \begin{bmatrix} H_t(\Omega_t) & 0 \end{bmatrix} \begin{bmatrix} x_t \\ \Omega_t \end{bmatrix} + \eta_t \quad (14)$$

The non-linearity can also be seen in equation (13). Then EKF procedure can be applied to estimate the state vector, which contains Ω_t as one of its components. That is, Ω_t is estimated optimally in an adaptive way. This procedure is called adaptive system identification, as noted in Anderson and Moore (1979). Both the extended Kalman Filter algorithm and its application in non-linear state space models are discussed in Chui and Chen (1993) and Chen(1993) in details.

V. Estimation Results and Discussion

As it is mentioned in the methodology section the extended Kalman filter is the appropriate estimation algorithm in non-linear state space models. Since the paper estimates both the time-varying parameters of the system and constructs a time series for "likelihood of crisis", the state space framework turns out to have a non-linear nature. Therefore, after the system of equations is written in a state space model, the extended Kalman filter is executed and the parameters as well as the unobserved "crisis" series are obtained[2].

Since the main goal of the study is to come up with a measure of crisis likelihood, this section is particularly devoted to the interpretation of the constructed series. Also, the

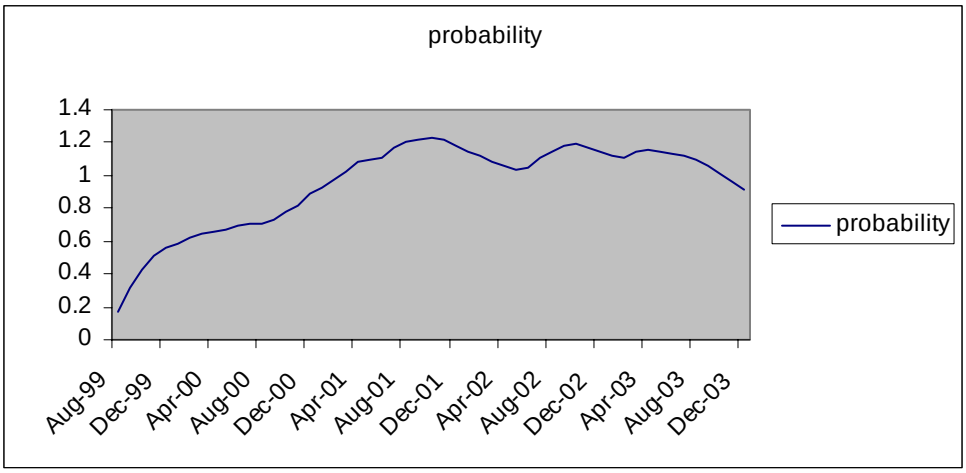
[2] For estimation purposes, MATLAB and the optimization toolbox will be used.

estimated parameters regarding the variables in the "crisis" equation for the will be shortly discussed.[3]

The Estimated "Crisis" Series

Table 1 in Appendix displays the unobserved crisis series. As it can be easily seen from the Figure 1 also, the series steadily increases and reaches a maximum on October 2001. After then, we detect a decline until the second quarter of 2002. Although the series tends to have a slight increase from May 2002 to November 2002, we observe a significant decrease until then. It should be reminded that the sample period is between August 2000 and December 2003. Such a time span includes the exchange rate based stabilization program, the financial crisis period and the first phase of the new economic program, which was intended for a structural transformation in the economy. Thus, the constructed 'crisis' series should be interpreted with respect to these important developments in the Turkish economy.

Figure 1 Unobserved Crisis Series



Following the 1998 Russian crisis and the devastating 1999 earthquake, it was clear that the Turkish economy entered into an unsustainable path, which necessitated the "2000-2002 program". The program can be regarded as an exchange rate based stabilization program, where there were also attempts to reduce the debt burden with a tight fiscal policy. However, due to the reluctance in implementing the structural reforms and the fragile banking sector, it was soon anticipated by the agents that the program was far from being successful to attain the goals of low inflation and sustainable debt stock. Actually, the estimated "crisis" series indicate that the likelihood of having a financial crisis steadily increased even when the

[3] The other estimated parameters are available on request.

"2000-2002 program" was introduced. Finally, when the uncertainties regarding the success of the economic program aggravated, the Central Bank of the Republic of Turkey announced in February 2001 that it would no longer defend the exchange rate target and the monetary policy framework would operate within a floating exchange rate regime. In addition, beginning with May 2001, a new program, supported by the IMF, was announced.

When the estimated "crisis" series is observed, it can be seen that the series did not reach a maximum at the collapse of the exchange rate based stabilization program but increased even after then. Such a result is totally consistent when the debt dynamics are taken into account. After the duty losses of the banking sector have been added to the debt stock of the government, the risk perceptions in the economy have further increased. The real interest rates have jumped up to around 30 percent. These negative developments on the fiscal side have brought the possibility that the government would default on its debt. As a result, the likelihood of having a further economic crisis has increased until the beginning of the fourth quarter of 2001. Such a finding suggests that even if February 2001 was regarded as the date of the financial crisis, the following months should be viewed as harder times.

At the end of 2001, the investors in the economy realized the first positive signs of the new stabilization program. Also, the government made it clear that it did not have any incentives to default on its debt. These positive factors can explain the decrease in the estimated "crisis" series. However, it can be seen from Table 1 that the series began to increase by May 2002. This is also expected since beginning from the second quarter of 2002, there was a high degree of political instability with the intensified discussion about an early election. At the same time, the worsening health condition of the prime minister was another factor for this increase in the series. Finally, on November 2002, the political instability came to after a single party has come into power. After then, the series had a downward trend, which indicates that the likelihood of a major economic crisis has been decreasing.

As a result, the above analysis suggests that the estimated crisis series fit well with the macroeconomic dynamics that the Turkish economy had between 1999 and 2003. In addition, the results suggest that the worsening conditions intensified and reached a maximum at the third quarter of 2001, indicating that October 2001 should be regarded as the deepest point of the economic crisis. Finally, and importantly, at the beginning of the exchange rate based stabilization program, although policymakers and the agents in the economy were optimistic about the success of the program, our crisis measure served as an early warning system about the likelihood of an economic crisis.

As a final exercise, it may provide insightful results to check whether the estimated "crisis" series tend to co-move with the EMBI (emerging market bond index) spread. Prepared by J.P. Morgan for each emerging market economy, this spread is broadly used as an overall risk measure and reflects mainly the default risk for that particular market. As it can be seen from Table 2, these two series move in the same direction. In fact, the correlation between the two series is found to be 0.76, which further validates this close link.

The Estimated Parameters

After investigating the estimated crisis variable, the next step is to discuss the parameters regarding the variables in the crisis equation. First, as a common finding, it has been found that the parameters do not vary over time during the time span. Such a result indicates that each variable in the crisis equation has the same impact through time.

It has been found that the coefficient for the lagged value of the crisis takes a value of 0.8. Such a finding implies some kind of inertia in the sense that once the economy is likely to suffer from a crisis; the situation tends to get worse unless some dramatic steps are taken.

On the other hand, the estimated coefficient for the current account balance is –0.4, which implies that if the economy generates a current account deficit, mostly due to an overvalued domestic currency, then the likelihood of having a crisis increases. Such a finding fits well with the nature of the February 2001 crisis that the Turkish economy had experienced.

The coefficient for the real rate of return for the foreign investor is found to be 0.5. Such a finding has important implications, especially in terms of short-term capital flows. If the real rate of return on Turkish securities increases, then a short-term capital inflow is expected. Once the economy gets surrounded with uncertainty, then one would expect massive short-term capital outflows, which generally triggers a currency crisis. The estimated coefficient for the real rate of return provides support for this channel.

Another related finding is the estimated coefficient for the misalignment measure. The coefficient is estimated to be around 0.6, which means that as the domestic currency gets overvalued, the likelihood of having a crisis increases dramatically. Such a finding also explains why the exchange rate based stabilization programs tend to be unsuccessful in emerging market economies. Consequently, all of the estimated parameters for the crisis equation make sense and provides support for the path that the Turkish economy had followed during the sample period.

VI. Conclusion

This paper proposes a new framework to utilize an early warning system about the likelihood of a financial crisis. Although the study takes the Turkish economy as its case study the introduced system of equations seems to be valid for the other emerging market economies as well. The likelihood of a financial crisis is treated as an unobserved variable and estimated within the context of a semi-structural macroeconomic model.

Another original aspect of the paper is the employed estimation methodology. After the semi-structural model is put into a state space form, the extended Kalman filter is executed. Since the time-varying parameters and the state variables are to be estimated simultaneously, the state space model will have a non-linear nature, where the standard Kalman filter is no longer appropriate. In such cases, the extended Kalman filter serves as the optimal estimation methodology.

The results indicate that both the derived "crisis" measure and the estimated parameters are meaningful and can successfully explain the path that the Turkish economy had followed between 1999-2003 period. Especially, the estimated "crisis" series show that the optimistic attitude of the agents in the economy right at the beginning of the exchange rate based stabilization program was misleading and the macroeconomic dynamics actually worsened. The estimated parameters also suggest that overvalued domestic currency, current account deficit and the increase in the default risk increase the likelihood of having an economic crisis in the economy. These results suggest that the estimation methodology introduced in this paper can also be applied to other emerging market economies as well.

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Appendix TABLE 1 UNOBSERVED CRISIS SERIES

Aug-99	0.1739	541	0.765668
Sep-99	0.3176	564	
Oct-99	0.4271	537	
Nov-99	0.5079	503	
Dec-99	0.5587	434	
Jan-00	0.5895	385	
Feb-00	0.6154	391	
Mar-00	0.6417	419	
Apr-00	0.6626	419	
May-00	0.6742	393	
Jun-00	0.6924	438	
Jul-00	0.7014	410	
Aug-00	0.7071	403	
Sep-00	0.7364	527	
Oct-00	0.7757	606	
Nov-00	0.8182	661	
Dec-00	0.8829	815	
Jan-01	0.9193	738	
Feb-01	0.9698	845	
Mar-01	1.0263	926	
Apr-01	1.086	998	
May-01	1.1006	831	
Jun-01	1.1137	838	
Jul-01	1.1687	1060	
Aug-01	1.2019	1005	
Sep-01	1.2198	961	
Oct-01	1.2303	941	
Nov-01	1.2143	817	
Dec-01	1.1805	711	
Jan-02	1.146	672	
Feb-02	1.1185	671	
Mar-02	1.0848	611	
Apr-02	1.0566	603	
May-02	1.0364	613	
Jun-02	1.0529	775	
Jul-02	1.1042	963	
Aug-02	1.1392	931	
Sep-02	1.1763	974	
Oct-02	1.1966	925	
Nov-02	1.1739	728	
Dec-02	1.1431	662	
Jan-03	1.1257	696	
Feb-03	1.1139	704	
Mar-03	1.1383	871	
Apr-03	1.1516	837	
May-03	1.1438	742	
Jun-03	1.1338	721	
Jul-03	1.1209	694	
Aug-03	1.0903	590	
Sep-03	1.0548	532	
Oct-03	1.0079	437	
Nov-03	0.9607	386	
Dec-03	0.9103	320	