Journal of Applied Economics and Business Research
JAEBR, 5(3): 148-160 (2015)

Appliance of quality control charts for sovereign risk modelling

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Abstract

In this paper an attempt was made to apply a statistical control process to sovereign insolvency risk modelling in order to control and detect potential risk signals. Country risk of default is a subject to many surveys nowadays, however all currently applied advanced technics were unable to foresee the global financial crisis. This analysis showed the high efficiency of x bar r chart for detecting crisis signals, from both a time and country perspective and no suitability of the p and np chart which might have been a first choice in default- based research.

JEL Codes: C3; C5; G2

Keywords: *Risk; Control chart; Default*

1. Introduction

Country risk of default is the subject of many surveys nowadays. The models which have been applied have become complex and advanced, however they still haven't fulfilled the hopes pinned on them. They were not able to detect and foresee the global financial crisis of 2008 and subsequent bankruptcies. This was my motivation for searching for some easily-implemented, intuitive and simple tool, which can be supportive to control sovereign tendency to default. Possible application of control charts seems to be the right decision.

The aim of this paper is not to analyze the role of credit rating agencies in the global financial crisis, but to check whether ratings can be used to detect and to predict sovereign insolvency. There is no uniform interpretation concerning the role and the possible use of ratings for forecasting all sorts of crises. According to (Bussière & Ristiniemi, 2012) ratings are not suitable for predicting debt distress. (Reinhart, 2002) claim that ratings are not participating currency crisis buy are able to predict sovereign debt crisis, despite the fact that the financial crisis is related to the debt crisis in developing countries. (Sy, 2003) has confirmed results of Reinhart, but noted the inverse relationship between the two mentioned above crises.

Control charts have found, with success, application in industrial production processes, medicine, geology, finance and many others. However this technique has not been explored in the field of country risk monitoring and rarely in portfolio analysis, e.g., (Gandy, 2012). Therefore in this study I have analysed whether it is possible to model and control country risk of default with usage of some popular control charts and whether the produced signals can warn against solvency difficulties. The following analysis is based on ratings for 20 developed (D) and 21 emerging (E) countries published by Standard and Poor's, Moody's and Fitch, covering a period of 21 years, from 1994-2014 (see Table 1). I have used yearly sovereign ratings to

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check whether they have both crisis detection and prediction ability. Such a combination of input data gives a meaningful contribution into both the risk and control chart field of study.

The rest of the paper is organized as follows: Section 2 presents data chosen for the analysis. The outcome of appliance of the binomial control chart is described in Section 3. Section 4 and 5 introduce a transition approach and summarized results of adoption of x bar R chart. The summary ends with discussion and consideration in Section 6.

2. Data

In this study I used yearly ratings for 20 developed (D) and 21 emerging (E) countries published by Standard and Poor's, Moody's and Fitch, covering a period of 21 years, from 1994-2014 (see Table 1). The countries have been rated at different points of time, e.g., in the mid-90's disintegrated Yugoslav Republic, and a few years earlier USSR. This influences the number of sample size within the years. Additionally S&P don't publish ratings for Armenia and Moldova and Moody's for Serbia and Macedonia. This will cause a minor differences between the samples as well.

Table 1: Data sampled for 41 European Countries for the period 1994-2014

1994-2014	Serbia (E)	**1996-2014**	**1998-2014**
Armenia (E)	Spain (D)	Hungary (E)	Bulgaria (E)
Austria (D)	Sweden (D)	Kazakhstan (E)	Latvia (E)
Belgium (D)	Switzerland (D)	Malta (D)	Moldova (E)
Denmark (D)	Turkey (E)	Romania (E)	
Finland (D)	UK (D)	Russia (E)	**2000-2014**
France (D)		Slovakia (E)	Azerbaijan (E)
Germany (D)	**1995-2014**	Slovenia (E)	Island (D)
Ireland (D)	Czech Republic (E)		
Italy (D)	Greece (D)	**1997-2014**	**2001-2014**
Luxembourg (D)	Macedonia (E)	Croatia (E)	Ukraine (E)
Netherlands (D)	Poland (E)	Estonia (E)	
Norway (D)		Georgia (E)	**2002-2014**
Portugal (D)		Lithuania (E)	Cyprus (D)

Source: S&P, Author

Ratings published by agencies range from AAA to D or alternatively from Aaa to C, where AAA or Aaa is the highest possible rating, meaning extreme confidence for a country in paying its obligations and D or C means a default on debt. To keep the analysis as simple as possible, the number of ratings have been reduced from 25 possible stages to 5 (see Table 2).

Table 2: List of ratings used in the analysis

	S&P, Fitch	Moody
AA	AAA, AA+, AA, AA-,A+	Aaa,Aa1, Aa2, Aa3,A1
A	A, A-, BBB+, BBB, BBB-	A2, A3, Baa1, Baa2, Baa3
B	BB+, BB, BB-, B+, B	Ba1, Ba2, Ba3, B1, B2
C	B-, CCC+, CCC, CCC-, CC+	B3, Caa1, Caa2, Caa3
D	CC, CC-, C+, C, D	Ca,C

Within the investigated period 46% of all countries have been downgraded at least once in the yearly perspective, from which 63% are emerging and 37% are developed countries. It may seem that developing countries are unstable and more likely to change the rating. However, among the countries, which lowered the credit rating of more than once, dominating developed countries (57%) against emerging (42%). After 2008, this difference even more intensified for the benefit of developing countries 17% against 53% of the developed countries. It is visible

 ISSN 1927-033X

that developed nations were hit by the global financial crisis harder than the emerging economies.

Six years after the outbreak of the global financial crisis there is no consistent definition of default or insolvency of a country. In this paper I will use assumptions similar to those applied by (Ciarlone, et al. 2005): insolvency appears when a sovereign suffers a debt crisis, announces bankruptcy, or obtains strategic rescheduling, restructuring, or financial support from a financial institution such as the IMF or the Paris Club. For that reason, in the further analysis, in addition to rating (D) also credit rating C was taken into account the as a determinant of a sovereign distress.

Within the selected period only one clear case of bankruptcy has been declared by the rating agencies (Moldova 2002, when Moldova violated the IMF's and World Bank's loan conditions). The other two were recorded as highly vulnerable (Greece 2012, Moldova 2001). After taking into account countries with a (C and D rating) 21 cases of insolvency has been observed.

3. Binomial Control Chart

It is important to check, whether control chart can detect the abnormal default periods. For this reason I have decided to use a p and np chart, which assumes a binomial outcome of an event, usually a zero for non-default and one for an event of default.

The central line is calculated as an average of the recorded defaults and as an average ratio of the total number of defaults to the total sample size. The np and p central line equals 1.4 and 0.03 accordingly. The limit lines were set as three times standard deviation and adjusted by the unequal sample size. (For details concerning technique of calculation and construction of control charts see (Zontec, 2010), (Levinson, 2011), (Oakland, 2012).

The general rule is that the control chart should give a warning signal – the process is out of control, after exceeding upper (UL) or lower control (LL) limit. However, when applying control chart for detection of crisis indicators, an issue of concern are observations, which are out of control. For this reason the only relevant boundary is an upper control line, which in the optimal case shall cover all the extremes. Reaching the UL is a signal for process interference, as non-default is treated as a normal or even desirable state. Figure 1 and 2 shows, that none of the employed charts produced a warning signal. Only after setting a boundary equals 1sigma, p chart gave a signal for the year 1999, when 3 cases of default were recognized. The np chart was too resistant to any changes in the upper control line. It can be seen that the control limits deviate significantly from the central line, so that they could produce a signal. In literature many adjustments of the adopted limits have been discussed, e.g., (Ryan & Schwertman, 1997), who has investigated range of optimal control limits for u and c charts. (Winterbottom, 1993) and (Chen, 1998) have adopted the Cornish-Fisher expansion of quantiles to contract improved control limits for p chart. have made an effort to check, whether the limits proposed by them, would be more suitable for this analysis. However the adjusted control limits were also too inefficient to detect an abnormal default periods. Both p and np charts seem not to be sensitive enough to be useful for sovereign default risk analysis, due to the small number of defaults, followed by overly broad control limits.

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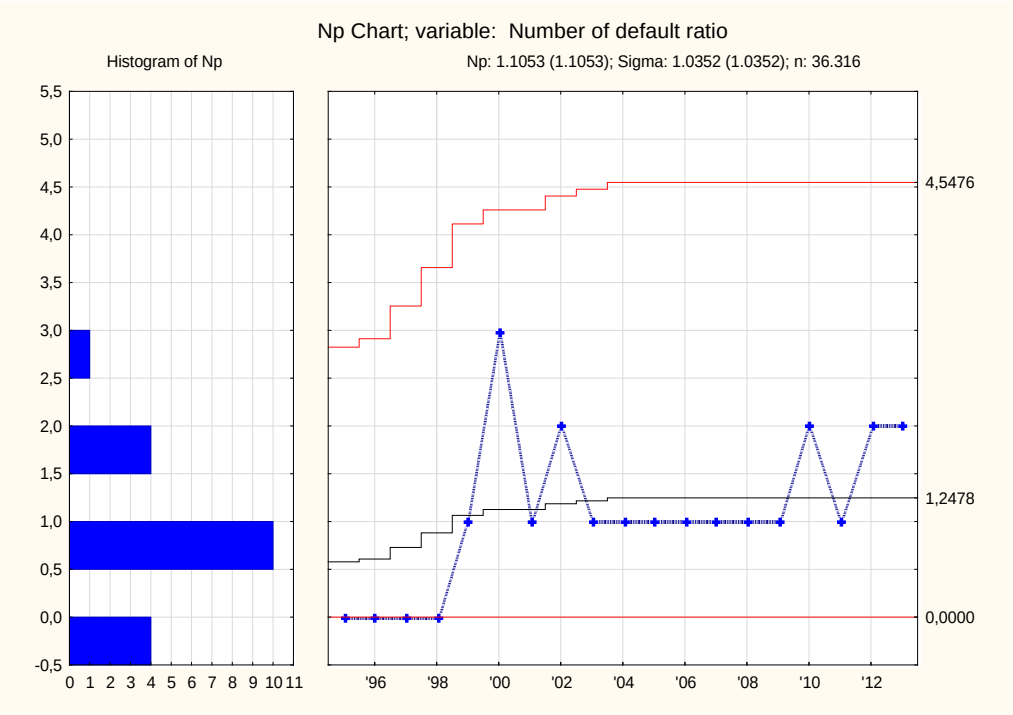

Figure 1: NP Control Chart for sovereign defaults, 3sigma Limit

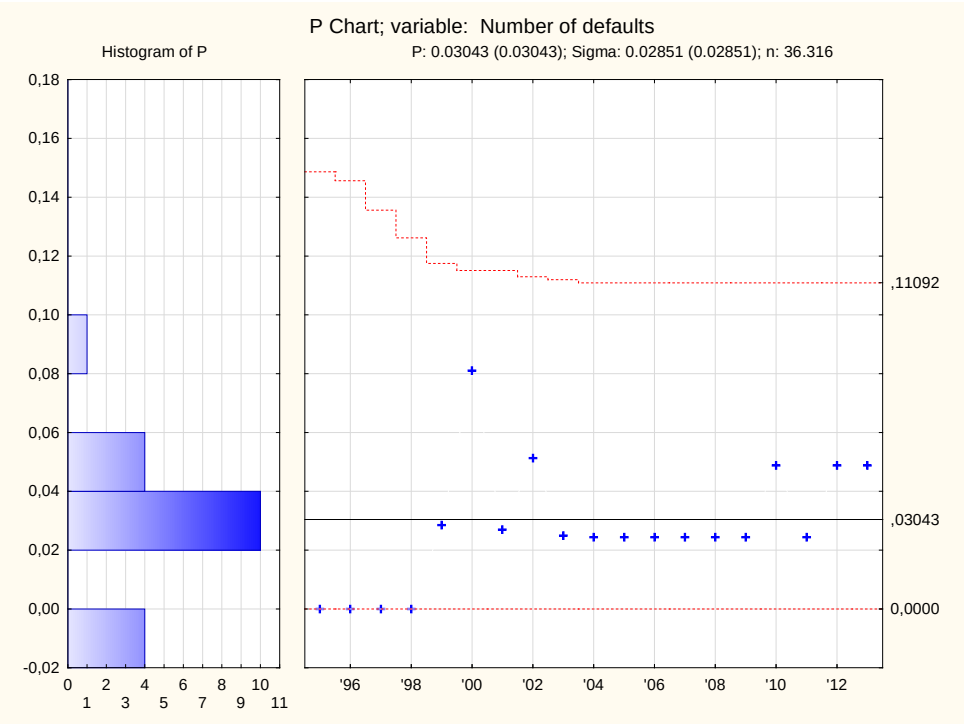

Figure 2: P Control Chart for sovereign defaults, 3sigma Limit

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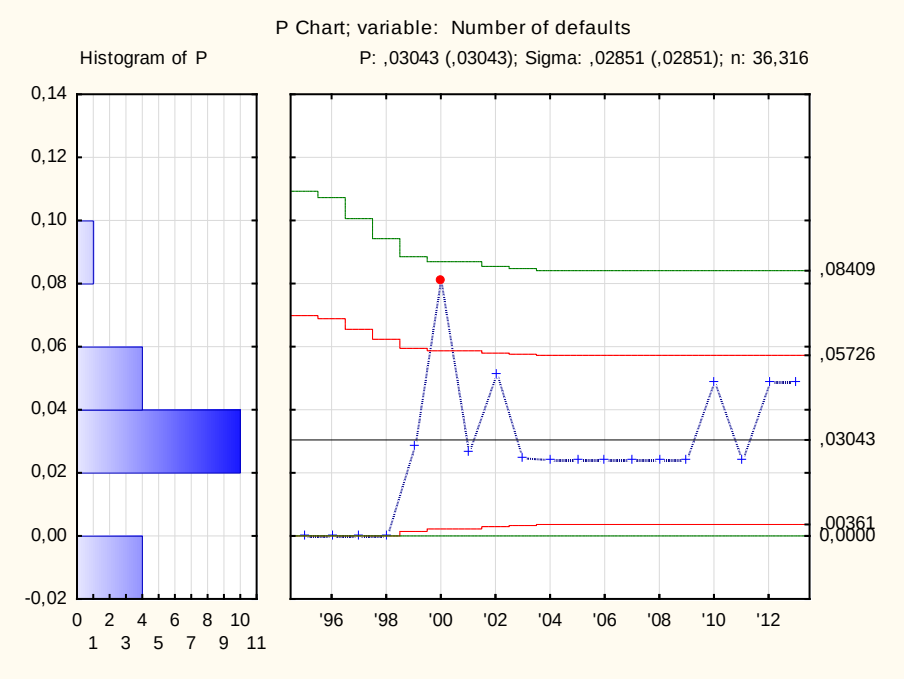

Figure 3: P Control Chart for sovereign defaults, 1sigma Limit

4. Range Chart

A way to overcome this issue was to transform a steady state into a dynamic process. In the initial situation a five-dimensional problem must be solved, as each country in every year may be rated from AA to D. It is thoughtful to construct a quasi-multivariate decision rule based on a p or np control chart constructed for each rating category separately. The decision rule would be $x_{\{it\}} - p_i > 3\sigma_i$, for at least one $i \in \{1,.,5\}$. What means that the quasi-multivariate control chart would signal a process inference, if at least one of the charts would produce a signal for a process being out of control. However, such an approach would in fact be reduced to a simple p or np chart presented above, because the probability of a country rated with AA being suddenly downgraded to C or D is extremely small, which is why the only charts that might produce any signal, would be the one based on rating C or D. Ergo, such an approach would overcome the dimensionality issue, but would not improve the results.

One solution, which at the same time may solve the problem of multidimensionality and introduces a dynamic factor into the model, is to apply of a one-year transition procedure. It should reflect a movement of rating within a set time frame.

The transition process is described as follows: each country at any point of time has an associated rating $R_{it} \in \{AA, A, B, C, D\}$. Rating grades have been denoted as consecutive integers $\{1,2,3,4,5\}$. S_{it} is the value in the transition state. In order to differentiate between up and downgrading, it can take values ranging from -4 to +4. $\bigwedge_{R_{i0}} S_{i0} = 0$, which means that the primary rating (regardless of its level) is set to 0. Zero is also possible, when $R_{it+1} = R_{it}$, meaning there were no changes in the ratings between two corresponding points in time. S_{it} can take value 4, when continuous upgrading is taking place or rapid changes were recognized:

$$S_{it} = 4\,;\begin{cases} R_{it+1} = R_{it} + 4\backslash(R_{it} = 0 \ \wedge \ R_{it+1} \neq R_{it}) \\ R_{it+1} = R_{it} + 3\backslash(R_{it} = 1 \wedge \ R_{it+1} \neq R_{it}) \\ R_{it+1} = R_{it} + 2\backslash(R_{it} = 2 \wedge \ R_{it+1} \neq R_{it})\,; \\ R_{\square t+1} = R_{it} + 1\backslash(R_{it} = 3 \wedge \ R_{it+1} \neq R_{it}) \\ \quad R_{it+1} > R_{it-m}; m \in \{0,1,2,3\} \end{cases} \tag{1}$$

 ISSN 1927-033X

where $(R_{it} + k); k \in \{1, \ldots, 4\}$, are the number of grades, by which the initial rating changed in t+1.

The same rules are valid for other possible values of S_{it}, which is why they will not be described here. In the Time view 41 and in the country view 20, subgroups have been created and the xbar R chart was applied.

5. Results

5.1 S&P

The central reference line is calculated as an average range, equal to 0.75 in the time view and 0.53 in the country view, supported by the upper control equals to adequately 0.99 and 0.84. The classification rule is similar as with other control charts. The process is under control, if the observations will not exceed the upper limit. Figure 4 presents the outcome of the analysis with usage of R control chart on S&P ratings.

Range chart is able to signal those periods being out of control, which range shift strongly from the mean of the process. The range chart has produced two warning signals for the years 2011 and 2012 considering the three sigma limit. It has mainly respond to a downgrading of Greece and Cyprus by a three rating grades. During that periods, the S&P has also lowered the credit rating for Croatia, Cyprus, Greece and Cyprus, Portugal, Slovakia, Slovenia, Spain respectively. It has correctly and timely anticipated the IMF loan request by Portugal (2011) and Spain (2012), but with a year delay responded to a request for a loan from Greece (2010) and did not consider the loan for Ireland (Q4 2010). Taking into account the limits of the two sigma, the R chart has also produced warning signals for the years 2001, 2004, 2008, 2010 and 2013. Year 2001 and 2004 were false alarms produced by this chart. The reason for this outcome is the low frequency of changes in the ratings. S&P holds ratings at the unchanged level by the most of the time. Predominantly the changes are made not rapid, mostly by one grade at the time. This results in the fact that even a change of 1 causes the alarm generated by the R chart.

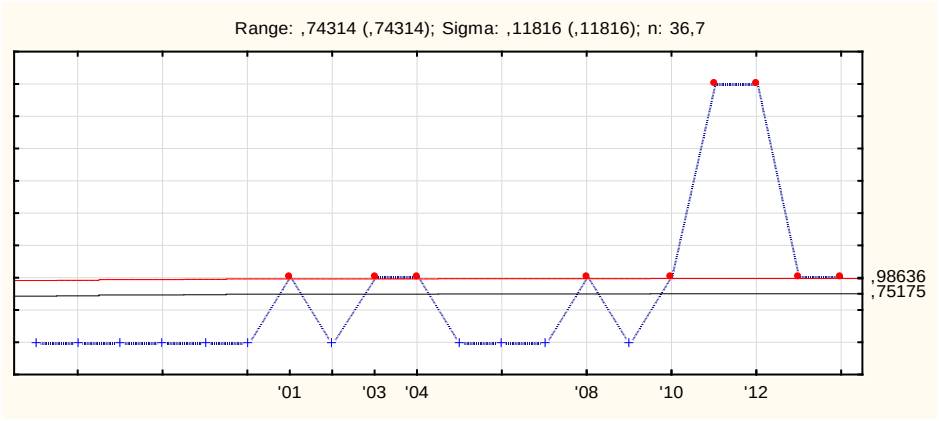

Figure 4:R chart for sovereign default, 2 sigma limit, time perspective

Supportive to the R chart, the x bar chart (see Figure 5) should be considered. It follows a mean of the process. The chart based on the average shows an interesting pattern. Starting from 1995 up to 2007 ratings have vary in the stable manner. We see a clear shift in the process in the year 2008, with the extreme in the year 2012. This is the year, when the world's economic meltdown started, Iceland declared bankruptcy, followed by Greek problems from the year 2009. It is important to notice, that year 2008 is the first warning signal, exactly one year before the real crisis appeared.

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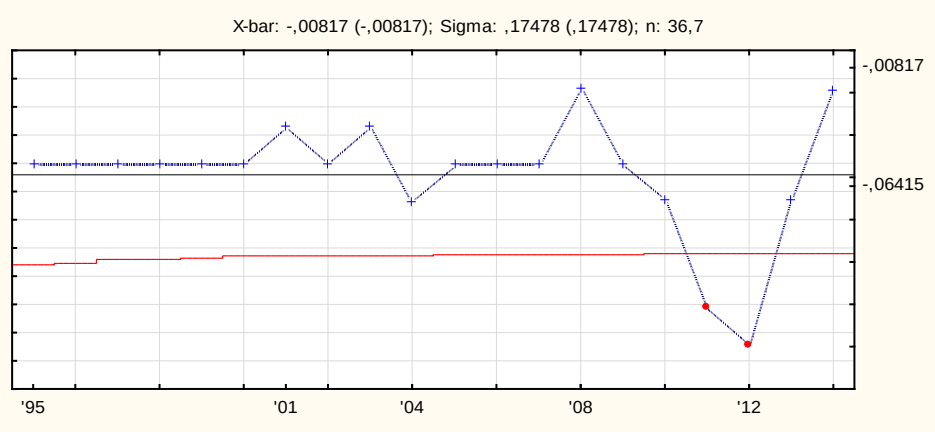

Figure 5: xbar chart for sovereign default, time perspective

Additionally it is worth seeing if the xbar R chart would be able to detect crisis episodes among countries within the sample period of 21 years. Figure 6 presents the results of applying xbar R chart from the country perspective (years have been treated as a subgroups). It is visible that the range chart has produced warning signals in the case of 12 countries: Azerbaijan, Croatia, Cyprus, Greece, , Latvia, Portugal, Romania, Russia, Slovakia, Slovenia, Spain and Ukraine. In the case of 3 of them (Latvia, Slovakia, Slovenia) false alarms were produced (The R chart does not recognized Moldova and Iceland as nations hit by the crisis. The appliance of 2 sigma limit would not decrease the misclassification rate or increase process efficiency.

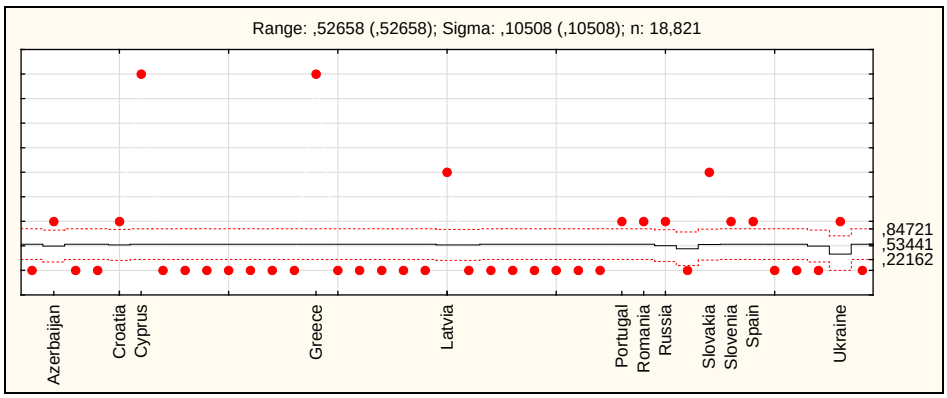

Figure 6: R chart for sovereign default, country perspective

The xbar chart (Figure 7) has produced even more strict results. The abnormal behaviour by the two sigma limit revel countries such as: Cyprus, Greece and Ukraine. Other four nations (Croatia, Portugal, Slovenia and Spain) deviate from the norm, but have not break the lower control limit, hence not produced the warning signal.

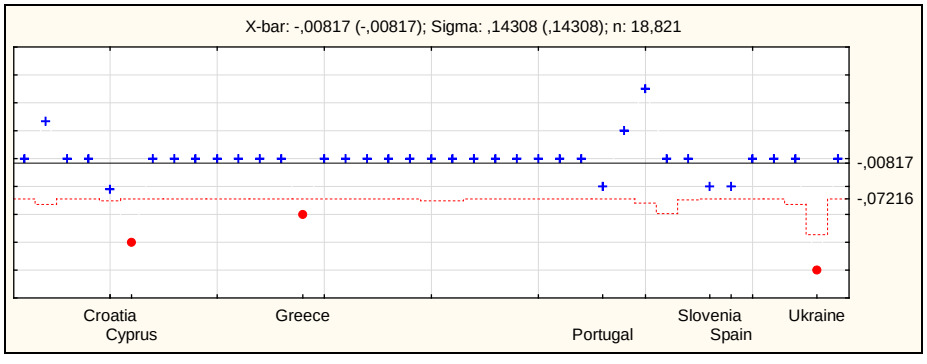

Figure 7: xbar chart for sovereign default, time perspective

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5.2 Moody's

Similar as above the central reference line is calculated as an average range, equal to 1.45 in the time view and 1.12 in the country view, supported by the upper control equals to adequately 1.92 and 1.77. Figure 8 presents the outcome of the analysis with usage of R control chart on Moody's ratings. By the three sigma limit the chart has produced warning signals for the years: 2010-2013. Moody has anticipated the IMF announcements quicker than S&P and has incorporated this news in the rating changes, these are: 2010 - the Greece loan; 2011 - Irish and Portuguese loan request to IMF and further collapse of Greeks economy, 2012 - Cyprus financial and banking crisis and finally 2013 – a technical false alarm produced by Slovenia, which had strong intern economical issued but has not requested for the IMF support, that is why according to the assumed definition, cannot be seen as a nation in a distress. Considering the two sigma limit, alarms appeared in years: 2000, 2002, 2006 and 2008. In case of Moody's year 2000 and 2002 were warning signal for Moldova, which has suffered a strong crisis in 2002 and 2003. According to Center for Social and Economic Research (Dabrowski, 2003) Moldova was on the verge of bankruptcy for the last couple of years. It has negotiated the financial support with IMF and the Paris Club, which has finally received at the end of 2002. Year 2006 was a false alarm, followed by 2008, when Moody's correctly anticipated the banking crisis in Island.

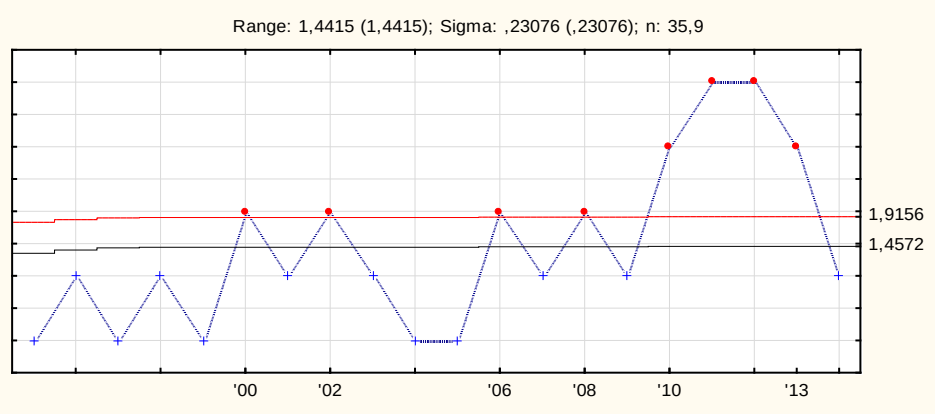

Figure 8: Range chart for sovereign default, time perspective

Compared to the mean chart for S&P, Moody's x bar chart (Figure 9), has signalled a beginning of a crisis in year 2007 already, but the shift was not so clear as I was the case of xbar chart based on S&P ratings. The extreme was set in 2011, when Moody's downgraded Greece by four grades, Ireland and Portugal by two and Cyprus, Hungary, Italy and Malta by a one grade. It has also shown, that between 1998 and 2002 there is a period of development. Except of Moldova, many countries were upgraded in that period, such as: Czech Republic, Estonia, Greece, Hungary, Kazakhstan, Lithuania, Russia, Slovakia, Slovenia and Ukraine.

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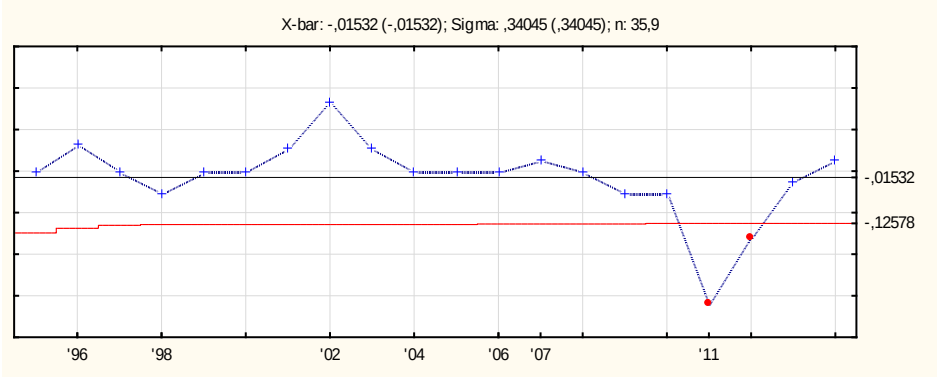

Figure 9: xbar chart for sovereign default, time perspective

The R chart based on Moody's ratings has detected warning signals for 14 nations (Figure 10): Croatia, Cyprus, Greece, Island, Ireland, Malta, Moldova, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia and Ukraine. Six countries (Croatia, Malta, Serbia, Hungary, Slovakia and Slovenia) have produced a false alarms. The supportive xbar chart (Figure 11) has pointed at Greece and Cyprus, as the nations, which have significantly deviate from the process mean. the other move more or less safely around its mean. In the case of Croatia, Portugal and Slovenia a negative trend is visible, a tendency to reach a lower limit needs to be observed and moderate.

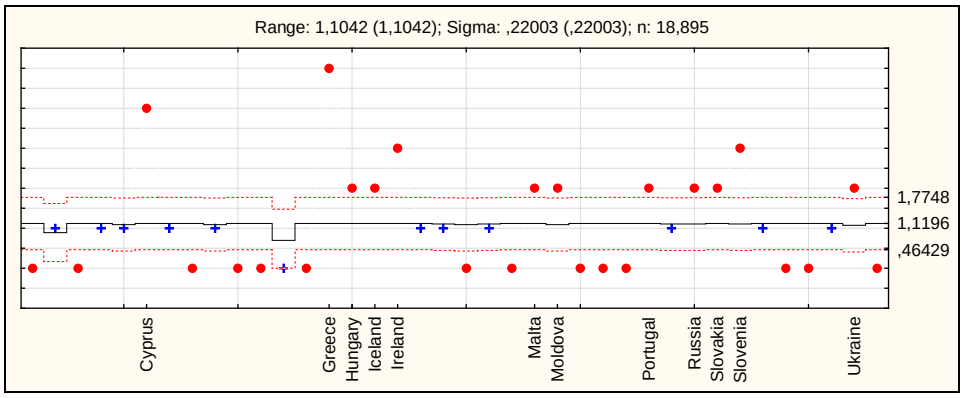

Figure 10: Range chart for sovereign default, country perspective

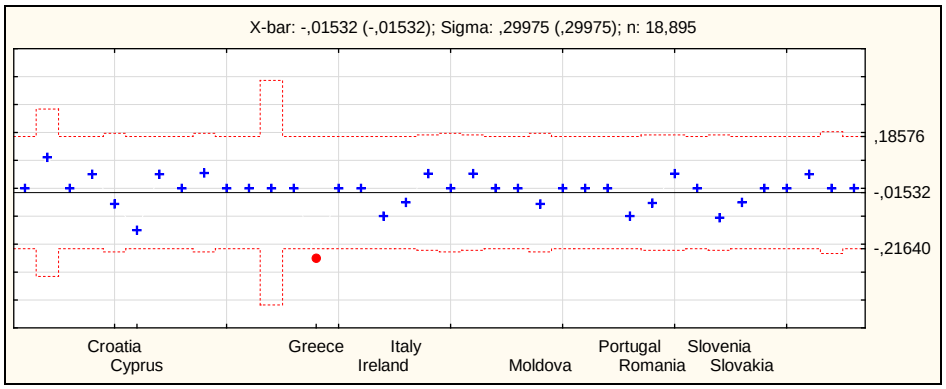

Figure 11: xbar chart for sovereign default, country perspective

5.3 Fitch

Similar as above the central reference line is calculated as an average range, equal to 1.30 in the time view and 0.96 in the country view, supported by the upper control equals to adequately 1.91 and 1.53. Figure 12 presents the outcome of the analysis with usage of R control chart on Fitch ratings. It is worth to mention, that R chart based of Fitch ratings has detected all warning signals by the three sigma limit already. These were the following years: 2001, 2003-2004, 2008, 2010-2013. Fitch seem to produce signals somewhere between S&P and Moody's

 ISSN 1927-033X

R charts. Year 2001 is a warning signal for Moldova, but year 2003, 2004 and 2013 are the false alarms. The chart has correctly recognised the bankruptcy of Iceland in 2008, the IMF loan for Ireland in 2010, Greeks and Portuguese problems in 2011, Cyprus crisis in 2012. The issue with the R chart based on Fitch ratings is, that despite the fact that frequent updating of ratings, the changes similar to S&P are minor. Fitch react faster than S&P but the reaction is toned. That is why even small changes in rating produces warning signals.

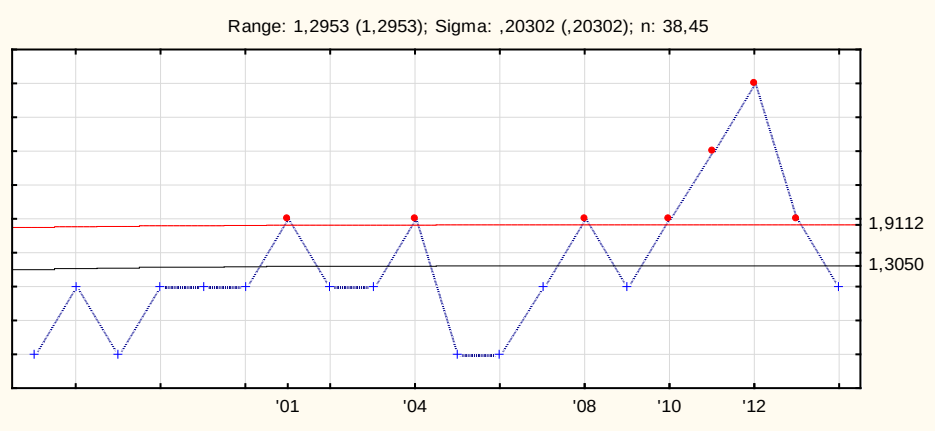

Figure 12: Range chart for sovereign default, time perspective

The x bar chart based on Fitch ratings (Figure 13), looks different than the other two presented above. It is less stable, the changes are clear and dynamic. The chart shows three cycles, one rising and two decreasing. The first decreasing one is between 1996 and 1999. This are the years when Ukraine, Bulgaria and Turkey have suffered some financial difficulties, and Russia received some support from the international financial institutions. No other chart presented above has pointed at this period. That negative trend is followed by a development phase started in the years 1999 and lasting up to the year 2004. And the third trend can be observed between 2007 and 2012, when the global financial crisis erupted.

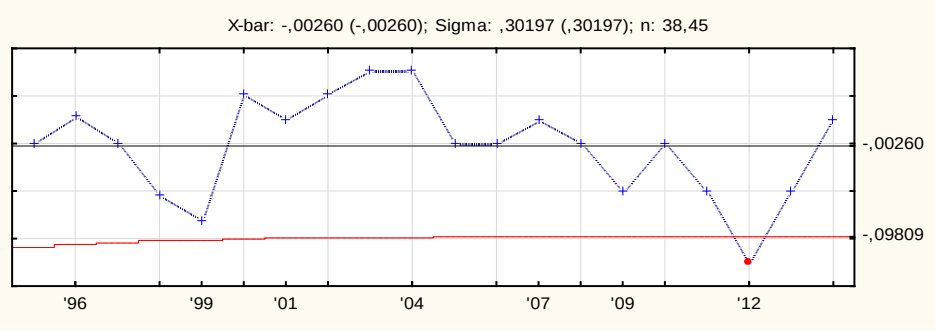

Figure 13: xbar chart for sovereign default, time perspective

Similar to R chart based on Moody's ratings, the Fitch R chart (Figure 14) has produced a warning signal for 14 countries: Croatia, Cyprus, Greece, Iceland, Latvia, Malta, Moldova, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia and Ukraine. This time five of them (Croatia, Malta, Serbia, Slovakia and Slovenia) produced a false alarm. The xbar chart (Figure 15) similar to the one based of S&P and Moody's rating detected Greece as the real process disturbance and pointed at Portugal as the nation, which must be observed and investigated. Other countries do not show movements pointing to a distortion of the process.

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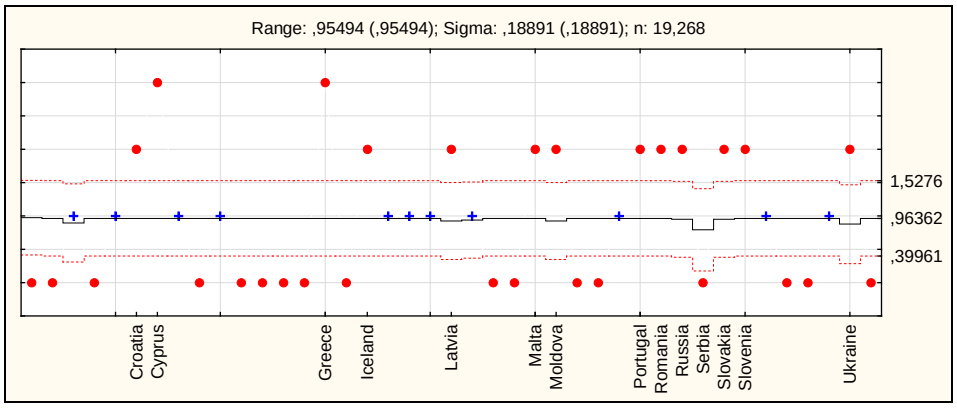

Figure 14: Range chart for sovereign default, country perspective

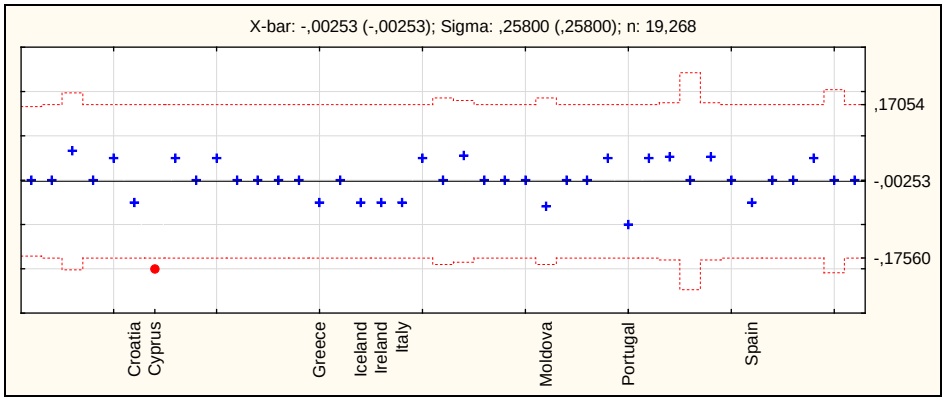

Figure 15: xbar chart for sovereign default, country perspective

6. Summary

The performed analysis has shown that statistical process control may also be used as a supportive tool for the analysis of a country distress. The analysis was based on sovereign ratings attained from the three biggest rating agencies: S&P, Moody's and Fitch. The main outcome of the analysis is that the xbar R chart is able to detect and in some cases even to predict the abnormal sovereign default periods from both time and country perspective. However there are significant differences within the individual results for each rating agency. The best results from the time perspective has been produced by the R chart constructed on the basis of the Moody's rating data. In this case the R chart has achieved the hit ratio of 44% within the 3 sigma and 67% within 2 sigma warning lines and the overall misclassification rate of 30%. The R chart based on the Fitch ratings has the same hit ratio of 56% regardless of the warning limits. The overall misclassification rate is the same as by the Moody's chart. S&P rating based R chart produced the lowest hit ratio of 22% by the 2 sigma and 56% by 3 sigma limits and overall misclassification rate of 45%.

The time perspective has delivered comparable results. S&P, Fitch and Moody's based chart has generated a hit ratio of ca. 42%-45% by 3 sigma and 64%-67% by 2 sigma limit and the overall misclassification rate of 21%-24%. The produced hit scores are comparable with the results produced by other, more advanced statistical methods like: 74% and 69% hit ratio using the Logit Model (Manase & Roubini, 2009) or (Ciarlone & Trebeschi, 2005), who have received results of 50%, 56% and 75% applying respectively binominal, multinomial model and CDS Spreads. The binomial control charts were not sensitive enough to detect insolvency cases (3 and 2 sigma Limit Lines gave no warning signals).

The additional information is provided by the xbar charts. All charts have signalled the coming global financial crisis in advance. The earliest signal (year 2007) was generated by the

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Moody's rating based chart. Other two have pointed at year 2008 as the beginning of the crisis. Also the duration of the crisis vary among the charts. Moody's proposed year 2011, S&P and Fitch year 2012, as the year from which the recovery started. It can be discuss, when the real crisis began, and when and whether the crisis ended and the recovery started. After all, the fact is that all xbar R charts has the ability to signal the crisis periods in advance and monitor its development. All presented mean charts can reflect both the positive and negative development cycles. It must be noted that the results are strongly dependent on the timing and frequency of rating updates. In this analysis Moody's and Fitch have generated far better results than S&P. Their updated were more determined and made more on a timely manner. They were better reflecting the economic condition of single nations.

However the described results should to be taken with caution, due to the analysed data set, which contains annual data of 20 developed and 21 emerging European countries. The covered period of 21 years is too short to make an explicit statement about the reliability of this method I was not possible to apply out of sample test because of the limited amount of crisis events. That is why the further analysis will be performed by involving the monthly data and the full range of rating grades, to confirm or improve the above presented results and by exceeding the analysed sample by other regions, where more default events occurred,. However, it can already be stated that the presented results are promising and perhaps control charts will find their wider use in the studied area.

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