The Review of Finance and Banking
Volume 03, Issue 2, Year 2011, Pages 095–110
S print ISSN 2067-2713, online ISSN 2067-3825

DISTANCE TO DEFAULT ESTIMATES FOR ROMANIAN LISTED COMPANIES

ALINA SIMA-GRIGORE AND ALIN SIMA

Abstract. This paper assesses the evolution of the distance to default during the recent crisis for some of the most traded companies on Bucharest Stock Exchange. The distance to default is formulated under the framework of the structural model of Leland (1994b) where the default threshold is endogenously determined. This model is reformulated as a (non-linear) state - space model where the (unobservable) state variable is the distance to default. After reviewing different methods proposed in the literature for estimation of the structural models, we estimate the model's parameters within the Bayesian approach with Markov Chain Monte Carlo (MCMC) methods.

1. Introduction

Although, structural models were originally proposed in the literature as solutions to corporate bonds evaluation, they have become an important tool in credit risk management. A relevant example is the Moody's KMV model developed under the structural models framework.

The first structural model is the well known Merton (1974) model that uses the option pricing framework of Black and Scholes (1973) to address the evaluation issue of bonds subject to default risk and to explain the observed credit spreads. This model assumes that the debt is composed by zero coupon bonds and the firm can default only at the maturity of the debt if the asset market value decreases below the face value of the bonds. The interest rate is assumed non-stochastic.

The Merton model was extended to account default prior to maturity, endogenous default threshold, bankruptcy costs, taxes or stochastic volatility. First passage models introduced by Black and Cox (1976) assume that the firm may default at any time, not only at the maturity of the debt. There is an extensive literature on first passage models; we mention here Kim, Ramaswamy and Sundaresan (1993), Leland (1994a), Longstaff and Schwartz (1995), Leland and Toft (1996), Briys and Varenne (1997), Hsu, Saa-Requejo and Santa-Clara (2004).

The default threshold was defined either exogenous (as a safety covenant of the firm's debt which allows the bondholder to take control over the company if the assets values has reached its level) or endogenous (chosen by the stockholders to maximize the value of the equity). For instance, Black and Cox (1976) considered an exogenous time dependent (deterministic) default threshold, Briys and Varenne (1997) assumed a stochastic exogenous default threshold, while Leland (1994a, 1994b) and Leland and Toft (1996) have specified an endogenous default boundary.

Received by the editors July 6, 2011. Accepted by the editors November 18, 2011.

Keywords. structural models, state space models, Markov Chain Monte Carlo methods, probability of default.

JEL Classification. C11, G32.

Alina Sima-Grigore, PhD Candidate, is Assistant Professor in the Department of Money and Banking, Bucharest Academy of Economic Studies. E-mail: alina.grigore@fin.ase.ro.

Alin Sima, PhD Candidate, is graduate student at the Bucharest Academy of Economic Studies. E-mail: alin.sima@piraeusbank.ro.

In models such as those proposed by Kim, Ramaswamy and Sundaresan (1993), Briys and Varenne (1997), and Hsu, Saa-Requejo and Santa-Clara (2004) interest rates are stochastic. This assumption introduces a correlation between firm's asset values and short interest rate.

One of the major drawbacks of the structural models mentioned above is the predictability of default - the default does not come as a surprise. This is due to the assumption of complete information about asset value and default threshold and that the assets value follows a continuous diffusion process. The implication of the default predictability is that the short-term credit spread predicted by the structural models mentioned above is close to zero which is not consistent with the observed credit spreads that incorporate the possibility of unexpected default.

In order to solve the issue of default predictability Zhou (1997, 2001) and Hilberink and Rogers (2002) have included a jump component in the dynamics of the firm value. Therefore, the asset value of the firm can decrease unexpectedly toward the default threshold. A second approach for avoiding the predictability effect was proposed by Duffie and Lando (2001), Jarrow and Protter (2004) and Giesecke (2005) by considering incomplete information about the firm value process and / or the default boundary (i.e. they cannot be perfectly observed). In this context investors can only infer a distribution of the model parameters. Korteweg and Polson (2009) using Markov Chain Monte Carlo (MCMC) methods have introduced parameter uncertainty by estimating a posteriori distributions of the firm asset value and volatility given equity prices and accounting data.

In this paper, we have used MCMC methods to estimate the evolution of the distance to default during the recent crisis for some of the most traded companies on Bucharest Stock Exchange. The theoretical framework employed here is the Leland (1994b) model where the default threshold is endogenously determined. Section 2 describes the chosen structural model, emphasizing the predicted value of equity and debt, and the boundary asset value. In section 3 we review four approaches for estimating structural models that have been proposed in the literature, highlighting their benefits and shortcomings. In section 4 we give more details about the data used to estimate the Leland model. In section 5 we present our results regarding the evolution of the distance to default for the selected traded companies, applying one of the four approaches that was proposed by Duan and Fulop (2006) and also used by Huang and Yu (2010). In section 6 we present the main conclusions of our empirical study.

2. Leland model (1994b)

The structural model of Leland (1994b) estimated in this paper is a generalization of a more cited model of Leland (1994a) to allow for finite maturity debt. It is assumed that the firm continuously redeems a constant fraction, m, of its debt and replace it with new issued debt that promise the same coupon rate as the matured debt. Therefore, the total debt principal at any moment is constant (at the level P) and the average maturity of the debt is T=1/m.

Specific to the class of structural models is that the asset value follows a continuous diffusion process. Leland (1994b) used the assumption of a geometric Brownian motion of the form:

$$\frac{dV_t}{V_t} = (\mu - \delta) \cdot dt + \sigma \cdot dW_t \tag{2.1}$$

where: V_t is the asset value of the firm at moment t, μ is the expected asset rate of return, δ is the proportional payout rate of the asset - the assets generates cash flows, δVt, that are pied out collectively to stock and bond holders; σ is the constant volatility of the asset return.

The Leland (1994b) model is a first passage model which means that the firm will default when the asset value hits the first time a boundary level, denoted here as V_B. More formally, the time of default is defined as:

$$t^{\circ} = \inf\{s \geq t_0 \mid V_s \leq V_B\}$$

Based on the reflection principle of the Brownian motion, a standard result in stochastic processes theory shows that the probability of first passage time (probability of default between t_0 and T) is given by:

$$P[t^\circ \leq T \mid t^\circ \geq t_0] = \Phi\left(\frac{-\ln(\frac{V_t}{V_B}) - \beta \cdot \Delta t}{\sigma \cdot \sqrt{\Delta t}}\right) + \left(\frac{V_t}{V_B}\right)^{-2\beta/\sigma^2} \cdot \Phi\left(\frac{-\ln(\frac{V_t}{V_B}) + \beta \cdot \Delta t}{\sigma \cdot \sqrt{\Delta t}}\right) \quad (2.2)$$

where:

$$\beta = \mu - \delta - \frac{\sigma^2}{2}$$
$$\Delta t = T - t_0$$

and $\Phi(.)$ is the cumulative distribution function for the standard normal distribution. Under the risk neutral measure the probability of default from relation (2.1) changes such that the asset expected rate of return, μ, is replaced by the risk free rate, r.

One of the contributions of Leland (1994a, 1994b) to structural models is that he introduced taxes (denoted here as τ) and bankruptcy costs (γ). In case of default, the debt holders will receive only a fraction $(1-\gamma)$ of the firm value due to bankruptcy costs.

In this context Leland (1994b) shows that the value of the equity and debt has closed-form solutions:

$$D_t = \frac{C + P/T}{r + 1/T} \cdot \left[1 - \left(\frac{V_t}{V_b}\right)^{-y}\right] + (1-\gamma) \cdot V_B \cdot \left(\frac{V_t}{V_b}\right)^{-y}$$

$$E_t = V_t + \frac{\tau \cdot C}{r} \cdot \left[1 - \left(\frac{V_t}{V_B}\right)^{-x}\right] - \gamma \cdot V_B \cdot \left(\frac{V_t}{V_B}\right)^{-x} - D_t \quad (2.3)$$

where:

$$x = \frac{\beta_\gamma + \sqrt{\beta_\gamma^2 + 2 \cdot r \cdot \sigma^2}}{\sigma^2}$$

$$y = \frac{\beta_\gamma + \sqrt{\beta_\gamma^2 + 2 \cdot (r + 1/T) \cdot \sigma^2}}{\sigma^2}$$

$$\beta_r = r - \delta - \frac{\sigma^2}{2}$$

Relation (2.3) is interpreted as follows: the first three terms represents the total value of the firm, so the value of the equity is given by the difference between the total value of the firm and debt value. Moreover, the total value of the firm is given by: the value of firm asset (first term) plus the tax benefits (the second term) associated to the debt financing due to the deductibility of coupon payments minus the bankruptcy cost in case of default (the third term).

The bankruptcy - triggering asset value, V_B, is determined endogenously as an optimal decision by the equity holders. When the cash flows generated by the firm's assets are not sufficient to cover the payouts (redeemed debt, interest and dividend payments), the shareholder may decide to raise new capital in order to meet the payouts. Bankruptcy occurs when the asset value of the firm decreases to a level that implies a (market) value of equity of zero, therefore the shareholders are no longer willing to issue new equity and decide to pass the control over the firm to the bond holders.

Leland (1994a) proposed to determine the bankruptcy - triggering asset value by maximizing the equity value at the default point:

$$\frac{\partial E(V)}{\partial V}\, |_{V=V_B} = 0$$

Solving for V_B gives:

$$V_B = \frac{\frac{C+P/T}{r+1/T} \cdot y - \frac{\tau \cdot C}{r} \cdot x}{1 + \gamma \cdot x + (1-\gamma) \cdot y}$$

In this paper the distance to default is defined as the natural logarithm of the ratio between asset value, V_t, and boundary asset value, V_B. When the asset value reaches the bankruptcy level, the distance to default as defined here takes the value of zero.

3. The estimation problem

The difficulty in estimating the structural models arise from the fact that the (market) value of the assets is not directly observable. An approximation of the asset value as the sum of market value of equity and traded debt and proxies based of the book value of non-traded debt can be found in Jones, Mason, and Rosenfeld (1984), Ogden (1987), Anderson and Sundaresan (2000), Eom, Helwedge and Huang (2004). Such proxies were not considered satisfactory, therefore more elaborate methods were adopted. In the empirical literature of structural models there are at least four approaches:

a. the volatility restriction method of Jones, Mason and Rosenfeld (1984);
b. the KMV method (Crosbie and Bohn, 2003);
c. the transformed data maximum likelihood method of Duan (1994, 2000);
d. the state space representation method of Duan and Fulop (2006).

In many articles the first method above is referred as "Ronn and Verma (1986) approach" who used it in insurance deposit applications, while the name of "volatility restriction method" was taken from Ericsson and Reneby (2005). This approach involve solving a system of two non-linear functions with two unknowns, asset value and asset volatility. The first equation represents the equity evaluation formula predicted by the structural model, while the second equation represents a relation between the equity volatility and the asset volatility obtained from the Itô lemma:

$$E_t = g(V_t, \sigma_V) \tag{3.1}$$

$$\sigma_E = \sigma_v \cdot \frac{V_t}{E_t} \cdot \frac{\partial_g}{\partial V} \tag{3.2}$$

where E represents the market value of the equity, V the asset value, σ_E the volatility of the equity's return and σ_v the volatility of the asset's return. Using historical observations of the equity market value and the sample standard deviation of the equity returns, one can solve the above system for V and σ_v.

This estimation approach was criticized because of the following issues:

1. the volatility of the equity is estimated as a constant parameter, although relation (3.2) shows it depends on the stochastic variable V_t;
2. relation (3.2) is redundant because is derived from the Itô lemma which is also used to determine relation (3.1);
3. this method does not allow the calculation of the distributions of the model parameters and therefore neither confidence intervals nor testing hypotheses can be performed.

As described by Crosbie and Bohn (2005), the commercial application Moody's KMV circumvent the first two shortcomings of the volatility restriction method by implementing an iterative algorithm which does not rely on relation (3.2) in order to estimate the asset volatility. Starting with an initial guess for asset volatility, equation (3.1) is solved numerically for the asset values, $V_t(fort = 1..n)$. An estimate of the asset volatility is obtained based on the sample standard deviation of the estimated asset values. The new value of σ_v is used to solve again equation (3.1) for V_t a.s.o. The iterative procedure stops when the difference between the new estimated value for asset volatility and the previous one is less than a specified tolerance.

In order to cope with the third shortcoming of the volatility restriction method, Duan, Gauthier, Simonato and Zaanoun (2003), Ericsson and Reneby (2005), Wong and Choi (2004) used a transformed data maximum likelihood method developed by Duan (1994).

Structural models assume a geometric Brownian motion of the firm's asset value that implies a normal distribution of the log asset value. For example, relation (2.1) involve the following distribution for $\ln(V_t)$ conditional on $\ln(V_{t-1})$:

$$\ln V_{t+1} \mid \ln V_t, \theta \sim N(\ln V_t + \beta \cdot h, \sigma^{2 \cdot h}) \tag{3.3}$$

where h is the time interval between $t+1$ and t expressed in years and θ is the parameter vector, i.e. $\theta = (\mu, \sigma)$.

However we cannot formulate a likelihood function directly from this distribution assumption due to the fact that the asset values, V_t, are unobservable variables. Instead, for listed companies we observe the evolution of the equity value from which a likelihood function can be derived through a data transformation method. More specifically, the structural models provide us a relation between asset value and equity value of the general form as in (3.1), $E_t = g(V_t)$, interpreted here as a transformation of a random variable. An example of such a function is relation (2.3). A standard result from statistics shows that probability density function of a transformed variable can be determined as:

$$p(E_t \mid \theta) = p(V_t \mid V_{t-1}, \theta) / \left| \frac{\partial g(V_t)}{\partial V_t} \right|$$

where $p(V_t \mid V_{t-1}, \theta)$ is determined from (3.3). The log-likelihood function of the observed equity data given the parameters vector θcan be determined as:

$$\ln L(E_1, E_2, ..., E_n \mid \theta) = \ln p(V_1) + \sum_{t=2}^{N} \ln p(V_t \mid V_{t-1}, \theta) - \sum_{t=1}^{N} \ln \left(\left| \frac{\partial g(V_t)}{\partial V_t} \right| \right)$$

For a sufficient large sample size, N, the distribution of the ML parameter estimates can be approximated by a normal distribution, as follows:

$$\sqrt{N} \cdot (\theta_{ML} - \theta) \to N(0, H^{-1})$$

where H represents the negative of the second derivative of the log-likelihood function evaluated at the ML estimates:

$$H = -\frac{\partial^2 \ln L(E_1, E_2, ..., E_n \mid \theta)}{\partial \theta \partial \theta'} \Big|_{\theta = \theta_{ML}}$$

Duan and Fulop (2006) proposed another approach for structural models that also takes into account that observed equity prices may have been contaminated by trading noises. They argue that by ignoring the trading noises can lead to significantly over-estimating the firm's asset volatility.

Structural models with trading noises can be formulated as a non-linear state space model of the form:

$$\left\{ \begin{matrix} z_t = f(\alpha_t) + \eta_t, \eta_t \sim N(0, R) \\ \alpha_t = d + \alpha_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, Q) \end{matrix} \right\} \tag{3.4}$$

The first equation in (3.4) is the measurement equation and links the observable variable z_t to the unobservable state α_t. This non-linear equation is obtained from the pricing function predicted by the structural model. It could be equation (3.1) or a transformation of it, adding an error term, η_t, which in our case is the trading noise. The second relation in the dynamic system (3.4) is the transition equation of the unobservable state and is determined based on the assumed Brownian nature of the firm's asset value. It is usually assumed that the error terms follow a normal distribution with constant variance, but the techniques developed under the Bayesian framework to estimate state space models are not restricted to this assumption. Various techniques have been proposed in the Bayesian literature for the estimation of non-linear and non-Gaussian state space models, such as: MCMC algorithms (Carlin, Polson and Stoffer, 1992), particle filters (Gordon, Salmond, Smith, 1993), importance sampling (Durbin and Koopman, 2000)

Duan and Fulop (2006) used the state space representation to estimate Merton (1974) model. They have employed the auxiliary particle filter developed by Pitt and Shephard (1999) further adapted by Pitt (2002) for smoothing.

Bruche (2007) used the importance sampling method developed by Durbin and Koopman (2000) to estimate three models: the Merton (1974) model, the Leland (1994a) model and the Leland and Toft (1996) model.

Korteweg and Polson (2009) and also Huang and Yu (2010) have employed MCMC algorithms to estimate Leland (1994b) model and Merton (1974) respectively.

In this paper we follow Huang and Yu (2010) approach to estimate the parameters of Leland (1994b) model for some of the most traded companies on Bucharest Stock Exchange. The same method was applied by Meyer and Yu (2000) in the context of stochastic volatility models who also showed that non-linear state space models can be estimated within the Bayesian framework using the WinBUGS software (Lunn, Thomas, Best and Spiegelhalter, 2000).

Leland's model is reformulated here in terms of the distance to default, as follows:

$$\left\{\begin{array}{c} z_t = \alpha_t + \ln[V_B - G\cdot\exp\{-(1+x)\cdot\alpha_t\} + H\cdot\exp\{-(1+y)\cdot\alpha_t\}] + \eta_t, \eta_t \sim N(0,\upsilon^2) \\ \alpha_t = \beta\cdot h + \alpha_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, h\cdot\sigma^2) \end{array}\right\} \tag{3.5}$$

where:

$$z_t = \ln(E_t - a + b)$$

$$\alpha_t = \ln\left(\frac{V_t}{V_B}\right)$$

$$V_B = \frac{b\cdot y - a\cdot x}{1+\gamma\cdot x + (1-\gamma)\cdot y}$$
$$G = a + \gamma\cdot V_B$$
$$H = b - (1-\gamma)\cdot V_B$$
$$a = \frac{\tau\cdot C}{r}$$
$$b = \frac{C + P/T}{r + 1/T}$$

In this formulation of Leland model, the state variable is the distance to default, while the observed variable is a function on market value of equity, outstanding debt, coupon, average maturity of the debt, tax rate and interest rate.

According to the Bayes rule the *a posteriori* distribution (the distribution of the parameters conditional on the observed data), is proportional to the likelihood (the distribution of the observed data vector $z = (z_1, z_2, ..., z_N)$ conditional on the parameters) multiplied by the *a priori* distribution of the parameters, where the parameter vector is augmented with the unobserved states, $\alpha = (\alpha_1, \alpha_2 ..., \alpha_N)^{'}$:

$$p(\alpha, \mu, \nu, \sigma \mid z) \propto p(z \mid \alpha, \mu, \nu, \sigma) \cdot p(\alpha, \mu, \nu, \sigma)$$

The likelihood is determined from the measurement equation as follows:

$$p(z \mid \alpha, \mu, \nu, \sigma) = \prod_{t=1}^{N} p(z_t \mid \alpha_t, \mu, \nu, \sigma)$$

While the a priori distribution is determined from the transition equation of the state variable and from the assumption that the parameters μ, ν, σ are a priori independent:

$$p(\alpha, \mu, \nu, \sigma) = p(\mu) \cdot p(\nu) \cdot p(\sigma) \cdot p(\alpha_0) \cdot \prod_{t=1}^{N} p(\alpha_t \mid \alpha_{t-1}, \mu, \sigma)$$

The a posteriori distribution of the parameters is determined with Gibbs sampling algorithm using WinBUGS software. In order to test the convergence of the MCMC samples to the target (a posteriori) distribution we have used the CODA package within R software. A well cited reference for the MCMC algorithms (including Gibbs sampling) and convergence tests is Gilks, Richardson and Spiegelhalter (1996).

4. Data

In our analysis we have included 35 of the most traded firms on the Bucharest Stock Exchange, grouped in 9 sectors/ subsectors:

1. construction (Condmag, Energopetrol Câmpina, Impact, Transilvania Construcţii);
2. manufacturing - pharmaceutical products (Antibiotice Iaşi, Biofarm, Zentiva);
3. manufacturing - machinery and equipment (Armătura Cluj, Comelf Bistriţa, Mecanica Ceahlău);
4. manufacturing - metallurgy (Alro Slatina, Mechel Târgovişte, TMK Artrom, Zimtub Zimnicea);
5. manufacturing - food and beverages (Bermas Suceava, Titan);
6. manufacturing - chemicals (Amonil Slobozia, Azomureş, Oltchim Rm. Vâlcea, Sinteza Oradea);
7. manufacturing - other subsectors (Aerostar Bacău, Altur Slatina, Carbochim Cluj, Compa Sibiu, Electroaparataj, Electrocontact Botoşani, Electroputere Craiova, Mefin Sinaia, Şantierul Naval Orşova, Uamt Oradea)
8. tourism (Casa de Bucovina Club Munte, Turism Felix, Turism Marea Neagră);
9. other sectors (Alumil Rom Industry, Transelectrica).

The value of the equity is determined using the daily market prices per share from Jan-2008 to Apr-2011 multiplied by the total number of shares, taking into account also the changes of the outstanding number of shares during this time period.

The total debt parameter, P, was approximated by the average of the year-end total debt from 2007, 2008 and 2009. We have used the available information regarding the short term debt and long term debt of the listed companies from 2004 to 2010 to approximate the average maturity, T, of the debt. More precisely, parameter T was approximated as a weighted average of the short term maturity (1 year) and long term maturity (assumed here to be ten years), where the weights are proportional to the amount of the short term debt and long term debt respectively. We have used the average of the annual financial expenditures from 2007, 2008 and 2009 as a proxy for the fixed coupon payments, C.

Another important parameter of the Leland model is the payout rate, δ. For each year from 2004 to 2009 we have estimate an annual payout rate as follows:

$$\delta_t = \frac{coupon.payments_t + dividends_t}{total.debt_t + equity.market.value_t}$$

and our final estimate was the median of the six annual raters.

The interest rate parameter, r, was set equal to the average of the National Bank of Romania monetary policy rate from 2008, 2009 and 2010, while the tax rate parameter, τ , was set to 16% and the time interval $h = 1/250$ (due to the fact that we have used daily observations).

5. Results of the empirical analysis

For each company we have estimated the augmented parameter vector $(\mu, \sigma, \upsilon, \alpha)$ of the Leland model using the single-move Gibbs sampling algorithm of WinBUGS. The convergence of the chains to the stationary distribution was monitored with Geweke z-score test and Raftery and Lewis test implemented in CODA package of R. Due to the high auto-correlation of the Gibbs sampling outcomes we have stored every k-th iteration, where k was chosen based of the autocorrelation order of the burn-in sample.

Our choice for the parameters prior distributions are: Normal distribution for the drift parameter, $\mu \sim N(0, 10-3)$; Gamma distribution for the trading noise precision, $1/\upsilon^2 \sim G(10-3, 10-3)$; Gamma distribution for the asset return precision, $1/\sigma^2 \sim G(10-6, 10-3)$.

The estimation results are reported in Table 1. The estimate of the parameter is the mean of the simulated a posteriori distribution denoted in table 1 as "mean", while its standard deviation is denoted as "sd". In this table we also report the 95% posterior confidence intervals for all the parameters.

For most of the selected companies the estimated asset return volatilities are between 0.01 and 0.06. Higher asset return volatilities (between 0.1 and 0.13) are found for Zimtub Zimnicea, Turism Marea Neagră and Comelf Bistriţa. The estimated trading noise volatilities range from 0.0055 to 0.0928, but for most of the analyzed companies (30 out of 35) this parameter is lower than 0.02. Based on the posterior confidence interval we found all the parameters significantly different from zero, except for the drift parameter, μ, for Sinteza Oradea (stz).

In Figure 1 we depict the evolution of the estimated distance to default in a "high-low-open-close" type chart, where, in our case, "open" refers to the initial estimated value (the distance to default as of 3. Jan. 2008), whereas "close" refers to the last estimate (distance to default as of 14 Apr. 2011).

Relatively high distances to default are found for the pharmaceutical and tourism sectors. However, all the selected companies recorded significant declines of their distance to default in the past three years: 29 firms declined with more than 50% from the initial value to the lowest one. From the Figure 2.a it seems that the higher the initial distance to default, the higher the absolute decline. In Figure 2.b we show that this is indeed the fact, but in terms of relative decline we have the reverse relation.

The distance to default estimates for the period Jan. 2008 - Apr. 2011 reveal that 10 companies almost reached the default threshold: Energopetrol Câmpina, Impact, TMK Artrom, Amonil Slobozia, Azomureş, Oltchim Rm. Vâlcea, Compa Sibiu, Electroaparataj, Electroputere Craiova, Uamt Oradea. Some of them showed signs of recovery (Azomureş, Energopetrol Câmpina, Impact, Compa Sibiu), but the other six mentioned companies remained close to the boundary level.

Figure 3 illustrates the term structure of the probabilities of default implied by the Leland model calculated with relation (2.2). In Figure 3.a we depict the probabilities of default as of Jan. 2008 while in Figure 3.b as of Apr. 2011. Companies that are not shown in these graphs have zero probability of default for tenors from one to ten years. Not surprisingly, Figure 3.b shows significant probabilities of default for the six companies reported earlier as being very close to the default threshold (TMK Artrom, Amonil Slobozia, Oltchim Rm. Valcea, Electroaparataj, Electroputere Craiova, Uamt Oradea) and another two companies that were reported as having high asset return volatilities (Zimtub Zimnicea and Comelf Bistriţa).

6. Concluding Remarks

In this paper we have used a structural credit risk model proposed by Leland (1994b) to estimate the distance to default for 35 companies listed on Bucharest Stock Exchange. The observed equity prices are assumed to be corrupted by microstructure noises, therefore the equity evaluation formula given by the Leland model is adjusted with an error term. The model is reformulated as a state space model where the state variable is the distance to default. In order to estimate the parameters of the model (the expected rate of return of the firm's asset, asset return volatility and trading noise volatility) we have employed a Bayesian approach.

Our results show that the distance to defaults for all the selected companies have significantly declined in the past 3 years. Moreover, some companies are found to be on the verge to default. Obviously, high probabilities of default have been predicted by the Leland model for the companies that in Apr. 2011 were close to the default threshold and also for the companies with high asset return volatility estimates.

References

[1] Anderson, R.W. & Sundaresan, S. (2000). A Comparative Study of Structural Models of Corporate Bond Yields: An Exploratory Investigation, Journal of Banking and Finance, 24 (1-2), 255-269.
[2] Black, F. & Cox J. (1976). Valuing Corporate Securities: Some Effects of Bond Indenture Provisions, Journal of Finance, (21), 351-367.
[3] Briys, E. & Varenne F. (1997). Valuing Risky Fixed Rate Debt: An Extension, Journal of Financial and Quantitative Analysis, (32), pp 239-248.
[4] Bruche, M. (2007). Estimating Structural Models of Corporate of Prices, working paper, CEMFI.
[5] Carlin, B., Polson, N. G. & Stoffer, D. (1992). A Monte Carlo Approach to Nonnormal and Nonlinear State Space Modeling, Journal of the American Statistical Association, (87), 493-500.
[6] Crosbie, P.J. & Bohn, J.R. (2003). Modeling Default Risk, working paper, KMV Corporation.
[7] Duan, J.C. (1994). Maximum Likelihood Estimation Using Price Data of the Derivative Contract, Mathematical Finance 4, 155-167.
[8] Duan, J.C. (2000) Correction: Maximum Likelihood Estimation Using Price Data of the Derivative Contract, Mathematical Finance 10, 461-462.
[9] Duan, J.C. & Fulop, A. (2006). Estimating the Structural Credit Risk Model when Equity Prices Are Contaminated by Trading Noise", ESSEC Research Center, DR-06015.
[10] Duan J.C., Gauthier, G., Simonato, J.G. & Zaanoun, S. (2003). Estimating Merton's Model by Maximum Likelihood with Survivorship Consideration", working paper.
[11] Duffie, D & Lando, D. (2001). Term Structure of Credit Spreads with Incomplete Accounting Information, Econometrica, (69), 633-664.
[12] Durbin, J. & Koopman, S. J. (2000): Time Series Analysis of Non-Gaussian Observations Based on State Space Models from Both Classical and Bayesian Perspectives, Journal of the Royal Statistical Society, vol. 62(1), pages 3-56.
[13] Ericsson, J. & Reneby, J. (2005). Estimating Strutural Bond Pricing Models, Journal of Business, 78, 707-736.
[14] Eom, Y.H., Helwege, J.& Huang, J. (2004). Structural Models of Corporate Bond Pricing: An Empirical Analysis, Review of Financial Studies, (17), 499-544.
[15] Giesecke, K. (2005). Default and Information, working paper, Cornell University.
[16] Gilks, W.R, Richardson, S. & Spiegelhalter, D.J. (1996). Markov Chain Monte Carlo in practice, Chapman & Hall/CRC.
[17] Gordon, N.J., Salmond, D.J. & Smith, A.F.M. (1993). Novel Approach to Nonlinear/Non-Gaussian Bayesian State Estimation, IEE Proceedings-F, 140, 107–113.
[18] Jarrow, R.A. & Protter, P. (2004). Structural versus Reduced Form Models: A New Information Based Perspective, Journal of Investment Management, (2), 1-10.
[19] Jones, E. P, Mason, S. P & Rosenfeld, E. (1984). Contingent Claims Analysis of Corporate Capital Structures: an Empirical Investigation, Journal of Finance, (39), 611-625.
[20] Kim, J., Ramaswamy, K. & Sundarensan, S. (1993). Does Default Risk in Coupons Affect the Valuation of Corporate Bonds?: A Contingent Claims Model, Financial Management, 3 (22).
[21] Korteweg, A. & Polson, N. (2009). Corporate Credit Spreads under Parameter Uncertainty, Paper presented at the annual meeting of the American Finance Association, San Francisco and the University of Chicago Statistics & Econometrics Colloquium, USA.
[22] Leland, H. (1994a). Corporate Debt Value, Bond Covenants and Optimal Capital Structure, Journal of Finance, (49), pp. 1213-1252.

[23] Leland, H. (1994b): Bond Prices, Yield Spreads and Optimal Capital Structure with Default Risk, Institute of Business and Economic Research, University of California.
[24] Leland, H. & Toft, K.B. (1996). Optimal Capital Structure, Endogenous Bankruptcy, and the Term Structure of Credit Spreads, Journal of Finance, (51), pp 987-1019.
[25] Longstaff, F.A. & Schwartz, E. (1995). A Simple Approach to Valuing Risky Fixed and Floating Rate Debt, Journal of Finance, (3), pp 791-819.
[26] Lunn, D.J., Thomas, A., Best, N. & Spiegelhalter, D. (2000). WinBUGS - A Bayesian Modeling Framework: Concepts, Structure, and Extensibility, Statistics and Computing, 10:325-337.
[27] Hilberink, B. & Rogers, C. (2002). Optimal Capital Structure and Endogenous Default, Finance and Stochastics, (6), 237-263.
[28] Hsu, J.C., Saa-Requejo, J. & Santa-Clara, P. (2004). Bond Pricing with Default Risk, working paper.
[29] Huang, S. J. & Yu, J. (2010). Bayesian Analysis of Structural Credit Risk Models with Microstructure Noises", Journal of Economic Dynamics & Control, (34), 2259-2272.
[30] Merton, R.C. (1974). On the Pricing of Corporate Debt: The Risk Structure of Interest Rates, Journal of Finance, (29), pp. 449–470.
[31] Meyer, R. & Yu, J. (2000). BUGS for a Bayesian Analysis of Stochastic Volatility Models, Econometrics Journal, (0), 1-17.
[32] Ogden, J. (1987). Determinants of the Relative Interest Rate Sensitivities of Corporate Bonds, Financial Management, 22–30.
[33] Pitt, M.K. (2002). Smooth Particle Filters For Likelihood Evaluation and Maximization, Warwick Economic Research Papers, No 651.
[34] Pitt, M. K. & Shephard, N. (1999). Filtering via Simulation: Auxiliary Particle Filters, Journal of the American Statistical Association, Vol. 94, No. 446, pp. 590-599.
[35] Ronn, E.I. & Verma, A.K. (1986). Pricing Risk-Adjusted Deposit Insurance: An Option-Based Model", The Journal of Finance, (41), 871–895.
[36] Wong, H. & Choi, T. (2004). The Impact of Default Barrier on the Market Value of Firm's Asset, Chinese University of Hong Kong, working paper.
[37] Zhou, C. (1997). A Jump Difussion Approach to Modeling Credit Risk and Valuing Defaultable Securities, Paper provided by Board of Governors of the Federal Reserve System (U.S.) in its series Finance and Economics Discussion Series, number 15.
[38] Zhou, C. (2001). The Term Structure of Credit Spreads with Jump Risk, Journal of Banking and Finance, (25), pp. 2015-2040.

Appendix

Table I. Bayesian estimation results for listed companies on BSE (a)

		μ			
Company	**Symbol**	**mean**	**Sd**	**2.5%**	**97.5%**
Construction					
Condmag	comi	0.0122	0.0010	0.0103	0.0142
Energopetrol Campina	enp	0.0096	0.0012	0.0071	0.0120
Impact	imp	0.0237	0.0007	0.0222	0.0251
Transilvania Constructii	cotr	0.0612	0.0013	0.0587	0.0638
Manufacturing - pharmaceutical products					
Antibiotice Iasi	atb	0.0185	0.0019	0.0148	0.0223
Biofarm	bio	0.0056	0.0010	0.0036	0.0076
Zentiva	scd	0.0207	0.0012	0.0184	0.0230
Manufacturing - machinery & equipment					
Armatura Cluj	arm	0.0460	0.0008	0.0445	0.0475
Comelf Bistrita	cmf	0.0737	0.0063	0.0612	0.0864
Mecanica Ceahlau	mecf	0.0522	0.0017	0.0489	0.0555
Manufacturing - metallurgy					
Alro Slatina	alr	0.1171	0.0016	0.1140	0.1203
Mechel Targoviste	cos	0.0430	0.0016	0.0398	0.0462
TMK Artrom	art	0.0881	0.0004	0.0873	0.0889
Zimtub Zimnicea	zim	0.0676	0.0077	0.0525	0.0830
Manufacturing - food & beverages					
Bermas Suceava	brm	0.0631	0.0015	0.0600	0.0661
Titan	mpn	0.0567	0.0009	0.0548	0.0585
Manufacturing - chemicals					
Amonil Slobozia	amo	0.0335	0.0011	0.0314	0.0356
Azomures	azo	0.0966	0.0006	0.0954	0.0978
Oltchim Rm Valcea	olt	0.0659	0.0004	0.0651	0.0668
Sinteza Oradea	stz	0.0039	0.0029	-0.0016	0.0098
Manufacturing - other subsectors					
Aerostar Bacau	ars	0.1000	0.0011	0.0978	0.1021
Altur Slatina	alt	0.0371	0.0008	0.0355	0.0388
Carbochim Cluj	cbc	0.0373	0.0027	0.0321	0.0426
Compa Sibiu	cmp	0.0431	0.0007	0.0418	0.0444
Electroaparataj	elj	0.0237	0.0018	0.0202	0.0273
Electrocontact Botosani	ect	0.0095	0.0012	0.0073	0.0119
Electroputere Craiona	ept	0.0217	0.0005	0.0208	0.0226
Mefin Sinaia	mef	0.0318	0.0030	0.0258	0.0379
Santierul Naval Orsova	sno	0.0543	0.0012	0.0519	0.0567
Uamt Oradea	uam	0.0591	0.0029	0.0534	0.0649
Tourism					
Casa de Bucovina Club Munte	bcm	0.0638	0.0016	0.0606	0.0670
Turism Felix	tufe	0.0053	0.0010	0.0033	0.0073
Turism Marea Neagra	efo	0.0086	0.0043	0.0004	0.0172
Other sectors					
Alumil Rom Industry	alu	0.0493	0.0007	0.0478	0.0507
Transelectrica	tel	0.0409	0.0004	0.0400	0.0417

(b)

		σ			
Company	**Symbol**	**mean**	**Sd**	**2.5%**	**97.5%**
Construction					
Condmag	comi	0.0284	0.0008	0.0268	0.0301
Energopetrol Campina	enp	0.0201	0.0009	0.0184	0.0220
Impact	imp	0.0193	0.0006	0.0182	0.0205
Transilvania Constructii	cotr	0.0274	0.0016	0.0244	0.0306
Manufacturing - pharmaceutical products					
Antibiotice Iasi	atb	0.0530	0.0028	0.0473	0.0586
Biofarm	bio	0.0293	0.0009	0.0277	0.0311
Zentiva	scd	0.0335	0.0009	0.0317	0.0354
Manufacturing - machinery & equipment					
Armatura Cluj	arm	0.0165	0.0010	0.0146	0.0186
Comelf Bistrita	cmf	0.1043	0.0045	0.0959	0.1134
Mecanica Ceahlau	mecf	0.0328	0.0018	0.0296	0.0367
Manufacturing - metallurgy					
Alro Slatina	alr	0.0452	0.0012	0.0428	0.0478
Mechel Targoviste	cos	0.0310	0.0019	0.0274	0.0349
TMK Artrom	art	0.0105	0.0006	0.0095	0.0117
Zimtub Zimnicea	zim	0.1260	0.0072	0.1121	0.1404
Manufacturing - food & beverages					
Bermas Suceava	brm	0.0403	0.0011	0.0381	0.0426
Titan	mpn	0.0198	0.0012	0.0175	0.0226
Manufacturing - chemicals					
Amonil Slobozia	amo	0.0300	0.0008	0.0285	0.0315
Azomures	azo	0.0170	0.0007	0.0158	0.0185
Oltchim Rm Valcea	olt	0.0116	0.0002	0.0113	0.0120
Sinteza Oradea	stz	0.0536	0.0028	0.0483	0.0591
Manufacturing - other subsectors					
Aerostar Bacau	ars	0.0282	0.0013	0.0258	0.0307
Altur Slatina	alt	0.0238	0.0008	0.0223	0.0253
Carbochim Cluj	cbc	0.0472	0.0023	0.0428	0.0516
Compa Sibiu	cmp	0.0184	0.0005	0.0175	0.0195
Electroaparataj	elj	0.0301	0.0012	0.0277	0.0325
Electrocontact Botosani	ect	0.0287	0.0015	0.0259	0.0320
Electroputere Craiona	ept	0.0115	0.0004	0.0108	0.0124
Mefin Sinaia	mef	0.0407	0.0031	0.0350	0.0471
Santierul Naval Orsova	sno	0.0315	0.0011	0.0295	0.0337
Uamt Oradea	uam	0.0532	0.0048	0.0460	0.0645
Tourism					
Casa de Bucovina Club Munte	bcm	0.0374	0.0021	0.0335	0.0418
Turism Felix	tufe	0.0277	0.0013	0.0252	0.0303
Turism Marea Neagra	efo	0.1088	0.0031	0.1028	0.1151
Other sectors					
Alumil Rom Industry	alu	0.0210	0.0007	0.0196	0.0221
Transelectrica	tel	0.0121	0.0004	0.0114	0.0129

(c)

		ν			
Company	**Symbol**	**mean**	**Sd**	**2.5%**	**97.5%**
Construction					
Condmag	comi	0.0092	0.0008	0.0076	0.0109
Energopetrol Campina	enp	0.0089	0.0009	0.0074	0.0108
Impact	imp	0.0067	0.0005	0.0058	0.0077
Transilvania Constructii	cotr	0.0154	0.0015	0.0125	0.0184
Manufacturing - pharmaceutical products					
Antibiotice Iasi	atb	0.0428	0.0025	0.0379	0.0476
Biofarm	bio	0.0088	0.0008	0.0073	0.0105
Zentiva	scd	0.0089	0.0009	0.0074	0.0107
Manufacturing - machinery & equipment					
Armatura Cluj	arm	0.0114	0.0009	0.0097	0.0131
Comelf Bistrita	cmf	0.0204	0.0045	0.0131	0.0303
Mecanica Ceahlau	mecf	0.0158	0.0019	0.0123	0.0196
Manufacturing - metallurgy					
Alro Slatina	alr	0.0104	0.0012	0.0083	0.0129
Mechel Targoviste	cos	0.0173	0.0019	0.0134	0.0211
TMK Artrom	art	0.0139	0.0015	0.0111	0.0168
Zimtub Zimnicea	zim	0.0299	0.0095	0.0159	0.0524
Manufacturing - food & beverages					
Bermas Suceava	brm	0.0095	0.0010	0.0077	0.0115
Titan	mpn	0.0148	0.0011	0.0126	0.0171
Manufacturing - chemicals					
Amonil Slobozia	amo	0.0077	0.0007	0.0065	0.0090
Azomures	azo	0.0124	0.0011	0.0103	0.0146
Oltchim Rm Valcea	olt	0.0118	0.0007	0.0104	0.0133
Sinteza Oradea	stz	0.0190	0.0030	0.0134	0.0251
Manufacturing - other subsectors					
Aerostar Bacau	ars	0.0136	0.0013	0.0109	0.0162
Altur Slatina	alt	0.0088	0.0008	0.0073	0.0104
Carbochim Cluj	cbc	0.0145	0.0021	0.0107	0.0191
Compa Sibiu	cmp	0.0063	0.0004	0.0055	0.0072
Electroaparataj	elj	0.0094	0.0010	0.0076	0.0116
Electrocontact Botosani	ect	0.0153	0.0015	0.0121	0.0183
Electroputere Craiona	ept	0.0055	0.0003	0.0049	0.0061
Mefin Sinaia	mef	0.0194	0.0031	0.0137	0.0257
Santierul Naval Orsova	sno	0.0124	0.0013	0.0099	0.0150
Uamt Oradea	uam	0.0928	0.0070	0.0793	0.1072
Tourism					
Casa de Bucovina Club Munte	bcm	0.0236	0.0022	0.0192	0.0279
Turism Felix	tufe	0.0156	0.0013	0.0130	0.0180
Turism Marea Neagra	efo	0.0156	0.0026	0.0111	0.0213
Other sectors					
Alumil Rom Industry	alu	0.0077	0.0006	0.0066	0.0090
Transelectrica	tel	0.0060	0.0004	0.0053	0.0067

Figure 1a. Evolution of the distance to default between Jan. 2008 and Apr. 2011 for companies traded on BSE

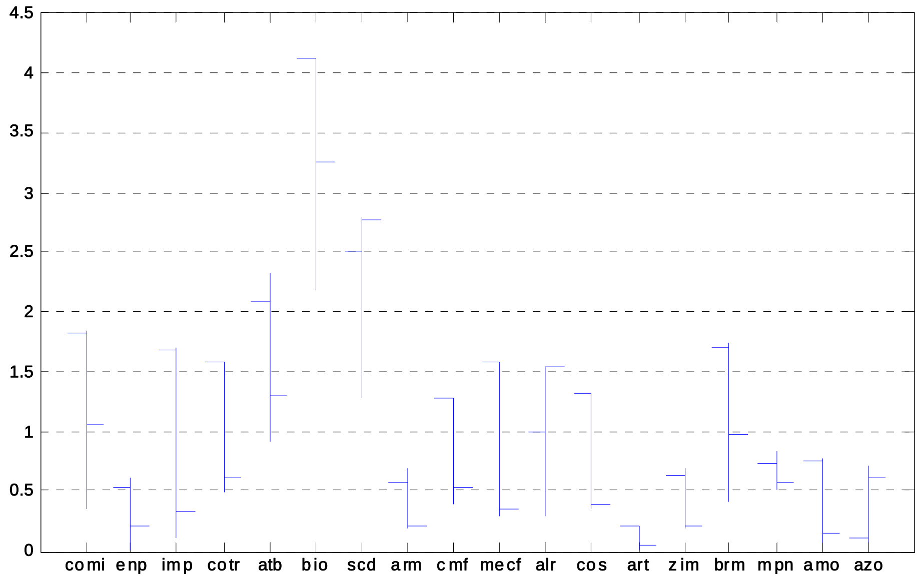


Figure 1b. Evolution of the distance to default between Jan. 2008 and Apr. 2011 for companies traded on BSE

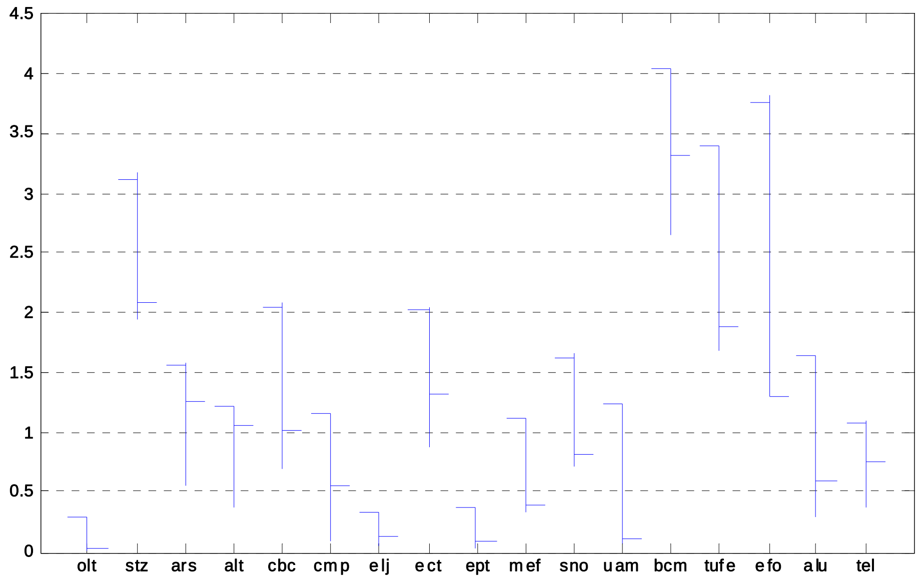


Figure 2a. Absolute decline of the distance to default

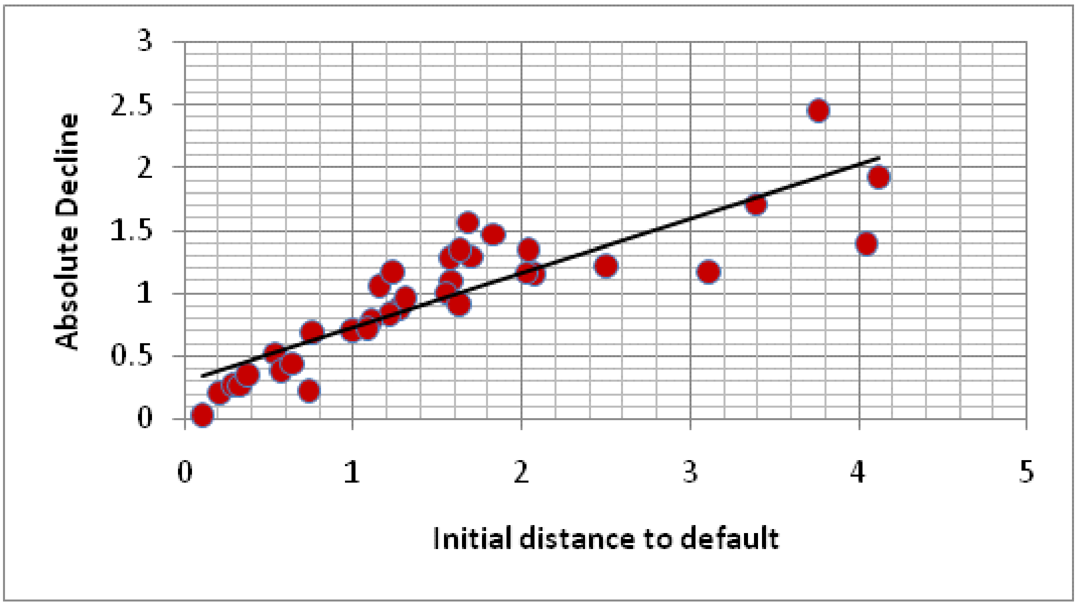


Figure 2b. Absolute decline of the distance to default

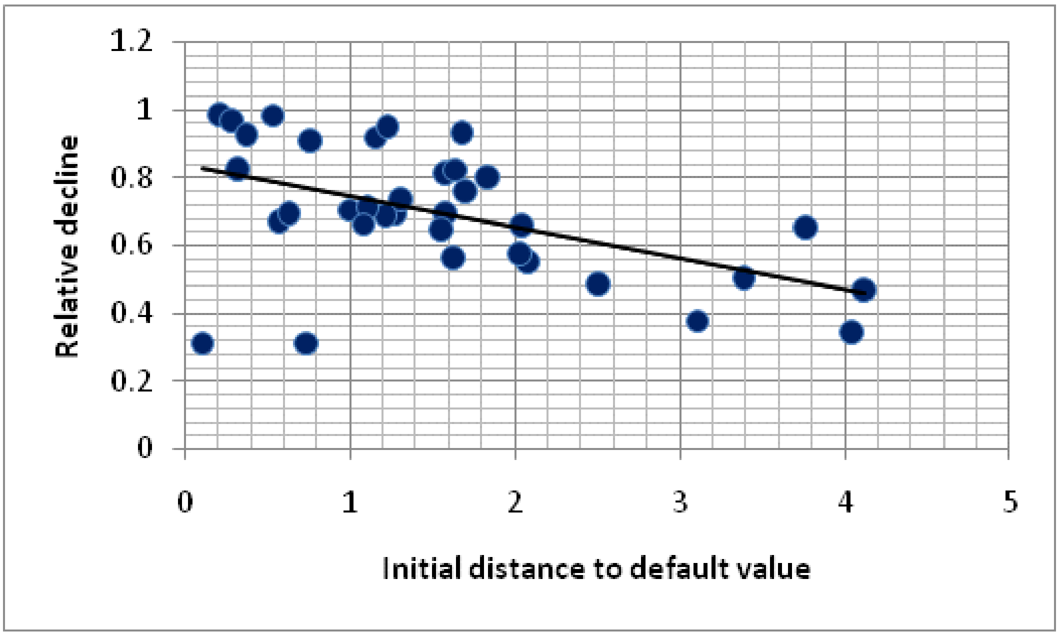
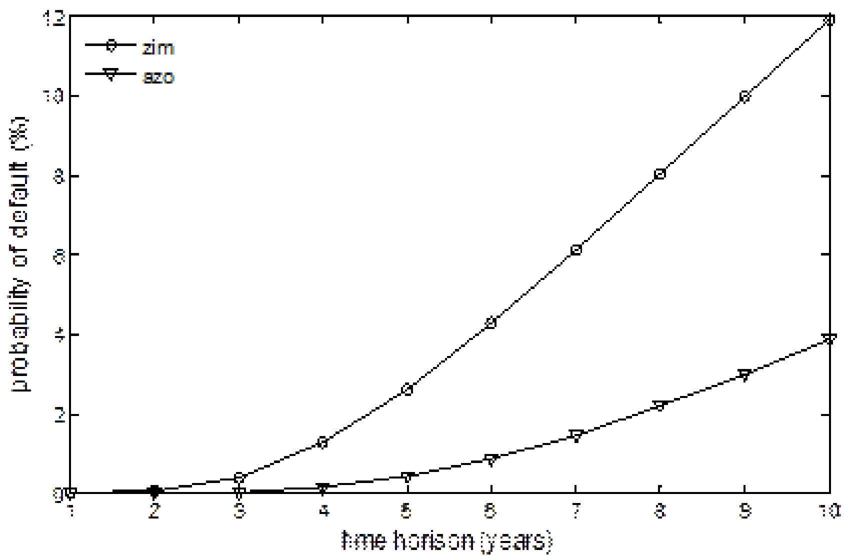


Figure 3. Probability of default
a. Initial probabilities of default



b. Final probabilities of default