REV. MIDDLE EAST ECON. FIN., 2004, VOL. 2, NO. 2, 87–107

Prediction of currency crises: case of Turkey

ROBERTO S. MARIANO,[†] BULENT N. GULTEKIN,[‡] SULEYMAN OZMUCUR,*[§] TAYYEB SHABBIR[‡] and C. EMRE ALPER[¶]

[†]School of Economics and Social Sciences, Singapore Management University and Department of Economics University of Pennsylvania, Philadelphia, USA
[‡]Wharton School, University of Pennsylvania, Philadelphia, USA
[§]Department of Economics, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104-6297, USA (e-mail: ozmucur@ssc.upenn.edu)
[¶]Department of Economics, Bogazici University, Turkey

This paper explores the issue of constructing an economic predictive model of financial vulnerability through an alternative econometric methodology that addresses drawbacks in existing approaches. The methodology entails estimating a Markov regime switching model of exchange rate movements, with time-varying transition probabilities. Experiments with monthly and weekly models indicate that real exchange rate, foreign exchange reserves and domestic credit/deposit ratio are the most important determinants of financial vulnerability. These variables should be observed very closely by researchers and policy makers in order to determine if the country is heading for financially difficult times.

Keywords: Markov switching financial vulnerability; foreign exchange crises; banking crises; Turkey

JEL Classification: C50; F30; O16; O50

1. Introduction

The decade of the 1990s was marked by an unusual number of financial and economic crises such as the attack on the European Monetary System in 1992–1993, the Mexican peso crisis in 1994–1995, the Asian crisis in 1997, the Russian default in 1998 and its spillover to Latin America. The Turkish currency and banking crisis in 2000–2001 and the recent difficulties in Argentina and Brazil indicate that financial crises are still part of the current economic events.

In the wake of such developments, there has been a resurgence of interest in early warning systems that can anticipate the likely occurrence of such crises.

*Author for correspondence.

Review of Middle East Economics and Finance ISSN 1475-3685 print/ISSN 1475-3693 online

http://www.tandf.co.uk/journals
DOI: 10.1080/1475368042000262802

There is extensive literature on the Asian financial crisis and early warning systems—with numerous surveys, including Kaminsky and Reinhart (1998), Mariano *et al.* (2002), Goldstein *et al.* (2000), Richter (2000) and Abiad (2002).

There are essentially two alternative methodologies that have been employed in the empirical studies of the early warning systems for currency crises. (1) The relatively more popular approach is to use probit or logit models, illustrated by Eichengreen *et al.* (1995, 1996), Frankel and Rose (1996), Eichengreen and Rose (1998) and Gochoco-Bautista (2000) for currency crises and by Demirguc-Kunt and Detragiache (1998) for banking crises. The first approach requires the construction of a crisis dummy variable that serves as the endogenous variable in the probit or logit regression. (2) Alternatively, the methodology adopted by Kaminsky and Reinhart (1999, 2000), Kaminsky *et al.* (1998) and Edison (2000) is known as the 'signals' approach which essentially optimizes the signal to noise ratio for the various potential indicators of crisis. Berg and Pattillo (1999) compared these two methodologies and are in favor of the probit models.

Despite the current popularity of these approaches, they have some drawbacks, which include inadequate treatment of serial correlations, inadvertent introduction of artificial serial correlations through the explicit manner in which the crisis dummy variable is constructed, the resulting classification errors due to the construction of the crisis dummy variable, inadequate framework for significance testing of the influence of explanatory or indicator variables, and the existence of possible inconsistencies in the estimation of crisis incidence probabilities because of heterogeneity across countries.

Along these lines, this paper explores the issue of constructing an economic predictive model of currency crises through an alternative econometric methodology that addresses drawbacks in existing approaches. The methodology entails estimating a Markov regime switching model of exchange rate movements, with time-varying transition probabilities. This approach is designed to avoid the potential misclassification in the construction of crisis dummy variables, which other approaches (such as probit/logit and signaling) require. The methodology also addresses the serial correlations and sudden behavior inherent in crisis occurrence, identifies a set of reliable and observable indicators of impending currency difficulties, delivers forecast probabilities of future crises over multi-period forecasting horizons and offers an empirical framework for analyzing contagion effects of a crisis and for improving short-run forecasts of key macroeconomic variables.

The paper is in five sections. Section 2 is devoted to reviewing the experience of Turkey in the aftermath of financial liberalization on August 1989. Modeling of currency crises and, especially, the Markov switching methodology is presented in Section 3 and empirical results based on the proposed methodology are given in Section 4. Major conclusions and policy recommendations are presented in the final section.

2. The Turkish experience with financial crises

Episodes of financial crises in Turkey in the post-financial account liberalization period provide an invaluable economic lesson:[1] fundamental macro imbalances and financing of these imbalances are the main causes behind the balance of payment crises. In retrospect, it might be argued that Turkey did not benefit fully from capital account openness. The capital account liberalization of August 1989 could be considered as 'premature' in nature since political stability, transparency of the state and the development of key institutions were absent prior to the capital account openness. The political instability led to inefficient use of the capital inflow and, combined with fiscal expansion, did not lead to the desired outcome of lower domestic real cost of capital. Political turmoil led to frequent capital reversals, which led to financial crises and/or increases in the debt/GNP ratio.

Following the financial account liberalization, the rate of economic growth substantially depended on volatile and reversible short-term capital inflows. On the other hand, 'instability' became the distinctive feature of the Turkish political environment, with the fragmented structure of the political party system, allowing shorter periods for governments and increased populist cycles. Given that expansionary fiscal policies under an appreciating exchange rate regime led to balance of payment or debt crises, the questions on the sustainability of the employed policies became more and more apparent; this manifested itself initially as the 1994 crisis. The policies employed to recover from the contracting effects of the 1994 crisis gave a chronic characteristic to the weaknesses in the public and financial sectors. High real interest rates led to rapid accumulation of public debt in the late 1990s, whereas full insurance of deposits created a high widespread 'moral hazard' problem.

The macroeconomic performance of the economy and developments in the banking sector exhibited a mutually linked structure in Turkey. The high borrowing requirement of the public sector as well as the unstable macroeconomic and political environment hindered the development of a healthy banking system. This revealed itself as an obstacle towards a sustainable growth path and a triggering factor for macroeconomic crisis. The Turkish banking system had three major dilemmas: predominance of the public banks, open positions and politicized licensing of private banks, and limited participation by the foreign banks (Alper and Onis, 2004).

In order to reverse the unsustainable trend in public debt management and, hence, to alter the ill structure of the economy, an International Monetary Fund (IMF)-backed three-year stabilization program was implemented in 2000. The program was essentially an exchange rate-based stabilization program supplemented by fiscal adjustments and structural reforms. The program also included an exit strategy from the 'pegged' exchange rate system, aiming to avoid the incredibility and ill effects associated with the programs that incorporate a reduction in devaluation rate that is not credible. The program targeted at reducing the annual Consumer Price Index (CPI) inflation rate to 25% at the end of 2000 and the public sector debt to GNP ratio to 54.8% in 2002.

The monetary policy was based on the 'quasi-currency board' setup, which did not allow the Central Bank to consider the daily requirements of the financial system as priority. Fiscal Policy envisaged the substantial increase in public sector primary surplus, reaching 6.5% of GNP in 2002. On the structural front, the government promised to achieve a set of reforms in agriculture, social security and banking sectors.

After roughly one year of the implementation period, Turkey experienced two financial crises in November 2000 and February 2001, the latest leading to the abandonment of the 'crawling' exchange rate policy and severe problems in debt rollover. Triggering factors of the crises may be summarized under four captions: Internal weaknesses of the program stemming from the appreciated Turkish Lira and 'quasi-currency board' role of the Central Bank of Turkey; vulnerability of the Turkish banking sector which is undercapitalized and highly invested in government debts; 'reform fatigue' manifested itself in delays in structural measures; and unfavorable external environment, including rising petroleum prices and interest rate hikes in the USA. The new economic program launched in May 2001 was designed as a 'structural adjustment' program, rather than a disinflation program, with special emphasis on the banking sector. Today, Turkey is still struggling with the issue of medium- to long-term financing of the public debt and is as prone to a financial crisis as ever.

3. Methodology

3.1. *Introduction*

Recent efforts (Demirguc-Kunt and Detragiache, 1998; Eichengreen and Rose, 1998; IMF, 1998a, 1998b; Kaminsky and Reinhart, 1998; Kaminsky *et al.*, 1998; Kamin *et al.*, 2001) towards devising an early warning system for an impending financial crisis have taken two related forms.

The first approach estimates a probit or logit model of the occurrence of a crisis, with lagged values of early warning indicators as explanatory variables. This approach requires the construction of a crisis dummy variable that serves as the endogenous variable in the probit or logit regression. Classification of each sample time-point as being in crisis or not depends on whether or not a specific index of vulnerability or speculative pressure exceeds a chosen threshold. For currency crises, the index of vulnerability is often based on a weighted average of the following three variables:

- percentage changes in nominal exchange rates;
- percentage change in gross international reserves;
- difference in local and foreign short-term interest rates.

Explanatory variables typically come from the real, financial, external and fiscal sectors of the economy.

The second method uses a signaling or leading-indicator approach to get a more direct measure of the importance of each candidate explanatory variable. Apart from constructing a crisis dummy variable, the approach also constructs binary variables from each explanatory variable—thus, imputing a value of one (a signal) or zero (no signal) for each explanatory variable at each point in time in the sample—based on whether or not each variable exceeds a chosen threshold. These signals are classified according to their ability to call a crisis: a signal is a 'good signal' if a crisis does ensue within a specified period (usually 24 months) and is a 'false signal' otherwise. Thresholds are chosen so as to strike a balance between the risk of having many false signals and the risk of missing many crises. More precisely, a signal-to-noise ratio is computed for each explanatory variable over the sample period—as a quantitative assessment of the value of the variable as a crisis indicator. Thresholds are then chosen to maximize the signal-to-noise ratio. Based on this metric, Kaminsky *et al.* (1998) found that the best early warning indicators for currency crises include exports, deviations of the real exchange rate from trend, M2/reserves, output and equity prices.

Whether this approach or a probit/logit approach is used, to cover a wider sample for purposes of estimating incidence probabilities for a crisis, many studies have been typically done on a panel of countries—and usually with some homogeneity assumptions about crisis behavior across countries.

3.2. *Limitations of current approaches*

Despite the current popularity of these approaches, they have a number of drawbacks (Abiad, 2002).

- Inadequate treatment of serial correlations inherent in the dynamics of a crisis. Neither the probit/logit approach nor the signaling approach provide information on dynamics—how long crisis periods tend to last—nor do they provide information about what variables affect the likelihood of a crisis period ending.
- Artificial serial correlations may even be introduced inadvertently through the explicit manner in which the crisis dummy variable is constructed. Many previous studies focus primarily on predicting the onset of a crisis, i.e. the first period where speculative attacks occur. To achieve this in their binary crisis variable, they make use of so-called 'exclusion windows' which remove any crisis signals that closely follow previous crisis signals. This procedure can introduce artificial serial correlations (Abiad, 2002).
- Classification errors may result when constructing the crisis dummy variable (either as a false signal or a missed reading of a crisis). Because the threshold used to delineate crisis periods from tranquil periods is arbitrarily chosen, misclassification of crisis episodes can occur. If the threshold is too high, for example, some periods of vulnerability may not be picked up.
- Inadequate framework for significance testing of the influence of explanatory or indicator variables (in the signaling approach). Because the signaling approach is not based on an explicit stochastic model, there is no way it can be evaluated using formal statistical tests and it is difficult to assess its performance *vis-à-vis* other approaches.
- Possible inconsistencies in the estimation of crisis incidence probabilities because of heterogeneity across countries. It is possible that the variables, which are important in determining crisis likelihoods for one country, are unimportant for another country. And even if the same variables affected crisis likelihoods for all countries, the degree to which they affect the likelihood of a crisis occurring may differ from one country to the next.

3.3. *The approach*

A new early warning methodology is applied to address these drawbacks. A Markov switching autoregressive model is constructed that allows intercepts, lag coefficients and error variances to stochastically switch over time according to the value taken by a latent Markov chain describing the vulnerability of the country's currency to speculative attacks. A related work, Martinez-Peria (1999), also applies a Markov switching model to speculative attacks, but the primary purpose in that paper was to evaluate the ability of the model in dating crisis periods and to see whether market expectations affected crisis probabilities. Here, the focus is on the use of the model as an early warning system. Thus, the predictive model of a currency crisis consists of two parts.

1. A Markov chain model of the unobservable financial vulnerability of the country, say S_t. It is argued that what is observed are indicators of this latent attribute of the country. Initially, two states are assumed:

   - normal ($S_t = 0$);
   - vulnerable ($S_t = 1$).

   It is further assumed that this Markov chain is of order 1, with transition probabilities that are time-varying through dependence on observable indicator variables. The preliminary results reported in this paper are based on the following indicator variables:

   - deviations of real effective exchange rate from trend;
   - month-to-month percentage changes in the ratio of M2 to international reserves;
   - month-to-month percentage changes in real domestic credit.

2. A Markov regime-switching time series model of percentage changes in nominal exchange rates. This model differs from standard ones in the sense that it includes the unobservable state variable S_t as an additional endogenous variable. The inclusion of S_t introduces the notion that the exchange rate dynamics behave in a different fashion depending on whether financial conditions are normal ($S_t = 0$) or vulnerable to currency pressures ($S_t = 1$). This is reflected in the model by allowing the parameters in the time-series model to change in value over time, as financial conditions become normal or vulnerable.

Let S_t be a two-state Markov chain of order 1 with transition probabilities p_t and q_t, so that at any given time t, S_t can take on two values, zero or one, according to the following probability law:

$$\Pr(S_t = 0|S_{t-1} = 0) = p_t \quad \text{and} \quad \Pr(S_t = 1|S_{t-1} = 1) = q_t. \tag{1}$$

Further, let y_t be the month-to-month percentage changes in nominal exchange rates, x_t be the vector of exogenous variables at time t used to explain y_t and z_t be the vector of exogenous variables at time t used as indicators of currency vulnerability, which may overlap with x_t.

It is also assumed that the transition probabilities vary over time according to values of indicator variables in the following manner:

$$p_t = \mathrm{F}(z_t'\gamma) \text{ and } q_t = \mathrm{F}(z_t'\delta), \tag{2}$$

where $F(\bullet)$ is the standard unit Gaussian cumulative distribution function.

The second part of the model consists of a univariate linear model for y_t:

$$y_t = \alpha_{St} + x_t'\beta_{St} + \sigma_{St}\varepsilon_t \tag{3}$$

In this model, the model parameters (α, β, σ) are subscripted by S_t—indicating that their true (unknown) values are shifting between two sets of possible parameter values: (α_0, β_0, σ_0) and (α_1, β_1, σ_1), depending on whether financial conditions are normal or vulnerable.

The estimation procedure used is direct maximization of the likelihood, where the likelihood function is calculated using an iterative process, described in detail in Hamilton (1994a, 1994b).[2] Collecting all the parameters of the model into a single vector $\theta = (\alpha_0, \beta_0, \sigma_0, \alpha_1, \beta_1, \sigma_1, \gamma', \delta')$ and using information available up to time t, Ω_t, one can calculate for each time t (using the iteration below) the value of $\Pr(s_t = j|\Omega_t; \theta)$, the conditional probability that the t^{th} observation was generated by regime j, for $j = 1, 2, \ldots, N$, where N is the number of states (in this paper, $N = 2$). These conditional probabilities will be stacked into an $(N\times 1)$ vector $\hat{\xi}_{t|t}$.

The same iteration also forms forecasts regarding the conditional probability of being in regime j at time $t+1$, given information up to time t: $\Pr(s_{t+1} = j|\Omega_t; \theta)$, for $j = 1, 2, \ldots, N$. These forecast probabilities are collected in an $(N\times 1)$ vector $\hat{\xi}_{t+1|t}$. Lastly, let η_t denote the $(N\times 1)$ vector whose j^{th} element is the density of y_t conditional on s_t. The optimal inference and forecast for each date t can then be found by iterating on the following equations:

$$\hat{\xi}_{t|t} = \frac{(\hat{\xi}_{t|t-1} \circ \eta_t)}{1'(\hat{\xi}_{t|t-1} \circ \eta_t)} \tag{4}$$

$$\hat{\xi}_{t+1|t} = \mathbf{P}_{t+1} \cdot \hat{\xi}_{t|t} \tag{5}$$

where $\mathbf{P}_t$ is the $(N\times N)$ transition probability matrix going from period t–1 to period t (for the two-state model in this paper, $\mathbf{P}_t$ is the 2×2 matrix $[p_t\ 1-p_t;\ 1-q_t\ q_t]$) and $^\circ$ denotes element-by-element multiplication. Given an assumed value for the parameters, θ and an assumed starting value for $\hat{\xi}_{1|0}$ (the unconditional probability of s_t at $t = 1$), one can then iterate on the above equations to obtain values of $\hat{\xi}_{t|t}$ and $\hat{\xi}_{t+1|t}$ for $t = 1, 2, \ldots, T$. The log likelihood function $L(\theta)$ can be computed from these as

$$L(\theta) = \sum_{t=1}^{T} \log f(y_t|X_t, Y_{t-1}; \theta) \tag{6}$$

where

$$f(y_t|X_t, Y_{t-1}; \theta) = 1'(\hat{\xi}_{t|t} \circ \eta_t). \tag{7}$$

One can then evaluate this at different values of θ to find the maximum likelihood estimate.

4. Prediction of currency crises in Turkey

There are a handful of studies, which try to predict economic and/or financial crises in Turkey.[3]

Neftci and Özmucur (1991a, 1991b) attempted to find coincident and leading indicators of economic activity based on monthly data for the period 1980–1990. Their coincident indicators are: index of manufacturing production, imports, newly established firms and railway freight. Real M1 and real M2, real central bank credits to banking sector, the ratio of central bank credits to M2, real value of capital reinvested, total surface area of buildings in new building permits, real value of government's consolidated budget expenditures and demand for jobs as reported by government employment bureaux are eight variables which make up the index of leading indicators. Leading indicators perform well in capturing cycles in economic activity during the 1980–1990 period.

Özmucur (1991) used logit and probit models to predict 'need for IMF programs' and 'bottlenecks' in the economy. Using 1950–1991 annual data, it was possible to predict seven out of eight years with 'bottlenecks'. Real exchange rate, real interest, external terms of trade, excess demand (money supply growth–real GDP growth) and share of current account balance in GNP, all with one or two lags, are used as explanatory variables in the model.

Ucer *et al.* (1998) examined the currency crisis of 1994 and concluded that the crisis was a result of deterioration of economic fundamentals and not only macroeconomic mismanagement. They used quarterly data and applied the methodology of Kaminsky *et al.* (1998) and proposed some new indicators. In addition to the 12 indicators used by Kaminsky *et al.* (1998), they added the ratio of exports to imports, real exchange rate, short-term external debt/GNP, debt maturity, reserves to M2Y plus debt stock, government deficit/GNP and short-term advances to the treasury/GNP.

Mariano *et al.* (2000, 2002), using Markov switching with varying transition probabilities, indicated the importance of the following variables on selected indicators (exchange rate, industrial production and stock prices): current account, inflation, export/import, direct investment, reserves/money supply, reserves/imports, foreign debt service/exports and short-term capital.

The modeling strategy is as follows: first, estimate the model with constant probabilities and then estimate the time-varying parameter model with a single indicator. The list of indicators is given in the Appendix. After choosing the most important indicator, based on log-likelihood statistics for the model and statistical significance of individual coefficients, include the second variable in the model; continue this process until there is no change in the log-likelihood statistics.

4.1. *Empirical results based on a monthly model*

The model consists of a univariate linear model for y_t:

$$y_t = \alpha_{S_t} + x_t' \beta_{S_t} + \sigma_{S_t} \varepsilon_t \tag{8}$$

where, y is the percentage change in the Turkish lira/US dollar exchange rate, x's are exogenous variables used in the model. In this model, the model parameters (α, β, σ) are subscripted by S_t—indicating that their true (unknown) values are shifting between two sets of possible parameter values: (α_0, β_0, σ_0) and (α_1, β_1, σ_1) depending on whether financial conditions are normal or vulnerable.

Initially, the model is estimated with constant switching probabilities, with no exogenous variables:

$$y_t = \alpha_{St} + \sigma_{St}\varepsilon_t \tag{9}$$

where y is the percentage change in the Turkish lira/US dollar exchange rate (figure 1). In this model, the model parameters (α, σ) are subscripted by S_t—indicating that their true (unknown) values are shifting between two sets of possible parameter values: (α_0, σ_0) and (α_1,σ_1) depending on whether financial conditions are normal or vulnerable.

The mean for state 0 (normal financial conditions) is a zero, while the mean for state 1 (vulnerable financial conditions) is 6.16. These are denoted by MEAN0(1) and MEAN1(1) in table 1 and the following tables. The standard deviations are 0.01 and 21.89 for state 0 and state 1, respectively. These are denoted as SIG0(1) and SIG1(1) in table 1 and the following tables. The constant term is 1.158 for state 0, and 1.911 for state 1, respectively. These are denoted as TVP0B(1) and TVP1B1(1) in table 1 and the following tables. It is clear from these results that two periods can be distinguished by their means and standard deviations (a measure of volatility). In state 0 (normal financial conditions), the average monthly percentage change in the exchange rate is almost zero, while in state 1 (vulnerable financial conditions) the average monthly percentage change is 6.16.

The model is successful in predicting the devaluations of 1960, 1971 and 1980. However, it predicts a state 1 almost for the entire post-1980 period. The major reason for this is the existence of a fixed exchange rate regime prior to 1980. Devaluations were made when it was absolutely necessary and when governments realized that a crisis was impossible to avoid.

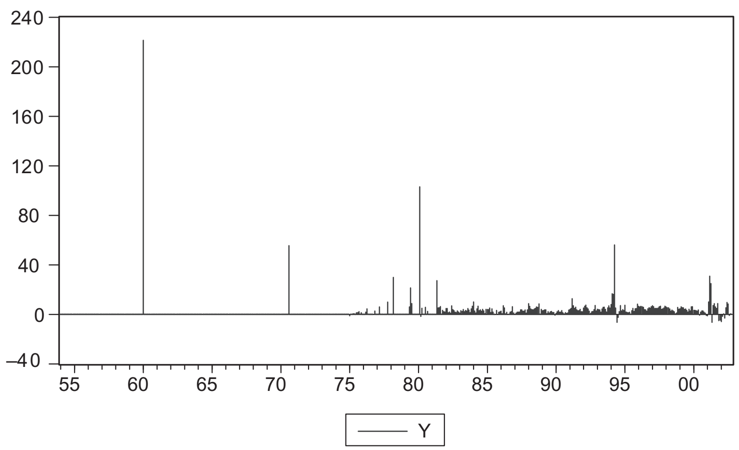

Figure 1. Monthly percentage change in Turkish lira/US dollar exchange rate, January 1954-October 2002.

Table 1. Estimates of regime-switching model (with constant switching probabilities), January 1954-October 2002.

	Coefficient	Standard error	z-statistic	Probability
MEAN0(1)	−0.000120	10.68729	-1.12×10^{-5}	1.0000
MEAN1(1)	6.164345	4.828647	1.276620	0.2017
SIG0(1)	0.014905	0.085766	0.173786	0.8620
SIG1(1)	21.89290	0.558329	39.21148	0.0000
TVP0B(1)	1.158114	0.172665	6.707286	0.0000
TVP1B(1)	1.911662	0.118379	16.14872	0.0000
Log likelihood	−350.1419	Akaike info criterion		1.215501
Avg. log likelihood	−0.597512	Schwarz criterion		1.260279
Number of coefficients	6	Hannan–Quinn criterion		1.232951

LogL: MODEL54M; method: Maximum Likelihood (Marquardt); sample: 1954:01 2002:10; included observations: 586

Table 2. Estimates of regime-switching model with real exchange rate as the exogenous variable, February 1964-August 2002.

	Coefficient	Standard error	z-statistic	Probability
MEAN0(1)	0.000218	11.62642	1.87×10^{-5}	1.0000
MEAN1(1)	4.358464	1.436562	3.033955	0.0024
SIG0(1)	0.015222	0.166224	0.091577	0.9270
SIG1(1)	10.06054	0.195689	51.41079	0.0000
TVP0B(1)	1.239752	0.205544	6.031550	0.0000
TVP0B(2)	0.701410	0.133946	5.236520	0.0000
TVP1B(1)	1.982477	0.187377	10.58013	0.0000
TVP1B(2)	−0.096901	0.065122	−1.487979	0.1368
Log likelihood	−500.6647	Akaike info criterion		2.197256
Avg. log likelihood	−1.081349	Schwarz criterion		2.268750
Number of coefficients	8	Hannan–Quinn criterion		2.225401

LogL: MODEL64MWITHX25; method: Maximum Likelihood (Marquardt); sample: 1964:02 2002:08; included observations: 463

The monthly model is also estimated using the real exchange rate (table 2). The model is estimated using 463 observations, February 1964 to August 2002, because of data constraints. This model slightly improves the performance of the model with constant transition probabilities. As in the first model, the mean and standard deviation for state 1 (vulnerable period) are higher than the mean and standard deviation for state 0 (normal period). The constant term for state 0 is 1.23 and 1.98 for state 1. These are denoted as TVP0B(1) and TVP1B1(1) in the table. Coefficients associated with the real exchange rate variable are 0.70 for state 0 and negative 0.097 for state 1. These are denoted as TVP0B(2) and TVP1B1(2) in the table. The probability of being in state 1 (financial vulnerable) decreases as the real exchange rate increases. On the other hand, the probability of being in state 0 (normal period) increases as the real exchange rate increases. The model is quite satisfactory in predicting devaluations of 1971 and 1980, but suffers from the same problem as the first model. There were major institutional changes in 1980 and a model which is built for the

Table 3. Estimates of regime-switching model (with constant switching probabilities) February 1981-July 2002.

	Coefficient	Standard error	*z*-statistic	Probability
MEAN0(1)	3.536336	0.133818	26.42639	0.0000
MEAN1(1)	7.681670	4.240834	1.811358	0.0701
SIG0(1)	2.065826	0.107911	19.14382	0.0000
SIG1(1)	12.98069	1.581044	8.210201	0.0000
TVP0B(1)	2.087203	0.251927	8.284948	0.0000
TVP1B(1)	1.253090	0.355361	3.526243	0.0004
Log likelihood	−631.0845	Akaike info criterion		4.938639
Avg. log likelihood	−2.446064	Schwarz criterion		5.021266
Number of coefficients	6	Hannan–Quinn criterion		4.971864

LogL: MODEL; method: Maximum Likelihood (Marquardt); sample: 1981:02 2002:07; included observations: 258; evaluation order: by observation; convergence achieved after 85 iterations.

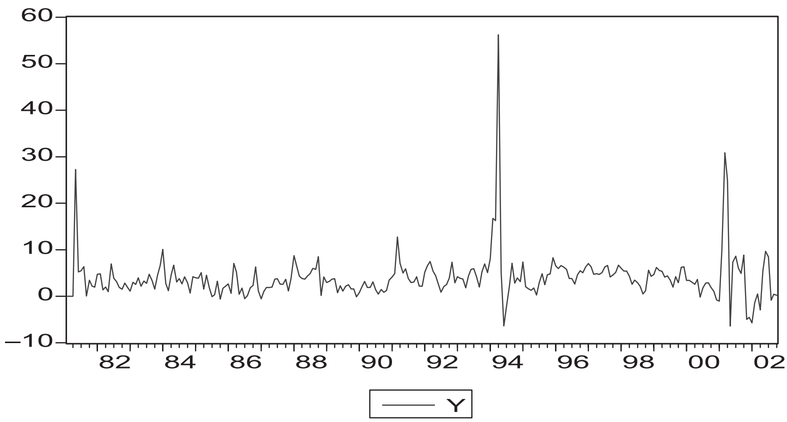

Figure 2. Monthly percentage change in Turkish lira/US dollar exchange rate, February 1981-October 2002.

entire period, which does not incorporate that structural change, may fail to perform well for the entire period.

The model with constant transition probabilities is also estimated for the post-1980 period (table 3). During this period there were four out of 256 percent changes which were greater than 20% (figure 2). About 90% of changes were between 0 and 10. There were 12 months when the exchange rate decreased. During the February 1981-July 2002 period, the mean was 4 and the standard deviation was 5. The mean was 3.53 for the normal period (state 0) and 7.68 for the period of vulnerability (state 1) (table 3). Standard deviations were 2.06 and 12.98 for state 0 and sate 1, respectively. Coefficients were 2.08 and 1.25 for state 0 and state 1, respectively.

The model is estimated with the percentage change in foreign reserves as the exogenous variable (table 4). This model correctly predicts the crises of 1994 and 2001, but it also signals a crisis in some months of 2002. The model is

Table 4. Estimates of regime-switching model (with percentage changes in foreign reserves as the exogenous variable) February 1981-July 2002.

	Coefficient	Standard error	z-statistic	Probability
MEAN0(1)	3.473569	0.141761	24.50300	0.0000
MEAN1(1)	8.103967	4.191058	1.933633	0.0532
SIG0(1)	2.096020	0.120067	17.45702	0.0000
SIG1(1)	12.74170	1.519934	8.383065	0.0000
TVP0B(1)	2.579521	1.119635	2.303896	0.0212
TVP0B(2)	0.135200	0.113194	1.194416	0.2323
TVP1B(1)	1.635250	1.010305	1.618570	0.1055
TVP1B(2)	−0.125968	0.170814	−0.737456	0.4608
Log likelihood	−627.7977	Akaike info criterion		4.928664
Avg. log likelihood	−2.433324	Schwarz criterion		5.038833
Number of coefficients	8	Hannan–Quinn criterion		4.972964

LogL: MODEL81MWITHX26; method: Maximum Likelihood (Marquardt); sample: 1981:02 2002:07; included observations: 258; convergence achieved after 88 iterations.

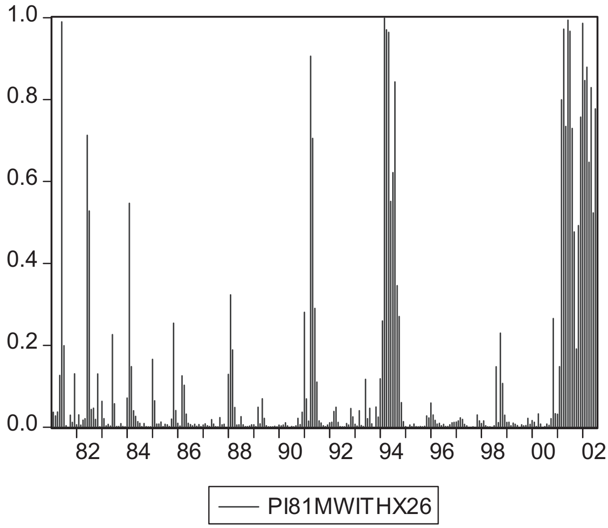

Figure 3. Probability of financial vulnerability based on a regime-switching model (with percentage changes in foreign reserves as the exogenous variable), February 1981-July 2002 ($\Pr(S_{t+1}=1|(I_t))$).

also very useful in pointing to financial difficulties in mid-1981 and mid-1982 (figure 3).

4.2. *Empirical results based on a weekly model*

Financial crises have a big amplitude but a very short duration. A crisis may typically last for a day or two, although it may have long lasting effects. This feature itself necessitates the use of high-frequency data, daily or weekly. Another advantage of weekly data is an increase in the number of observations which is very important in any statistical analysis. Most of the financial variables are available on a weekly or even on a daily basis. There are, however, some limitations in using weekly data. It should be noted that real variables, such as industrial production or prices, are unavailable on a weekly basis. The other limitation is the shortness of the lead time. Policy makers will know about the extent of vulnerability in the following week, which may not give them enough time to respond. With these advantages and limitations, in this section weekly data are used to determine periods of financial vulnerability. This model is the first of its kind.

The model is estimated using 667 observations, data from the week of January 12, 1990 to the week of October 18, 2002 (figure 4, table 5). The mean for state 0 (the tranquil period—normal period) is 0.848, while the mean for state 1 (the crisis period—vulnerable) is 1.89. The standard deviation for the tranquil period is 0.729, while the standard deviation for state 1 is 5.872. The volatility is much higher in state 1 compared with state 0. These two states are distinguished by their means and standard deviations. The coefficient for state 0 is 2.05 and the coefficient for state 1 is 1.24. As it is clear from high

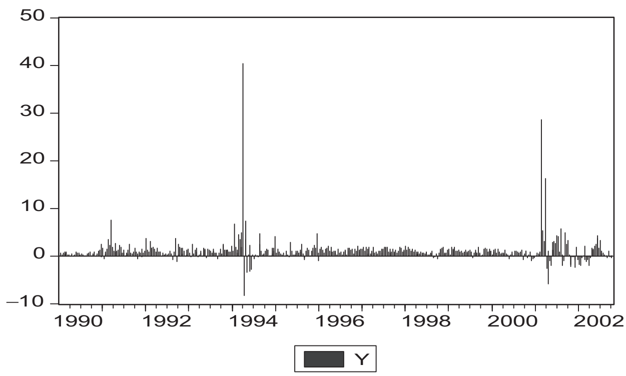

Figure 4. Weekly percentage change in Turkish lira/US dollar exchange rate, 12 January 1990-18 October 2002.

Table 5. Estimates of regime-switching model (with constant switching probabilities) 12 January 1990-18 October 2002.

	Coefficient	Standard error	z-Statistic	Probability
MEAN0(1)	0.848557	0.031512	26.92834	0.0000
MEAN1(1)	1.890051	0.920210	2.053935	0.0400
SIG0(1)	0.728655	0.022661	32.15425	0.0000
SIG1(1)	5.872782	0.203057	28.92182	0.0000
TVP0B(1)	2.054357	0.132621	15.49041	0.0000
TVP0B(2)	1.241961	0.159084	7.806929	0.0000
Log likelihood	−1022.798	Akaike info criterion		3.084851
Avg. log likelihood	−1.533430	Schwarz criterion		3.125356
Number of coefficients	6	Hannan–Quinn criterion		3.100544

LogL: MODEL; method: Maximum Likelihood (Marquardt); sample: 1/12/1990 10/18/2002; included observations: 667; convergence achieved after 118 iterations.

Table 6. Estimates of regime-switching model (with percentage changes in foreign reserves and changes in domestic credit/deposit ratio as exogenous variables) 12 January 1990-18 October 2002.

	Coefficient	Standard error	z-Statistic	Probability
MEAN0(1)	0.843	0.030	27.643	0.000
MEAN1(1)	1.856	0.886	2.095	0.036
SIG0(1)	0.714	0.021	33.241	0.000
SIG1(1)	5.687	0.183	31.126	0.000
TVP0B(1)	2.717	0.292	9.299	0.000
TVP0B(2)	0.251	0.053	4.757	0.000
TVP0B(3)	−13.657	6.494	−2.103	0.035
TVP1B(1)	1.607	0.239	6.738	0.000
TVP1B(2)	−0.082	0.049	−1.657	0.098
TVP1B(3)	−23.985	11.904	−2.015	0.044
Log likelihood	−1231.703	Akaike info criterion		3.723
Avg. log likelihood	−1.847	Schwarz criterion		3.791
Number of coefficients	10.000	Hannan–Quinn criterion		3.749

LogL: MODELX1X4; method: Maximum Likelihood (Marquardt); included observations: 667; convergence achieved after 100 iterations.

z-statistics (or low probability values associated with z-values), all parameters are significant at the one percent level.

The model with percentage changes in foreign reserves and changes in domestic credit deposit ratio as exogenous variables is quite satisfactory (table 6). The mean for state 0 is 0.84 and the mean for state 1 is 1.85. The standard deviations are 0.71 and 5.68 for state 0 and state 1, respectively. All coefficients are statistically significant at 10%, most of them at 1%. The coefficients associated with 1 (the constant term), foreign reserves and domestic credit are 2.71, 0.251 and negative 13.657 when the economy is in state 0 (normal period). Corresponding coefficients are 1.60, negative 0.082 and negative 23.985 when the economy is in state 1 (financial vulnerability). This model is quite successful in predicting various crises episodes. These can be seen from estimated probabilities given in table 7 and figure 5.

5. Conclusions

The experiments with monthly and weekly models indicate that real exchange rate, foreign exchange reserves and domestic credit/deposit ratio are the most important determinants of financial vulnerability. These variables should be observed very closely by researchers and policy makers in order to determine if the country is heading for financially difficult times.

Since modeling of financial crises is still evolving, the ability to predict is somewhat constrained. Thus, financial panics may be expected to occur at unpredictable times. This implies that it is important for countries and other economic agents such as multinational organizations to set aside 'insurance' reserves against such a contingency. In light of the fact that there are unforeseen financial and social costs attached to financial crises, it is important to have adequate social safety nets to cushion the impact from such an eventuality.

Table 7. Estimated probabilities and the 1994, 2000 and 2001 crises.

Date	Probability
1/07/94	0.41
1/14/94	0.25
1/21/94	0.04
1/28/94	0.26
2/04/94	0.90
2/11/94	0.99
2/18/94	0.94
2/25/94	0.65
3/04/94	0.07
3/11/94	0.84
3/18/94	1.00
3/25/94	1.00
4/01/94	0.64
4/08/94	0.55
4/15/94	0.97
4/22/94	1.00
4/29/94	0.99
5/06/94	1.00
5/13/94	1.00
5/20/94	1.00
5/27/94	0.97
6/03/94	0.84
6/10/94	0.96
6/17/94	0.96
6/24/94	0.98
7/01/94	0.00
7/08/94	0.00
7/15/94	0.00
7/22/94	0.00
7/29/94	0.00
11/03/00	0.01
11/10/00	0.04
11/17/00	0.02
11/24/00	0.47
12/01/00	0.56
12/08/00	0.25
12/15/00	0.61
12/22/00	0.19
12/29/00	0.21
1/05/01	0.00
1/12/01	0.00
1/19/01	0.01
1/26/01	0.01
2/02/01	0.00
2/09/01	0.00
2/16/01	0.00
2/23/01	0.97
3/02/01	1.00
3/09/01	0.92
3/16/01	0.98
3/23/01	0.99
3/30/01	0.98
4/06/01	0.52
4/13/01	0.96
4/20/01	0.99
4/27/01	0.90
5/04/01	0.52
5/11/01	0.96
5/18/01	0.75
5/25/01	0.64

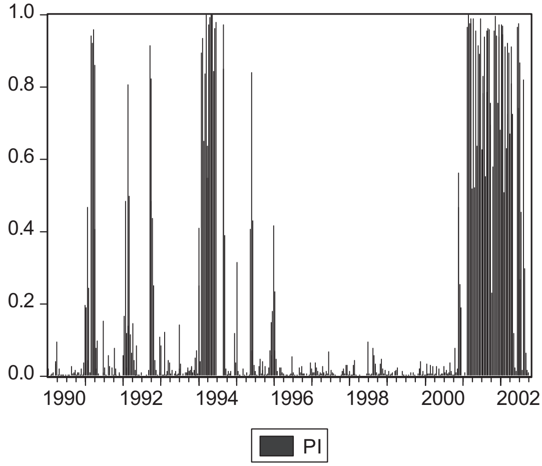

Figure 5. Probability of financial vulnerability based on a regime-switching model (with percentage changes in foreign reserves and changes in domestic credit/deposit ratio as exogenous variables), 12 January 1990-18 October 2002 ($\Pr(S_{t+1}=1|I_t)$).

What conclusions can be drawn from the Turkish post-capital account liberalization experience? Turkey did not benefit fully from capital account openness. In retrospect, the capital account liberalization could be considered as 'premature' in nature since political stability, transparency of the state and the development of key institutions were absent prior to the capital account openness. The political instability led to inefficient use of the capital inflow and, combined with fiscal expansion, did not lead to the desired outcome of lower domestic real cost of capital. Political turmoil led to frequent capital reversals, which led to financial crises and/or increases in the debt/GNP ratio. As a result of these crises and the possibility of a future crisis, Turkey is now finally taking the necessary measures to achieve fiscal transparency and strong accountability of the state.

However, one should also note that, in a democracy such as Turkey, the fiscal authority will be tempted to open up the capital accounts prematurely, since there is a short- to medium-term political bonus from opening up. The inflow of foreign capital and the availability of a cheaper source of finance will be used for additional fiscal spending, reducing the crowding-out effect and increasing employment, providing support of the electorate. In a democracy, then, capital account liberalization is a fact of life.

Should there be full capital controls? The answer is probably no. Capital controls may insulate economies and erode the incentive to reform. After all, there is no guarantee that fiscal transparency and a strong accountable state can be achieved in a closed capital market economy. The policy prescription here is that there should be sequenced capital account liberalization so that long-term flows (such as foreign direct investment and terms loans) are favored over short-term loans. As the Turkish case shows, until banking and financial sectors are strengthened, until fiscal prudence and political stability are achieved, volatile short-term capital controls will not be beneficial. On the other hand, capital controls may be successful if these conditions are satisfied or if they are implemented for a pre-specified period (Rodrik, 2001).

Acknowledgments

The authors thank the Editor and the Board of *Review of Middle East Economics and Finance*, Professor Mine Cinar and an anonymous referee for comments and improving presentation. A larger and expanded version of this study was supported by the Economic Research Forum (ERF), for which the authors are very grateful. Earlier versions of the paper were presented at ERF's Annual Meeting in Cairo 1999, Project LINK Fall Meeting in Athens, 1999, Middle East Economic Association Annual Meetings in Boston, 2000, University of Pennsylvania Wharton School, 2001, and Singapore Management University, 2002. The authors thank organizers and participants of these meetings.

Notes

1. See, among others, Aricanli and Rodrik (1990), Rodrik (1991), Önis and Riedel (1993), Cecen *et al.* (1994), IMF (1998c, 2002), Metin-Ozcan *et al.* (2001), Boratav *et al.* (2000), Cizre-Sakallioglu and Yeldan (2000), Owen and Pamuk (2000), Alper (2001), Boratav and Yeldan (2001), Dibooglu and Kibritcioglu (2001), Ertugrul and Selcuk (2001) and Alper and Onis (2003)
2. See also Harvey (1987, 1989), Kim and Nelson (1999). State–space models and the Kalman filter are introduced by Kalman (1960, 1963) and Kalman and Bucy (1961). See Quandt (1958, 1960, 1972) and Goldfeld and Quandt (1973) for early efforts on switching regressions.
3. See Ersel (1996, 1999), Özatay (1996, 1998), Celasun (1998), Mariano *et al.* (2000, 2002) and Alper (2001).

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Appendix: Indicators

The indicators used in building the time-varying Markov switching model are given below in eight groups. (Data are obtained from the State Institute of Statistics and Central Bank of Turkey; international data are obtained from IMF):

1. Output and prices
   Industrial production index (%change)
   GNP growth rate
   Inflation rate (%change in consumer price index)
   Inflation rate (%change in wholesale price index)
   Real wage rate in manufacturing (%change)
   Share of wages in national income (%change)
2. Real effective exchange rate
   Trade-weighted real effective exchange rate (based on consumer price indexes) (%change)
   Trade-weighted real effective exchange rate (based on wholesale price indexes) (%change)
   Real effective exchange rate (based on consumer price indexes in the USA and Turkey) (%change)
3. Exports, imports and terms of trade
   Total merchandise exports (%change)
   Total merchandise imports (%change)
   Export import ratio (total merchandise exports/total merchandise imports) (change)
   Import prices (%change)
   Export prices (%change)
   Terms of trade (export price index/import price index) (%change)
4. Balance of payments and foreign exchange reserves
   Foreign exchange reserves (%change)
   Share of balance of goods and services in GDP (change)
   Real value of balance of goods and services (%change)
   Real value of capital flows (%change)
5. Money and credit
   Real value of domestic credit (%change)
   Income velocity of circulation (based on M2) (change)
   Real value of the net foreign assets of the financial system (%change)

Money multiplier $(1 + c/d)/(r/d + c/d)$, where c is currency, d is deposits and r is reserves
Money supply(M2)/foreign exchange reserves (change)
Foreign currency deposits/M2Y (change)
Foreign currency deposits/total assets of the financial system (change)

6. Interest rates and equity prices
   Istanbul Stock Exchange National Index (%change)
   Real interest on 12-month deposit (change)
   3 month deposit rate – 3-month US Treasury bill rate (change)
   Cost of borrowing, $(r/(1–L))$, where r is the deposit rate, L is the required reserve ratio (change)
7. Government budget
   Share of consolidated budget balance in GDP (change)
   Share of consolidated primary, excluding interest, budget balance in GDP (change)
   Total consolidated budget revenue/total consolidated budget expenditures (change)
   Total consolidated budget interest expenditures/total consolidated budget expenditures (change)
8. Domestic and foreign debt
   Domestic debt outstanding/GDP ratio (change)
   External debt outstanding/GDP ratio (change)
   Short-term external debt/total external debt (change)
   External debt of the public sector/total external debt (change)
   Total debt (domestic + foreign)/GDP ratio (change)