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## **SIMULATION FOR THE ESTIMATION OF THE SURVIVAL PROBABILITIES OF ENTERPRISES AND BANKS WITHIN A PROLONGED DURATION OF THE DEBT CRISIS**

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### **ABSTRACT**

In the current paper, we study the stability and the survival probabilities of enterprises and banks within a prolonged duration of the debt-crisis, with Monte Carlo simulation. We utilize historical data from banks and enterprises within the debt-crisis to define crisis-variability and crisis-average values of input parameters of the simulation. We introduce the concept of equities maximum draw-down as dynamic survival indicator. Finally we estimate the survival probabilities of enterprises and banks within a prolonged duration of the debt crisis

**Key words:** Monte Carlo simulation, Bankruptcy probabilities, Debt-crisis, Bank stability

### **1. INTRODUCTION**

Non-parametric simulation and Monte Carlo simulation become particularly powerful in cases, where the final random variables, are derived from the other known input variables with complicated, combinatorial and non-linear equations. The use of the computers in such cases, is very effective, and the accuracy of the results rather impressive. In this paper we derive the probabilities of bankruptcy of various types of enterprises, within continuing economic crises, through the technique and geometric combinatorial indicator of Maximum Draw-down of Equities. That is why the Monte Carlo simulation here is indispensable. We had to code a special simulator, to compute the maximum Draw-down of equities. Other techniques in the bibliography, (e.g. see [1]) use in a rather arbitrary way classes of functional formulas for the probability, which try to simulate. We consider our method, more realistic. On the other hand the methodology in the paper [2] and [5] is closer to our approach. The concept of equities maximum draw down, is a technique that has been used extensively, in investments, especially through an algorithmic trading system, in investments in securities, futures over commodities, and spot interbank currencies foreign exchange cross-rates (Forex). Any serious investor in algorithmic trading, but also simple buy-and-hold investor would consider and try to measure it. Many modern platforms of back-tests of algorithmic trading, like Ttradestation, Metatreader4 etc have encapsulated the measurement of the equities maximum draw down.

But as far as I know we apply it for the first time, in assessing the risk and probability of bankruptcy in commercial business, banking, etc during the stress of the debt crisis, using Monte Carlo simulation. We also derive through the computer a quantitative relation (not in closed formulae, but in tables) between the debt-to-assets ratio, the horizon of the duration of the crisis and the survival probabilities.

### **2. THE ACCOUNTING AND DYNAMIC FINANCIAL MANAGEMENT POLICY EQUATIONS**

For the sake of the modelling and application of the simulation we need a minimalist accounting structure and financial management policies for a generic enterprise. So when we say "enterprise" in this paper, we assume a corporation or business organization that functions according to the next accounting equations, and financial management policies.

1. Balance sheet equation:

$$A_n = E_n + L_n \quad \text{E1}$$

where  $A_n$  is the total assets at the end of the year  $n$ ,  $E_n$  the total equities and  $L_n$  the total real liabilities again at year  $n$ . The above is a static equation.

2. Income statement equation:

$$I_n = R_n - E_n \quad E2$$

where  $I_n$  is the net income or profits at the end of the year  $n$ ,  $R_n$  the revenues and  $E_n$  the expenses again at year  $n$ .

3. Dynamic most probable policy equations:

$$\Delta A_{n+1} = I_n - D_n = \Delta E_{n+1} + \Delta L_{n+1} \text{ if } \Delta A_{n+1} > 0, \quad E3$$

where

$$\Delta A_{n+1} = A_{n+1} - A_n \quad E4$$

is the increase of the Assets,

$$\Delta L_{n+1} = L_{n+1} - L_n \quad E5$$

is the increase only ( $\Delta L_{n+1} \geq 0$ ) of the Liabilities and

$$\Delta E_{n+1} = E_{n+1} - E_n \quad E6$$

is the increase of the Equities, from year  $n$  to year  $n+1$ , and  $D_n$  are the dividends at the end of the year  $n$ . When the  $\Delta A_{n+1}$  is negative, that is, there is shrink of the assets, we assume for the liabilities

$$L_{n+1} = L_n \text{ or } \Delta L_{n+1} = 0, \quad E7$$

or that their level remains approximately the same (as inability to decrease them by paying capitals under stress), while the stress of shrinking is absorbed almost entirely from a corresponding decrease of the Equities

$$E_{n+1} < E_n \quad E8$$

(e.g. in the form of reduction of the working capital, or cash, or provisions etc.) On the other hand, when the assets are increasing, we assume that the Liabilities will be non-decreasing, and the Equities increasing but only so as to move as much and fast as possible to a fixed safe debt-to-assets ratio.

$$DtA_0 = \frac{L_n}{A_n} \quad E9$$

Thus new positive  $I_n - D_n > 0$  will increase the Equities if due to previous years of Assets decrease, we had

$$DtA_0 < \frac{L_n}{A_n} \quad E10$$

This also gives that years of decrease of the Assets, will also increase the debt-to-assets ratio

$$\frac{L_n}{A_n} \quad E11$$

and that this ratio never gets better than a safe  $DtA_0$ . The rule 3) here also gives, that whenever the assets are increasing so are the equities too, and whenever the assets are decreasing so are the equities too.

The bold criterion of survival is that the maximum draw-down of the assets, as decrease of the equities too, may be at most as much as the average equities-to-assets, ratio. If an enterprise after a sequence of bad years loses almost all of its equities (sufficient equities criterion) it cannot survive.

### 3. THE CONCEPT OF EQUITIES MAXIMUM DROWN-DOWN, AS DYNAMIC RISK INDICATOR FOR THE SURVIVAL, DURING CONTINUING CRISES

The precise definition of the maximum draw-down of a path (e.g. of equities) over time is the next.

Let a path of equities over  $n$  periods  $E1, E2, \dots, En$

A draw-down is any pair  $(Ei, Ej)$  as part of the path, with start  $Ei$ , and end  $Ej$  ( $1 \leq i < j \leq n$ ) such that it is a downward move:  $Ei > Ej$

Definition of Maximum Draw-Down of an equity path:

From all possible draw-downs of a path as above, any one such that the  $(Ei - Ej)$  is the maximum among all draw-downs is a maximum draw-down, of the path. There may be more than one for a path, but the value of  $(Ei - Ej)$  is unique.

In the next figure of a path, we have picked up the maximum draw-down part.

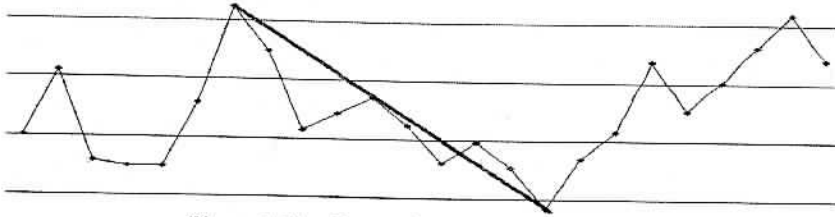


Figure 1. Equities and assets maximum draw-down

Due to the equations of dynamic policy, in paragraph 2 above, the years of a maximum draw-down in the path of equities is also simultaneously a maximum draw-down in the path of the assets too.

The significance of the maximum draw-down of equities as dynamic indicator for the stress for bankruptcy is quite obvious. During the years of a draw-down, the equities are successively decreasing, the debt-to-assets ratio successively increasing. Above a level of decrease, the working capital is exhausted and non-operational anymore, the cash is exhausted, and the equities are exhausted leading to unavoidable bankruptcy. The maximum draw-down defines also the maximum stress for bankruptcy during the time interval of the total path.

#### 4. THE SIMULATION EQUATIONS AND THE PROGRAM

We utilize Monte Carlo simulation to estimate the probability of bankruptcy (when the maximum draw-down of equities is above a critical value). This means of course that we utilize the uniform distribution derived by (pseudo) random numbers from the operational system of the computer, which are transformed to a normal distribution of the percentage of change of the assets. This of course gives a lognormal distribution of the assets at the end of each year.

To simulate the assets annual percentage change, as a normal random variable, we need not only the average value but also the standard deviation. These two parameters are derived from historical data, of various types of business.

The simulation equations are:

$$1) A_{n+1} = (1 + r_n) A_n$$

where  $r_n$  is the annual percentage change of the assets, from year  $n$  to year  $n+1$

$$2) \text{Average}(r_n) = r_0, \text{Standard Deviation}(r_n) = s_0$$

If  $u_n$  is the uniform random variable, with values between 0 and 1, derived from the computer operational system, then, the normal (Gaussian) random variable that simulates the normal  $r_n$  is

$$3) R_n = \text{Sqr}(-2\text{Log}(u_n))$$

$$4) V_n = R_n \text{Sin}(2\pi u_n)$$

where,  $\text{Sqr}$  is the square root function,  $\text{Log}$  is the natural logarithm function,  $\text{Sin}$  is the trigonometric sinusoidal function, and  $\pi$  is the well-known number 3.14159265

The  $V_n$  a normal random variable with average 0 and standard deviation 1.

$$5) r_n = r_0 + V_n s_0$$

This method of producing a normal random variable, from a uniform random variable is known as the Box-Muller transform method. (see e.g. [12]).

The stochastic process of assets, as produced, by the above equations, can be recognized also, as a discrete approximation of stochastic processes relevant to the geometric (exponential) Brownian motion, and the Wiener process, within the ITO's stochastic calculus. (see [14])

We have coded a special simulator, in the VBA programming language, of the MS-Excel, so as to compute the maximum draw-downs of the paths of assets (also of the equities), and their distribution and probabilities. Ordinary Monte-Carlo simulators would not do it, so we had to code a special program.

The coded simulator produces, samples of paths of the assets (here 10,000 paths), in a forward horizon of 5 or 11 years and also computes the maximum draw-down for each of these paths, as a percentage of the assets of that year. Finally it estimates an accumulative histogram of their frequencies-probabilities. We chose horizons of 5 years and 11 years, as 11 years is the global climate cycle (see [10]) and also half of the Kuznets (Nobel prize winner), business cycle of 22.2 years (see [11]).

## 5. THE HISTORICAL DATA

The historical data of enterprises are used to compute the average value  $r_0$  and standard deviation  $s_0$  of the annual percentage changes of the assets. They are used also to define the critical value of the equities maximum draw-down, above which the enterprise is lead to bankruptcy.

We utilized, 50 non-bank Greek enterprises that are listed in the Athens Stock Exchange market (FTSE/ASE 20, FTSE/ASE 40 & FTSE/ASE 80), with higher capitalization compared to the rest.

We calculated the  $r_0$ , and  $s_0$ , within the debt-crises, that is from 2008 till 2011

We also utilized all of the 14 Greek banks. We calculated the  $r_0$ , and  $s_0$ , within the debt-crises, that is from 2008 till 2010.

We may raise here the issue that the enterprises may overstate their achievements in their financial statements (see e.g. in the references the papers [15] and [16]). This is often unavoidable. In our case also some banks did not publish at all financial statements for 2011, that is why we used data from 2008 to 2010. We skip here this issue and we assume that the financial statements are fair enough.

## 6. THE SURVIVAL PROBABILITIES OF NON- BANK ENTERPRISES WITHIN A PROLONGED DURATION OF THE DEBT CRISIS.

Here we calculate with the simulator the survival probabilities for 5 years and for 11 years of continuing debt-crisis, for the average profile of 50 enterprises. The result is that they do not seem to be really in danger as a whole. But we also calculate 3 particular indicative cases that give lower probabilities of survival. The main positive feature of these companies is their rather high percentage of equities in the assets, or low capital structure leverage. If an enterprise has negative momentum, in the assets changes (decreasing assets), it is of higher risk. The same happens if it has low rate of increase of assets, but very high standard deviation of this rate.

Table 1

Name of the Enterprise	Equities to Assets ratio	Survival probability for 5 years of debt-crisis	Survival probability for 11 years of debt-crisis
Average of 50 enterprises	41%	100%	99.87%
MOH	21%	62.39%	30.39%
OPAP	55%	92.67%	79.28%
AVAX	23%	84.74%	61.89%

## 7. THE SURVIVAL PROBABILITIES OF BANKS WITHIN A PROLONGED DURATION OF THE DEBT CRISIS.

Here we calculate with the simulator the survival probabilities for 5 years and for 11 years of continuing debt-crisis, for the average profile of 14 banks, and for each bank separately. The result is that they do have significant risk and survival probabilities close to 60%, as a whole. Some banks are safe, with 100% probability of survival, but some cases give low survival probabilities. The banks as a whole have at least double the risk of bankruptcy, compared to the non-bank enterprises. The main risk factor here is the fractional reserve rule 1 to 10 or more, that gives very low percentage of the equities in the assets, or high capital structure leverage.

Table 2

Name of the Bank	Average Equities to Assets ratio	Survival probability for 5 years of debt-crisis	Survival probability for 11 years of debt-crisis
Average of 14 Banks	6%	59.88%	31.35%
National bank	9%	100%	100%
Alpha Bank	8%	58.36%	26.7%
Agricultural Bank (ATEbank)	3%	35.66%	16.55%
EFG Eurobank	7%	78.05%	52.48%
Bank of Cyprus	6%	100%	100%



Name of the Bank	Average Equities to Assets ratio	Survival probability for 5 years of debt-crisis	Survival probability for 11 years of debt-crisis
Marfin Egnatia Bank	5%	48.83%	20.66%
Piraeus Bank	6%	67.88%	38.48%
Post Bank	5%	41.58%	13.82%
Geniki Bank	5%	9.55%	0.39%
Proton Bank	10%	45.55%	17.81%
Attika Bank	10%	50.14%	20.58%
Emporiki Bank	3%	7.65%	0.14%
T Bank	4%	3.27%	0%

The next picture is the histogram of cumulative survival probabilities of the average profile of a bank. The probability in the y-axis e.g. 50.54% as in the above table, for a value e.g. 6% in the x-axis, and it gives the probability (of the maximum draw-down of assets) for a horizon of 5 years of debt crisis, to be 6% or less (not losing all the equities).

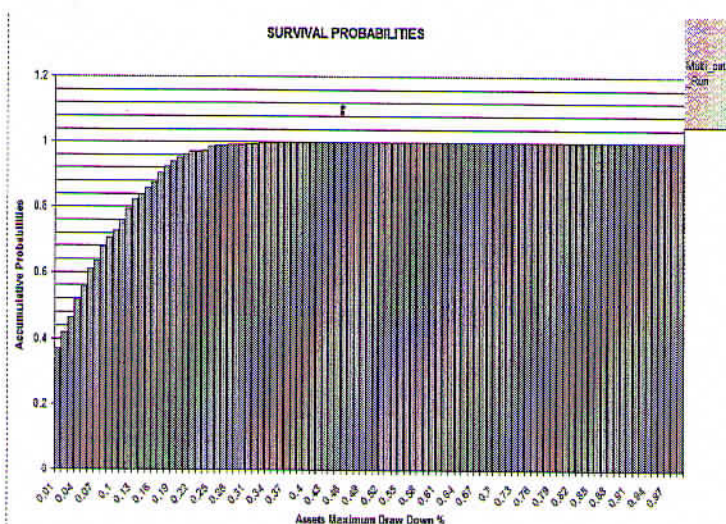


Figure 2

## 8. CONCLUSIONS

We conclude here that the banks are far more in danger, compared to the other enterprises, in a prolonged duration of the debt crisis. The survival probability of the average profile of a bank is about 60%. Of course the above results assume that the debt crisis will continue with a momentum neither worse nor better, for a horizon of 5 or 11 years. In addition that the financial management policy is the usual common sense, most probable decision making. Radical changes of the banks like merging, splitting, recapitalization etc are not included in the above simulation. More radical extraordinary financial management, as above, would improve the survival probabilities. The above analysis may be also considered a sophisticated fundamental analysis with simulation that can select less risky enterprises from the stock exchange market for a safer investment portfolio.

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