Karmann, Alexander; Maltritz, Dominik

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Evaluating Sovereign Ability-to-Pay and Probability of Default

ALEXANDER KARMANN

DOMINIK MALTRITZ

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Address of the author(s):

Alexander Karmann
Technische Universität Dresden
Münchner Platz 3
01062 Dresden
Deutschland

e-mail : Alexander.Karmann@mailbox.tu-dresden.de

Dominik Maltritz
Technische Universität Dresden
Münchner Platz 3
01062 Dresden
Deutschland

e-mail : Dominik.Maltritz@mailbox.tu-dresden.de

Editors:

Faculty of Business Management and Economics, Department of Economics

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Working paper coordinators:

Michael Berlemann
Oliver Greßmann
e-mail: wpeconomics@mailbox.tu-dresden.de

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Sovereign Risk in a Structural Approach
Evaluating Sovereign Ability-to-Pay and Probability of Default

Alexander Karmann
Technische Universität Dresden
Fakultät für Wirtschaftswissenschaften
01062 Dresden
Alexander.Karmann@mailbox.tu-dresden.de

Dominik Maltritz
Technische Universität Dresden
Fakultät für Wirtschaftswissenschaften
01062 Dresden
Dominik.Maltritz@mailbox.tu-dresden.de

Abstract:

We quantify the probability that a sovereign defaults on repayment obligations in foreign currency. Adopting the structural approach as first introduced by Merton, we consider the sovereigns ability-to-pay, characterised by the sum of discounted future payment surpluses, as the underlying process. Its implicit volatility is inferred from market spreads. We demonstrate for the case of Latin America and Russia that our approach indicates default events well in advance of agencies and markets.

JEL-Classification: F 34

Keywords: Sovereign Risk, Probability of Default

1 Introduction

In this paper, we present a model to analyse sovereign risk. Sovereign risk is defined as the risk that the sovereign declares to be unable to fulfil its repayment obligations in a foreign currency which leads to the sovereign's default on liabilities in foreign currency. The model is based on the structural approach to evaluate corporate risk, an approach which dates back to MERTON(1974). We will present an adaptation of the Merton model for determining a sovereign's probability of default, PoD.

A default results if the sovereign's ability-to-pay is smaller than the value of the repayment requirements in foreign currency. Thereby, the ability-to-pay is understood as a stochastic variable which follows an Ito process. We assume that the value of repayment obligations at some future time T is publicly known. Then, for any time t prior to T, one can estimate the PoD at T if the parameters of the Ito process as well as of the sovereign's ability-to-pay at time t, A_t, are known.

Modelling a sovereign's ability-to-pay is a challenging task. The approach proposed here relies on what is taken as value of the firm within the theory of the firm. Though there is no directly observable market value of a country available, we can adopt the idea of discounted future net incomes which limit the firm's - here: the sovereign's - capacity to borrow from others. Hence, we will define a sovereign's ability-to-pay to consist of the amount of actual forex reserves and of its potential to attract capital. ¿From economic reasoning, we know that the volume of potential net capital imports today is limited by the volume of discounted future payment surpluses. Estimating these surpluses by a simple time-series approach, we finally derive the levels as well as the drift of the respective ability-to-pay process.

The process' implicit volatility will be inferred from the price spreads in the bond market being interpreted as a risk premium. To do so we adopt the standard Black and Scholes framework. Based on these parameter estimates, it is a straightforward exercise to calculate the sovereign's PoD.

The paper is organized as follows. In section 2, we modify the structural approach, originally designed to valuate corporate liabilities, to capture the risk of sovereign default. We close with a brief overview over related literature based on option pricing models of sovereign risk. Section 3 deals with the empirical application to calculate PoDs. We demonstrate the steps involved for the case of Argentina 1994 - 2002 and discuss the relationship between input data and PoDs. We extend our investigation to selected countries in Latin America and to Russia. Adopting simple evaluation criteria, we conclude that our model indicates default events well in advance, even when compared to market signals and rating changes.

2 A structural approach to sovereign risk

2.1 The structural approach to corporate risk

The structural approach to valuate corporate liabilities relies on the Merton model as the fundamental contribution to this strand of literature. The approach of Merton (1974) is inspired by the seminal paper on option pricing by Black and Scholes (1973).

For the case of a stock option the following assumptions are made:

a) The short term interest rate is known and constant over time.

b) The stock price follows an Ito process. Hence, the distribution of the stock prices is log-normal, the distribution of the returns is normal.

c) There are no dividends.

d) There are no transaction costs.

e) Borrowing any fraction of the underlying is possible, at the short term interest rate.

f) There are no penalties to short selling.

g) The stock option can be exercised at maturity, only.

Black and Scholes (1973, p. 641) argue that for a (delta-) hedged portfolio containing a long position in a stock and a short position in the related call option, the drift rate equals the riskless interest rate, otherwise arbitrage possibilities would result. This argument allows to derive a valuation formula for European stock options.

Merton (1974) shows that this option pricing formula can be used to valuate corporate liabilities as being contingent claims on the value of the firm. The value of the firm represents the underlying of the option contract while the value of the repayment obligations is the strike price. Adopting the assumptions of the Black Scholes model to the topic of corporate liabilities allows to derive valuation formulas for both equity as well as liabilities. The value of the equity is just the value of the call option on the firm's value. The value of the liabilities equals the value of a portfolio in the hand of the creditor consisting of the firm's value and a call option which is short sold.

Empirical applications of the Merton model are described e.g. in Saunders (1999, p. 19 - 37) who also provides an outline of the KMV-Credit-Monitor model well known among practitioners in the financial sector. Another application is given by Delianedis and Geske (1998). Within this type of models, the empirical estimation of the firm's equity and its returns is derived from the market prices of the stock. The volatility of the firm's equity is estimated by historical data on the firm's equity. Solving a system of stochastic differential equations finally leads to the value of the firm and to its volatility. Thus, the value of the liabilities and the probability of default of the firm are determined.

2.2 Adapting the approach to sovereign risk

2.2.1 Macro fundamentals and the ability-to-pay

Sovereign risk is a complex issue not only because of missing 'market' data for a country's net wealth, corresponding to the firm's equity capital, but also because of aggregating economic (solvency, liquidity), institutional (market integration, cooperative enforcement) and political (willingness-to-pay, credibility) aspects (Cantor and Packer 1996). In general terms, it is the repayment prospect (Fischer 1999) of outstanding claims which drives the market perception of sovereign default. In our context, we disregard from 'unwillingness-to-pay', an issue broadly discussed in the 1980ies but believed to be of shrinking relevance due to the increasing integration of individual sovereigns into the world economy (Rogoff 1999, p. 31). Instead, we focus on the sovereign's ability-to-pay at time t, A_t. Thereby, the ability-to-pay is the maximum amount of foreign currency, say US Dollar, the sovereign is able to dispose in order to meet his repayment obligations from borrowing in foreign currency. A_t is composed of already existing forex holdings, FX_t, and the country's potential to attract capital imports, KI_t. From an economic point of view, KI_t will be limited by the sum of discounted future payment surpluses ('net cash flows')NX_t from exports X_t minus imports I_t. We operationalize NX_t by a simple autoregressive process and set KI as the corresponding steady-state capital flow NX^* discounted by an appropriate interest rate ρ^{risk} reflecting the market participants' risk premium in lending to the sovereign. We approximate the risk adjusted discount factor by selecting a sovereign bond of high liquidity and set ρ^{risk} equal to the bond's effective interest rate r_t^{risk} at time t. Formally:

Assumption 1: The sovereign's ability-to-pay A_t is given by

$$A_t = FX_t + KI_t^* \tag{1}$$

where FX_t are the country's foreign exchange reserves and KI_t^* are the potential capital imports equating discounted future income out of net exports NX^*,

$$KI_t^* = \frac{NX^*}{r_t^{risk}}; \tag{2}$$

thereby, NX^* is the steady-state value of the net exports $NX_t := X_t - I_t$ which follow an $AR(1)$ process

$$NX_t = c_0 + c_1 NX_{t-1} \tag{3}$$

and the discount rate r_t^{risk} is the effective interest rate of some highly liquid sovereign bond.

Our procedure to operationalize potential capital import is merely some first-hand approximation for which other alternatives can be formulated. In practitioners' applications, private knowledge may become an important tool to valuate the potential of capital imports. Primarily, capital inflows are provided by investors who outweigh the country's future exports. In addition to these economically based capital inflows, the potential of international aid based on political reasoning may also be taken into account.

We proceed in describing the sovereign's debt structure and the repayment perspectives for a sovereign bond traded in secondary markets to mature at time T. As the decision to default or not hinges on the principle rather than on the coupon payments, we concentrate on zero bonds only. It is often argued that seniorities are involved in serving repayment obligations. Therefore, we assume default to occur if the sum of repayment obligations till time T with priority higher or equal to the sovereign bond considered exceeds the sovereign's ability-to-pay. Or,

Assumption 2. There will be no repayments prior to T. The total amount K of (net) repayment obligations (in international currency) at T with priority higher or equal to the sovereign zero-bond maturing at T is publicly observable. The sovereign will default when holds

$$A_t < K. \tag{4}$$

Relaxing assumption 2 of a single maturity and modelling the debt structure in more detail leads to more complex 'compound' options, as described in Geske (1977). There, for each maturity date, an option contract is specified whose strike price equals the respective repayment obligations. Alternatively, the duration of the liabilities can be taken as a proxy (see Clark (1991, pp. 89) or Delianedis and Geske (1998)). As in general there is no public information on the debt structure, both generalizations would need private information to be implemented.

2.2.2 Market spreads and PoDs

There are two ways to explain the spread between the price of a risky and a default-free bond. The cost-oriented approach explains the spread as equal to the total costs for holding the risky bond. These costs include a risk premium to account for default (see Edwards (1984) for an early approach). The arbitrage-based approach explains the spread as the implicit price of an insurance against default. This approach can be used after clarification of the economic content of the sovereign's ability-to-pay A_t. According to the Black Scholes mechanism, we characterize the process (A_t) as follows:

Assumption 3: The ability-to-pay process (A_t) is given by

$$dA_t = \mu A_t dt + \sigma A_t dW_t \tag{5}$$

where μ and σ are constant and W is Brownian motion.

To derive a parameter estimation of the process' drift μ we first estimate the expected continuously compounded rate $\mu^* = \mu - \sigma^2/2$ as follows.

Assumption 4: An estimation of μ^* is given by the log differences of (A_t) as

$$\hat{\mu^*} = logA - logA_{-1} \tag{6}$$

where A is the latest available data for the sovereign's ability-to-pay and A_{-1} is its realization lagged by one year.

To infer for σ, we again invoke the Black Scholes mechanism and assume the existence of a risky and a secure bond with otherwise identical characteristics, more precisely

Assumption 5: There are two types of zero bonds of identical maturity T and identical face value B_t. Both are denominated in one international currency, say US Dollar: risky bonds $B_{t,T}^{risk}$, issued by a foreign sovereign or sovereign institution; and a default-free bond $B_{t,T}^{sec}$, say US-T bonds, with interest rate r.

Non-arbitrage arguments immediately characterize the price a bondholder is willing to pay for an insurance against default. Let us assume that there are no further repayment obligations, i.e. $K = B_T$. In this case, an international investor who holds the entire stock of risky bonds would be willing to pay an insurance against default at a price P which does not exceed the difference $B^{sec} - B^{risk}$ in stock values.

The value of such an insurance equals the value of a hypothetical put option on the sovereign's ability-to-pay where the volume of repayment requirements is the strike price. This holds because the insurance and the put option both have the same pay-off structure. Thereby, we assume that in case of default the sovereign repays as much as he is able to do. In case of non-default, there is no payment from the insurance. In case of default, given our assumption, the insurance pays the difference $K - A_T$ between the repayment requirements and the ability-to-pay at maturity time T. This contingent pay-off structure is identical to the pay-off function of the put. Putting all together, we interpret the price spread between the secure bond and the risky bond as the value of the hypothetical put option introduced above.

Furthermore, if there are other repayment obligations of at least the same priority involved, the bondholders hold only a fraction $\alpha = B_T/K$ of the relevant claims, and the difference in stock values reflects only the part αP of total insurance against the sovereign default or

Assumption 6: Non-arbitrage between holding risky and secure bonds holds. Hence, the price $P_{t,T}$ of a (European) put option to sell the total volume of risky claims with face value K at T is given as follows: let $\alpha := B_T/K$ then

$$B_{t,T}^{sec} = B_{t,T}^{risk} + \alpha P_{t,T}. \tag{7}$$

In practical applications, starting with the price spread per unit of share, expressed as percentage points of the international currency unit, say $b^{sec}_{t,T} - b^{risk}_{t,T}$, these percentage points have to multiplied by the total volume K of repayment obligations to get the option price $P_{t,T}$.

Observing bond spreads in secondary markets and calculating the option price $P_{t,T}$ according to total repayment obligations K, we can use the Black Scholes put price formula

$$P_{t,T} = Kexp(-r(T-t))N(-d_2) - A_t N(-d_1) \tag{8}$$

where

$$d_1 = \frac{ln(A_t/K) + (r + \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}$$

and

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

to solve for σ as the market's implicit volatility of the log returns of the ability-to-pay process, by inserting the other input data t, T, r and A_t. Given estimates $\hat{\mu^*}$ and $\hat{\sigma}$ we finally get an estimate of the drift μ to be $\hat{\mu^*} + \hat{\sigma}^2/2$.

Having identified the parameters μ and σ, the probability of default can be calculated straight forward, using assumption 3, as

$$\begin{aligned} PoD &= P(A_T < K | A_t = A) \\ &= N_{0,1}\left(\frac{ln(K/A) - (\mu - \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}\right). \end{aligned} \tag{9}$$

Equation (9) represents a fundamental as well as market based quantification of sovereign risk which is based on fundamental data and on market information.

2.3 Related literature on sovereign risk

We briefly review some contributions to sovereign risk which also rely on the structural approach. There are three main differences among models covering sovereign risk. First, one has to specify the type of option ('put' or 'call') and the specific option pricing formula used. Second, the underlying has to be determined empirically. This, of course, is the most challenging part in any application and may be based on aspects like e.g. the capital stock of a national economy or the solvency coefficient. Third, the process' characteristics have to be estimated. Especially, volatility estimates can be derived either by using the past realizations of the underlying process or, as implicit volatility, by using the market spreads.

One of the earlier, and remarkably elaborate, contributions is Clark(1991). The focus is in valuating an European call which represents the 'market value of the residents' equity'. Thereby, the underlying is the 'market value of a national economy', V, which is defined as the cash flows of future net exports NX discounted at the economy's rate of return r. Forex reserves and their role are neglected thereby. To estimate r, and finally V, the recursive equation: $\Delta V + NX = rV$ is regressed by rewriting the r.h.s. to consists of a constant (steady-state) return c out of pre-sample period capital stock and of a return rV' out of new capital stock V'. Next, the economy's annual rates of return are calculated as $(\Delta V + NX)/V$ (Clark, 1991, p. 80-81). This is somewhat inconsistent with the process' characteristics implying annual rates of $ln(V/V_{-1})$ (see assumption 3 above). Finally, the volatility is estimated by taking the standard deviation of the annual rate-of-return time series. As an alternative volatility estimate, Clark (1991, p. 101-102) uses the implicit volatility, similarly to our approach. To get somewhat consistent volatility values, he calibrates the model by using different collateralisation levels transforming into different strike prices for the economy.

Klein (1991) and Lichtlen (1997) both adopt a put approach to price new credits or to valuate the fair risk premium for already existing loans. Without employing an empirical application, Klein (1991) proposed a logit approach to estimate the relationship between solvency ratios and fundamentals in order to forecast solvency ratios for new market entrants; thereby, the solvency ratio is the ability-to-pay divided by the repayment requirements. He suggests to approximate the volatility of the underlying by the standard deviation of the bond prices, an assumption which of course does not completely conform with the referred framework. Lichtlen (1997) uses rescheduling events, as documented in the World Bank's 'World Debt Tables'/ resp. 'Global Development Finance', to estimate a logit model of rescheduling probabilities and its macroeconomic determinants. For any tentative σ-value, the put option pricing formula allows to infer from estimated rescheduling resp. default probabilities to the respective solvency ratios. As the overall appropriate volatility value LICHTLEN (1991, p. 167) finally choses the one which minimizes on average the distance of volatility and the standard deviation of the respective solvency ratios.

CLAESSENS and WIJNBERGEN (1993) use a put option formula to price outstanding debt and apply their approach to the question whether Mexico or the international lending community did win from a Brady bond deal. Their 'net amount of financing to serve foreign debt' consists of three elements: expected non-oil current account; adjustments to serve senior debt, FDI and reserve accumulation; and expected oil earnings (CLAESSENS and WIJNBERGEN (1993, p. 971)). They approximate the volatility as the standard deviation of the forward prices for oil.

KARMANN and PLATE (2000) differ from our approach mainly in the definition of the underlying as forex reserves available to the debtor nation which consist of actual reserves and the amount of net exports expected till the expiration date (one year ahead). In another recent contribution, LEERBASS (1999) bases his notion of the underlying on a stock index of the national economy, arguing that this would closely reflect discounted future

GDP and thereby the economy's ability-to-pay.

3 Evaluating the model

3.1 Input data generation

In our model, some data are available on an annual base, like forex reserves or repayment requirements, others are given on a daily base, like bond prices or interest rates (all data are taken from Data Stream ; the sample period is begin of 1980 till end of January 2002). This comination deserves some closer description on the generation of the ability-to-pay values.

For each year t^y, the respective steady-state forecast NX^* of net exports will be estimated by regressing equation (3) with monthly data for exports X and imports I for the sample period 1980.1 till end of the year $t^y - 1$. Using the coefficient estimates $\hat{c}_0$ and $\hat{c}_1$ we get

$$NX^* \equiv \hat{c}_0/(1 - \hat{c}_1) \qquad (3')$$

as the steady-state forecast for the year t^y.

For any day $t^d(t^y)$ of the particular year t^y we valuate the PoDs for exactly one year ahead. Implicitly, this asks for considering risky and secure bonds maturing at day $t^d(t^y + 1)$ and their spread. But, typically there are few, or just one, risky bonds issued by the sovereign. We therefore meet the assumption that the term structure of the risk premium is flat. The option value $P_{t^d(t^y),t^d(t^y+1)}$ is now given by the relation

$$\alpha P_{t^d(t^y),t^d(t^y+1)} = exp \quad (-ln(1 + r^{sec}_{t^d(t^y),t^d(t^y+1)}) - \qquad (10)$$
$$exp \quad (-ln(1 + r^{risk}_{t^d(t^y),t^d(t^y+1)})).$$

3.2 Evaluation criteria

Evaluating the performance of a method proposed to quantify risk needs a set of explicitely defined criteria and standards, as the Mathieson and Schinasi (1999, Annex V, p. 192) point out. A straight forward condition is that the approach taken has to clearly indicate default events by signalling them well in advance. The second criterion is the performance of the approach in comparison to markets and agencies. I.e. we have to relate our results on PoDs with the movement of market spreads and with changes of ratings from agencies, like S&P's or Moody's, or from market analysts, as represented by Institutional Investor or Euromoney.

While we will take up this first set of criteria in evaluating our approach, there are some other criteria proposed in the literature which would deserve a more detailed discussion about their appropriateness. PoDs could be transformed into ones ('default') and zeros ('non default') by some threshold value, say $p = 0,5$, to count the hits and misses. This is a criterion well known in evaluating 'early warning' systems. But one has to assign appropriate relative weights for type-I and type-II errors, a task which heavily depends on the intended use of such a model: to maximize profits or to minimize losses from international portfolio investments. Another criterion is the degree of correlation between sovereign PoDs and corporate defaults of the respective countries. There should be a high correlation between the creditworthiness of the sovereign and the one of the corporate sector (see Mathieson and Schinasi (1999, p. 193)). Finally, the question arises how durable the PoD signals are because frequent 'large' jumps would affect the predictive power of the values derived from the model.

3.3 The case of Latin America and Russia

We start with the case of Argentina, finally rated as SD ('selected default') by S&P's in Nov. 6, 2001, due to nonpayment on debt obligations. In fig. *A.ARG.I*, the PoDs are shown as calculated for the observation period from begin of 1995 till Nov. 6, 2001. The relevant input data are presented in fig. *A.ARG.II*, containing the sovereign's ability-to-pay A_t at date t and the repayment obligations K for the respective year, and in fig. *A.ARG.III*, containing the market spread between the risky and the secure asset.

To analyse the PoDs of Argentina, we distinguish 5 different periods of time:

1. 1995 where PoDs are at a high level of 20 - 35 %.

2. 1996/97 where PoDs are at a low level of 5 %.

3. 1998/99 where PoDs are at a level of 20 - 30 %, with a Peak of nearly 50 % in autumn 1998.

4. 2000/2001 where PoDs vary between 40- 50 %.

5. Since July 2001 where PoDs remain at a 50 % level.

In 1995, our macro fundamentals suggest a 'non critical' economic situation. The high PoD levels mainly reflect the high risk premia prevalent in many bond markets just after the Mexican crisis. Indead, the fear of contagion is a phenomenon not limited to the Tequila crisis but observed also during the Asian crisis (see e.g. Karmann, Gressmann and Hott (2002) quantifying contagion for Asia). In 1996/97, the former tension in bond markets calmed down lowering the spreads for Argentinian dollar-denominated bonds. On the other side, increasing repayment obligations were fully matched by the sovereign's ability-to-pay which improved within this period of time. The resulting PoD levels of around 5 % increased since October 1997. This was a consequence of rising risk premia during the Asian crisis reflecting the market's fear that the Asian crisis may affect Argentina.

The period 1998/99 is characterized by two countervailing effects. The trend of increasing repayment obligations remained valid but the sovereign's ability-to-pay shrunk due to deteriorating net exports perspectives NX. Hence, PoD levels rose to reach around 30%. The Russia crisis of mid 1998 drove PoDs up to some 50%, a consequence mainly of the considerable increase in market spreads.

In 2000, news on macro-fundamentals let jump the PoD to levels between 40 and 50 % when repayment obligations now nearly coincided with the sovereign's ability-to-pay and the drift became negative. In contrast, the market spreads did not react significantly until July 2001. Then the spread increase rapidly. As a consequence the PoD remains at a level of about 50%.

To evaluate the explanatory power of our model for Argentina, we concentrate on the co-movements of PoD figures and rating changes. Starting in 1995, Argentina, rated as $BB-$, improved considerably in terms of calculated PoDs well in advance of the subsequent upgrading in April 2nd, 1997. Two quarters later, our PoDs indicate growing concern on repayment perspectives. News on fundamentals at the end of the year 2000 may have led S&P's to downgrade Argentina, by a slight change to $BB-$ in November 14th, 2000, to be followed by further downgradings during 2001 till SD. Our PoDs, when updated with the news available end of the year 2000, already suggest that the risk of default within a on-year period is high. While our

PoDs react well in advance of rating changes they also lead w.r.t. market spreads as the period from December 1998 till end of the year 2000 shows when markets did not react.

We complete our exercise by investigating PoDs for two sovereigns, Ecuador and Russia, having defaulted and for two countries, Chile and Venezuela, not having defaulted in the entire period 1995 - 2002.

The case of Ecuador is somewhat between fundamental crisis and market herding. Ecuador defaulted on Brady bonds in July 27th, 2000. In October 1st, 1999 the government announced first-time that it will be unable to fulfill the repayment obligations in the future (see http://www.east-west.be/news4.htm1#F). In advance the PoD reaches a level of about 50 %. In Juli 2000, when Ecuador in fact defaulted, our model predicted a PoD of around 60 % after starting at a close to 8 % level in April 1998 (earlier data were not available). As there is no sovereign rating by S&P's we concentrate on comparing PoDs and market spreads. The increase of calculated PoDs is, at first, a direct consequence of increasing spreads during the Russia crisis. It is enforced by fundamentals deteriorating since early 1999, in terms of decreasing expected flows NX, a negative drift - expressing on-average negative returns - and a higher discounting. As the latter expresses market expectations, we conclude that our model and the market both are signaling an increasingly risky situation during the nine-month period prior to default.

The case of Russia seems to be more a matter of perceived credibility. Though macro fundamentals remained unchanged and forex reserves accumulation (12,2 bill. USD) nearly covered repayment obligations (13 bill. USD), the expected net exports (10 bill. USD) were discounted by the market at extremely high rates. This implicitly means that market belief strongly limited the sovereign's potential to borrow from international markets, regardless of solvency aspects. In contrast to Argentina and Ecuador, there was a rapid and remarkable increase of PoDs before default was announced by August 17th, 1998.

Does this mean that markets have not foreseen default and/or fundamentals did not react properly? A closer analysis of the PoDs and the input data reveals that during the year 1997, the PoD was around 2%. This corresponds to the observed lending boom during that period (see Semenkov (2000, p. 27)). At the end of 1997, the POD increased to a level of about 5% together with a slight increase in the market spread which lowered the sovereign's ability-to-pay. News on macro fundamentals at the beginning of 1998 led to lower solvency ratios while spreads remained unchanged till mid of the year. The following increase of the PoDs, starting with values between 5% and 10% during the first six months to increase to 20% by August 1st and finally to 80% till the date of default, was merely driven by the increase of spreads from a 10% level to a 65% level.

Putting together, news on fundamentals of Russia at the beginning of 1998 directed PoDs to react somewhat in advance before half-a-year later market participants started to panic. Like in a second generation crisis model (see e.g. Obstfeld (1984)), expectations of market participants switched to drive the economy towards the bad equilibrium. W.r.t. rating changes we see that the process of downgrading began in June 9th, 1998 when our PoDs were already back at some 25% level. Even one week before the announcement of default, Russia was still related as $B+$ while our PoD levels had already reached some 50 % (August 11th, 1998).

Chile represents the case of a sovereign without any default and without any change of rating during the entire period since bond data are available. Macro fundamentals indicate a solvency ratio of as large as 3. As expected, net exports are negative here, in this case the ability-to-pay just consists of the country's foreign exchange reserves. The calculated PoDs seem to be in a reasonable range of 4 - 8% according to low spreads (1,5 - 2,0%) which had been unaffected even by the Argentina crisis. Venezuela is a similar case. There is no sovereign default in terms of nonpayments on governmental bonds though, admittedly, there are considerable arrears over a long period of time resulting from non-repayments by some governmentally owned steel manufacturers. Venezuela's solvency ratio is at least as large as the corresponding one of Chile but market spreads are higher and also reflect contagion fears during the Tequila crisis and the Russia crisis. Consistently, the PoDs of Venezuela are higher than the ones of Chile, well in line with a sovereign rating below the grade of $A-$ for Chile. But, comparing the co movement between PoDs and rating grades the decision of S&P's to downgrade Venezuela by Februar 23rd, 1996, seems to be questionable in the light of our data indicating considerably reduced PoDs of less than 5%. But also the process thereafter of successive upgrading by S&P's is not supported directly by our PoDs which remain within a range of 5 - 10% since 1996.

4 Summary

We presented a model to compute the probability of default of sovereigns on their foreign exchange liabilities. The ability-to-pay of a sovereign results from the existing foreign exchange reserves and the potential of possible capital imports which are approximated using a time series model. For the development of the ability-to-pay, a stochastic process of the Ito type is assumed. We estimate the volatility of the process by applying the Black Scholes formula for put options to the price-spreads on the bond markets. Thereby, the price-spread between a bond regarded as free of default risk and a risky bond issued by the sovereign of a developing country is interpreted as risk premium for the risk of default.

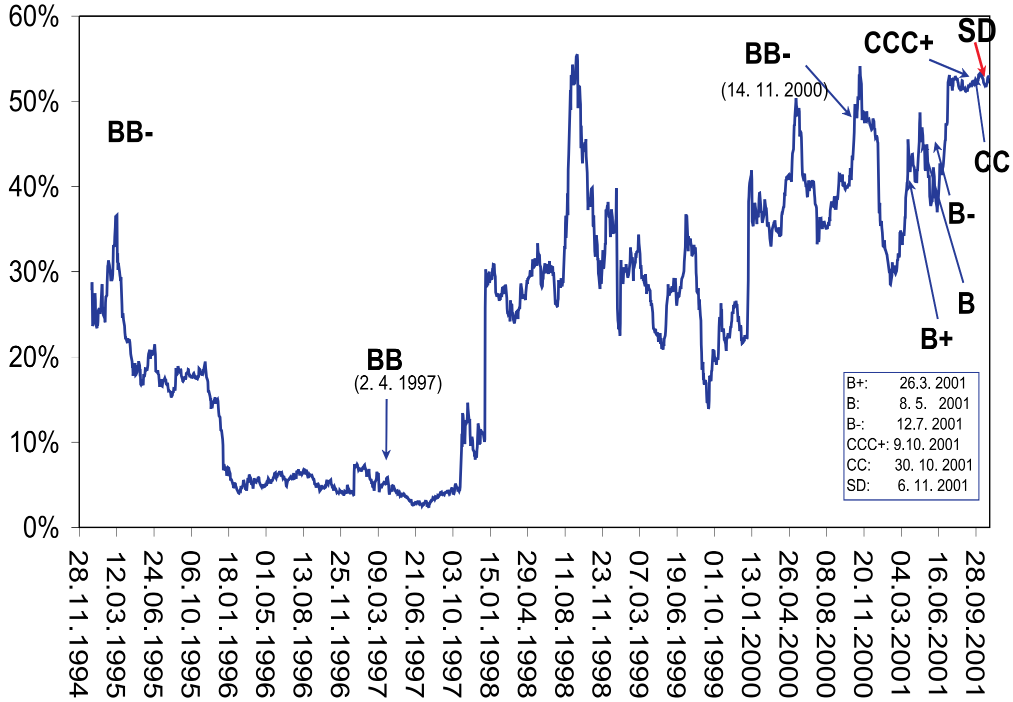
The computed probability of default depends on macro economic fundamentals which primarily determine the ability-to-pay. In addition, data from the international capital markets are used. These market data reflect the risk assessment of the market participants so that they are well capable for estimating the volatility as the risk parameter of the process.

Our approach is applied to some countries. The probabilities of default determined so far are discussed in detail. It is shown that a strong rise of the computed probabilities of default precedes the occurrence of default in each case. Also related events, like financial crises in other countries, are reflected by the model. Furthermore, we see that the computed probabilities of default run clearly ahead of rating migrations.

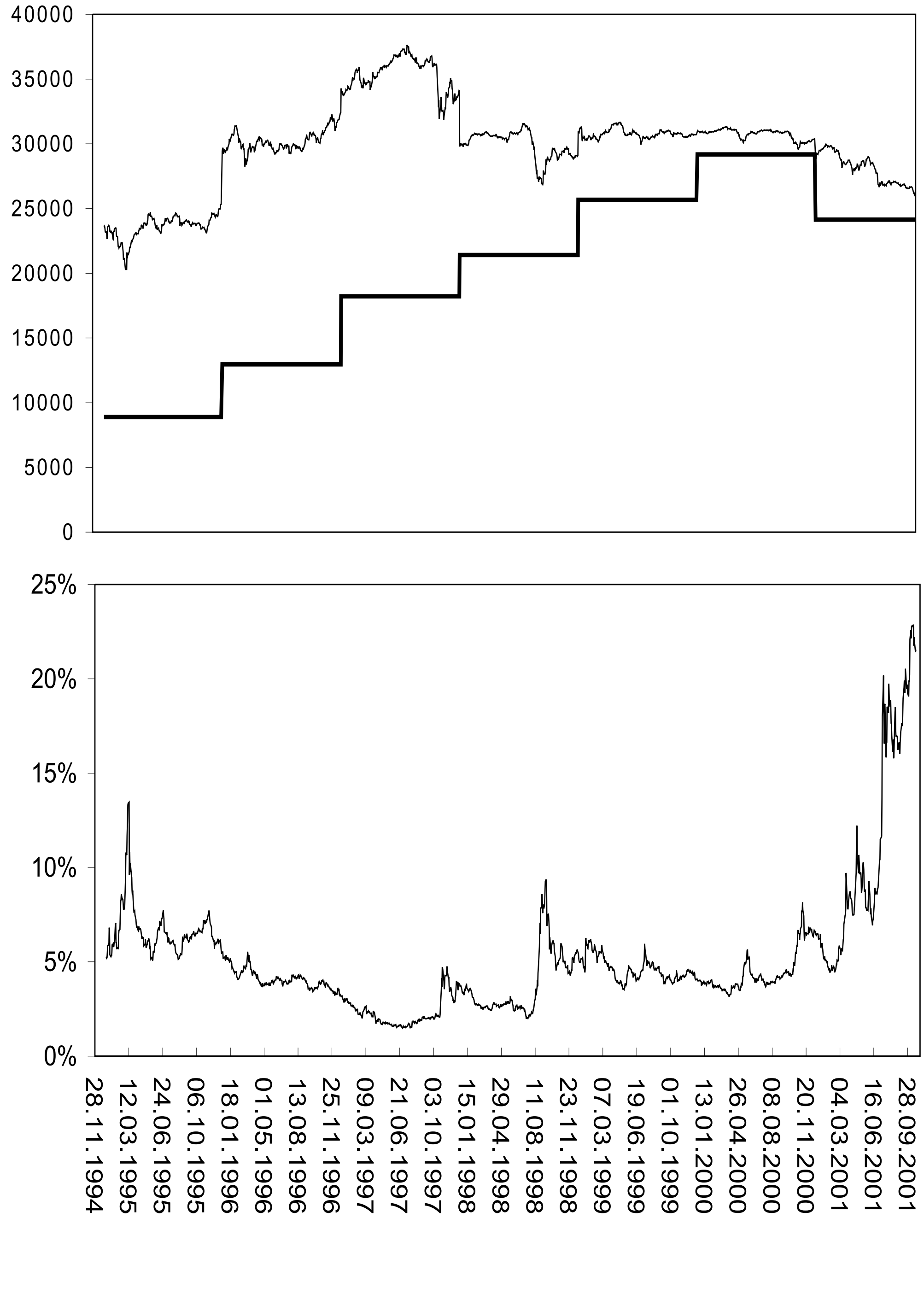
Thus, we conclude that our model seems to be well convenient to determine the sovereign probability of default, whereby areas for future research remain, like the prediction of future payment surpluses.

5 Appendix

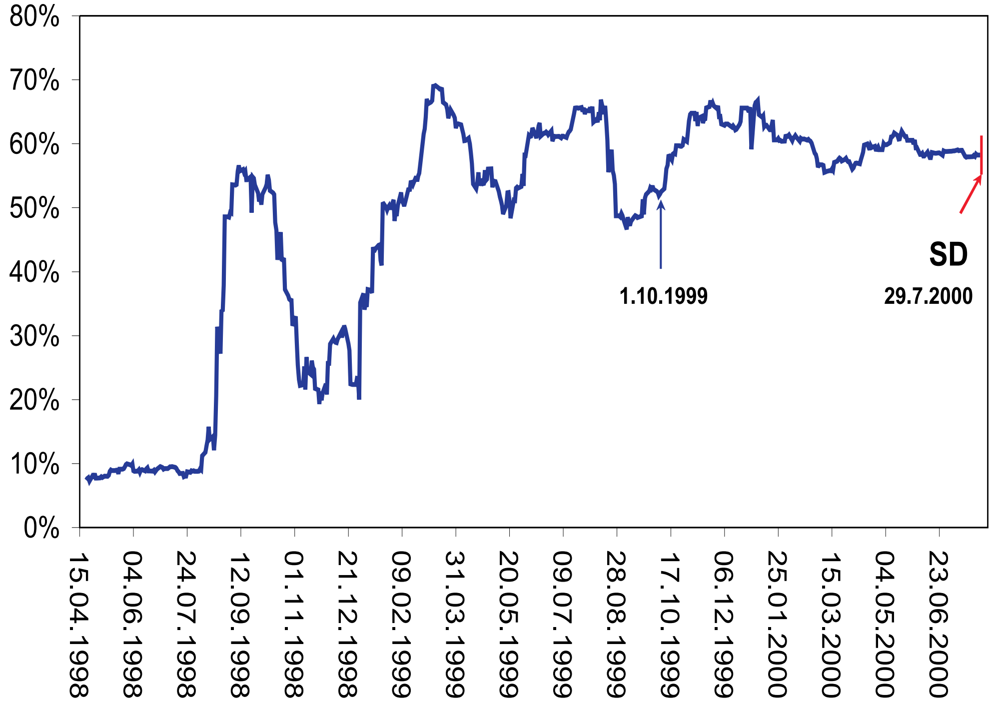
A.ARG.I: Probability of Default for Argentina



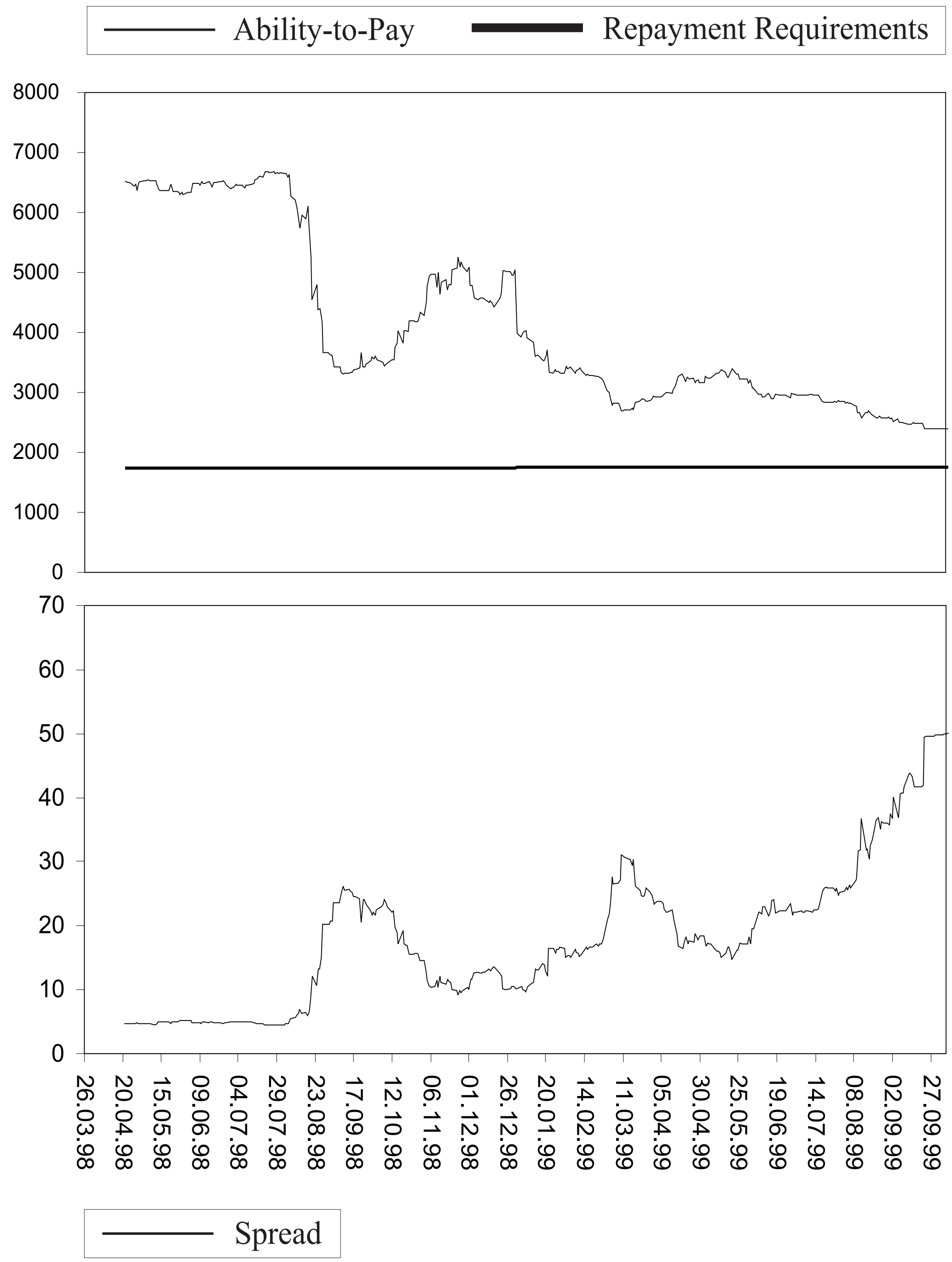
A.ARG.II/III: Input Data for Argentina



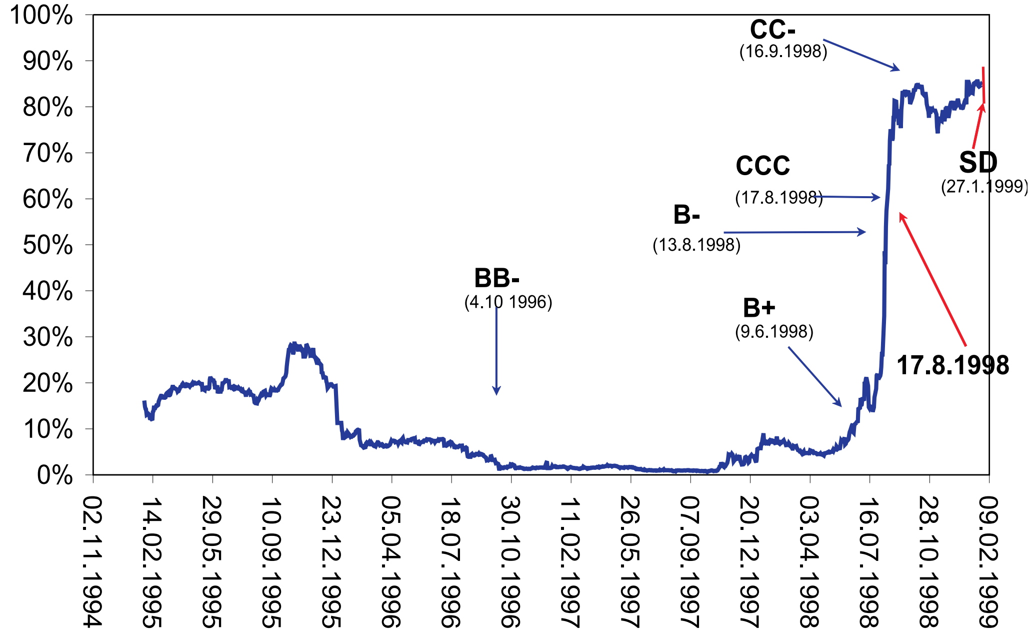
A.ECU.I: Probability of Default for Ecuador



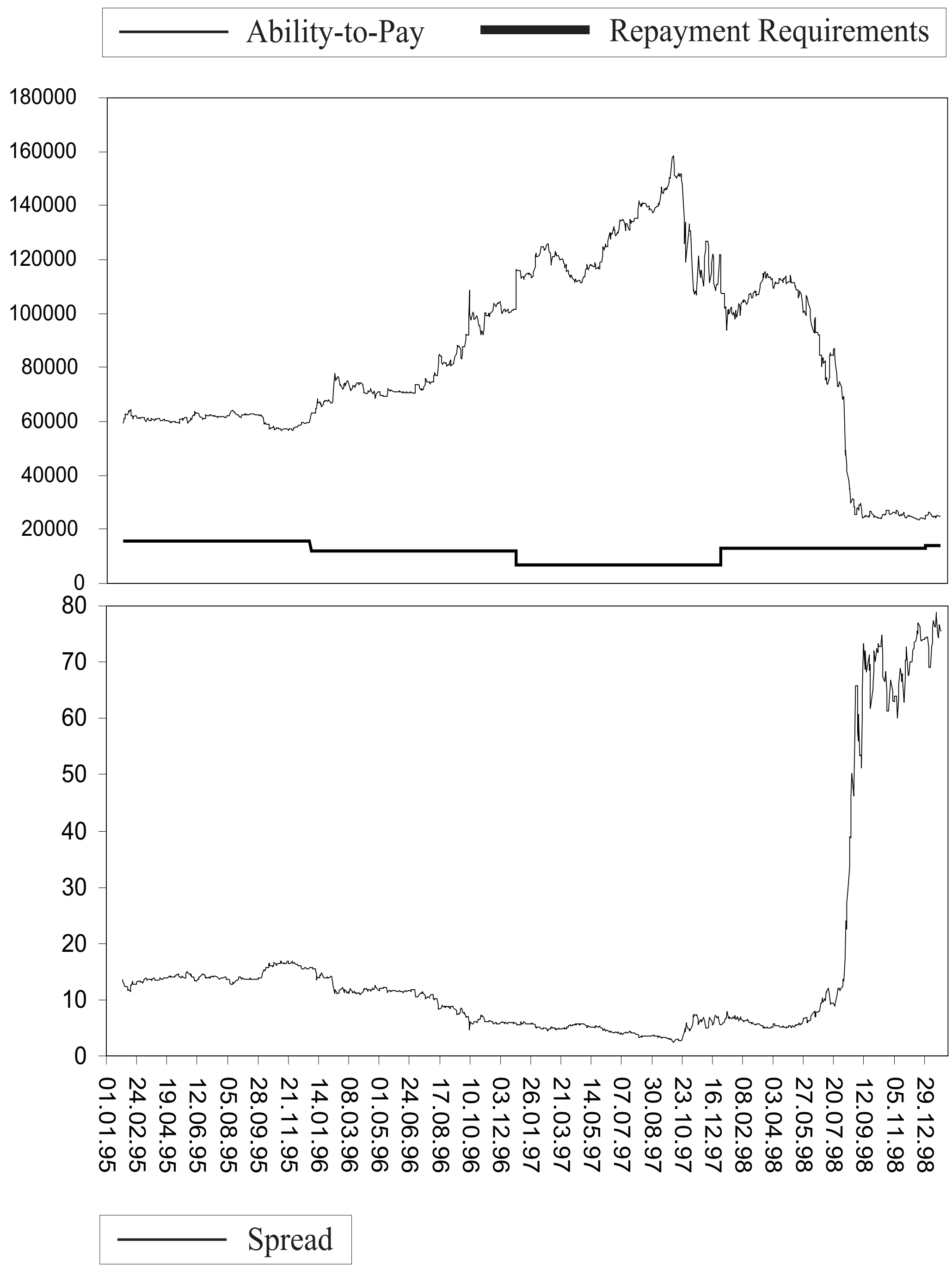
A.ECU.II/III: Input Data for Ecuador



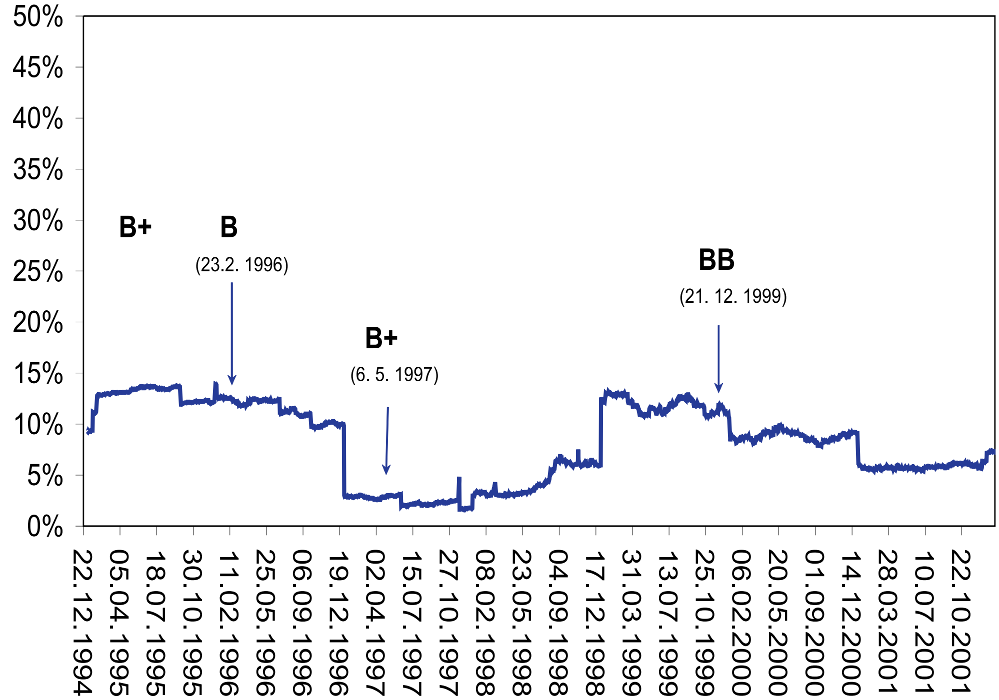
A.RUS.I-a: Probability of Default for Russia



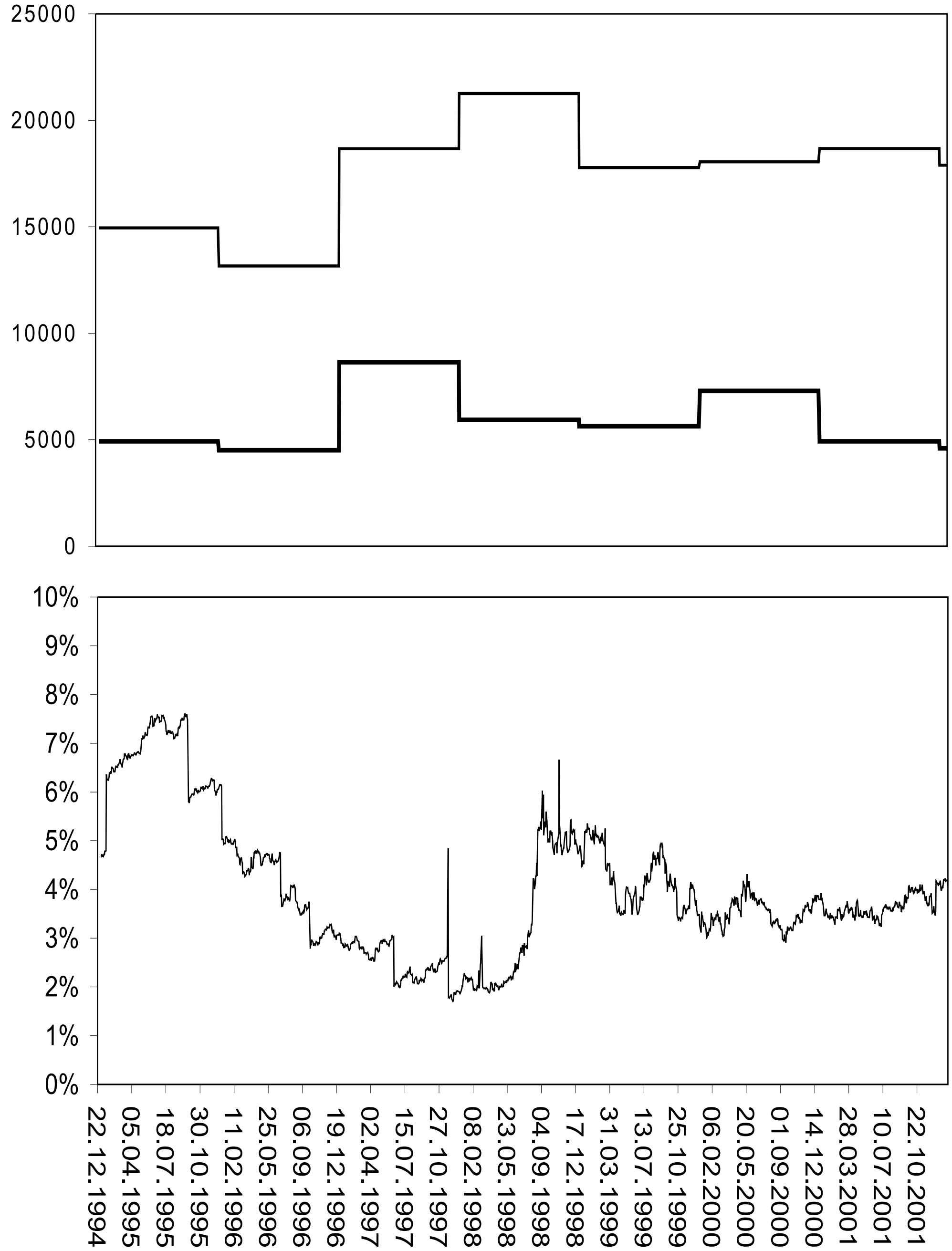
A.RUS.II/III: Input Data for Russia



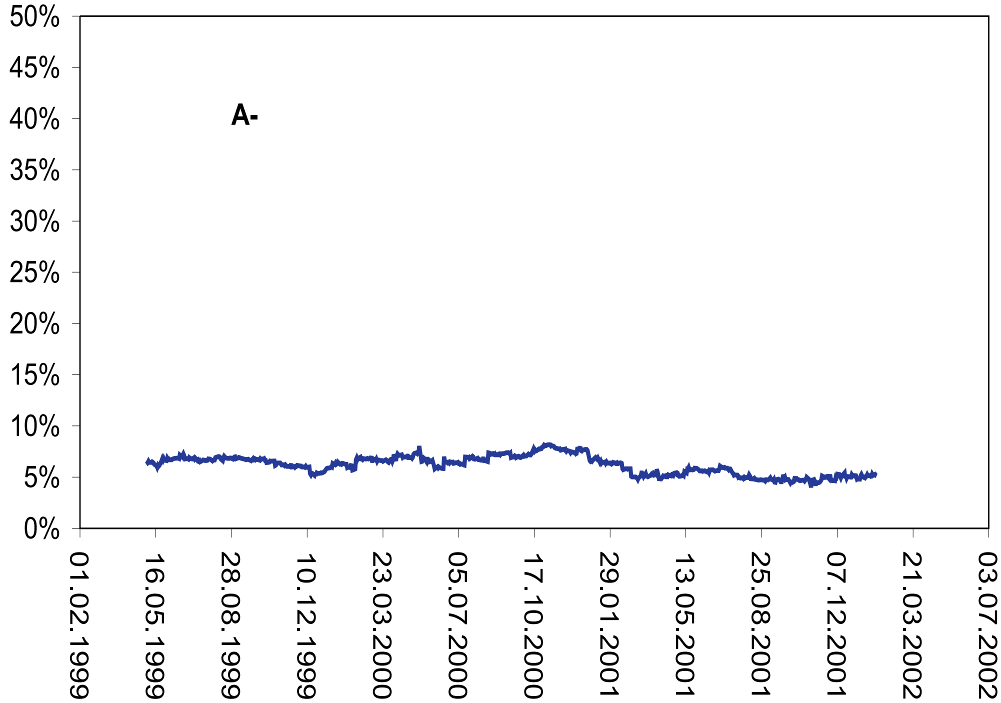
A.VEN.I: Probability of Default for Venezuela



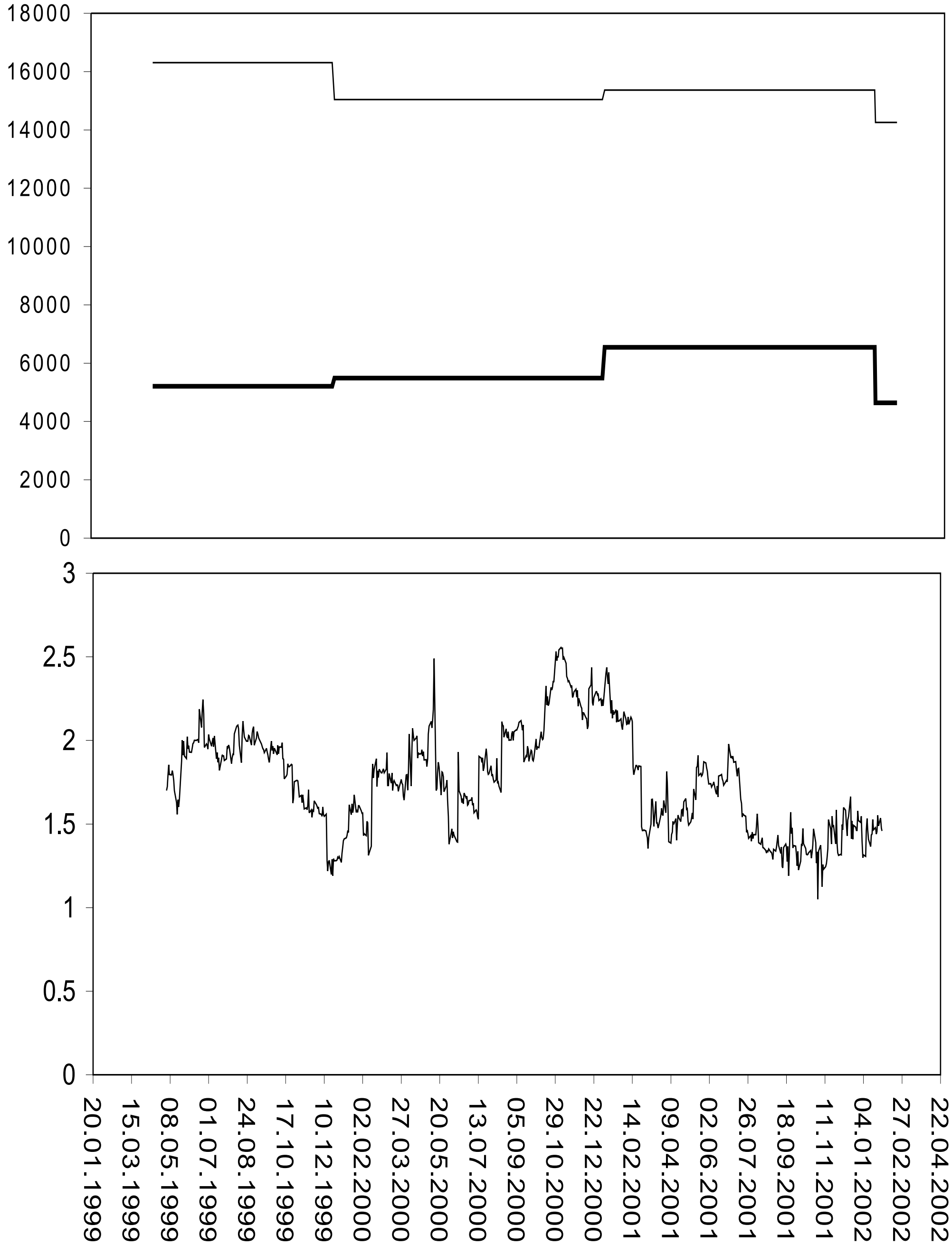
A.VEN.II/III: Input Data for Venezuela



A.CHI.I: Probability of Default for Chile



A.CHI.II/III: Input Data for Chile



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