

## APPLICATION OF MULTIDIMENSIONAL STATISTICAL METHODS IN STEEL INDUSTRY

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**Abstract:** The aim of this paper is to assess financial health of 49 companies in steel industry. Financial situation of the companies has been evaluated by cluster analysis. 13 financial ratios were reduced into 4 factors by using factor analysis. The dataset for financial analysis was in 2003-2012 and the focus is on crisis period 2008-2009 and after crisis period 2010-2012. Chinese companies grew throughout the whole period while European and American companies recorded losses in 2009.

**Keywords:** cluster analysis; financial ratios; factor analysis; principal analysis, steel industry.

**Note:** See the journal's instructions for authors for details on style. This document is a template for this journal.

### 1 INTRODUCTION

The aim of the paper is to present an application of factor analysis and cluster analysis in global steel industry. Steel production and metallurgy industry is key industry of world economy. Metallurgy industry employs directly more than two million people worldwide, with a further two million suppliers and four million people in supporting industries. The industry is the key product supplier to industries such as construction, automotive, transport, power and machine goods, etc. The housing and construction sector is the largest consumer of steel today, using around 50% of world steel production. Personal environment could be characterized by a multiplier of 25:1. The steel industry is at the source of employment for more than 50 million people [1].

### 2 LITERATURE REVIEW

Other approaches for diagnosis of financial situation are for instance discrimination analysis which was firstly applied by [4], rough sets [5], fuzzy and neural networks [6]. Cluster analysis was selected because it classifies objects into homogenous groups that are described by several parameters. This method was used in many studies for example [7], [8] and [9].

### 3 DATA

The data were obtained from the financial reports (especially balance sheet, profit and loss statement and cash flow statement) from annual reports available in companies' websites from 2003 to 2012 (Table 1-appendix). The companies applied in the analysis were selected from the list of top steel producers in the world [10]. The sample consists of about 41 % world production [2].

There were some changes in the sample, i.e. M&A and rename. In 2007 Arcelor S.A (ARCE) and Mittal Steel Company N.V. (MITTAL) merged. BlueScope Steel Limited (BLUE) acquired Smorgon Steel (SMORGON), Tata steel (TATA) took over Corus Group (CORUS). Nippon steel Corporation (Nippon) and Sumitomo Metals Corporation (Sumitomo) merged in October 2012. New company is called Nippon steel Sumitomo Metals Corporation (NSSMC). Onesteel was renamed "Arrium" on 08.05.2012. JFE steel (JFE) has not published its annual reports since 2008 but only within JFE Holding. Hadeed from Saudi Arabia does not publish its annual reports individually but only within the holding. The data were collected from annual reports available on the websites.

### 4 METHODS

Individual companies were characterized by 12 financial ratios (FPU). The ratios are presented in Table 1. All of used multivariate statistical methods can be found for instance in [11]. Aim of cluster analysis (CA) is to classify companies into clusters by FPU. Factor analysis (FA) has to be used because number of companies and number of FPU does not meet criteria suggested by [12]:

- (1)  $2^k \leq n$
- (2)  $5 * 2^k \leq n$

where n – number of companies:

k – number of FPU.

Equation (1) is applied as it is not so rigid and it reflects more nature of the data. It is important to emphasize that these criteria are not only one. See e.g.

[13]. The objective of FA is to find hidden, latent variables form original data. Requirement is that new latent variables explain as much of variance of original variables as possible. These new variables simplify financial and economic analysis and consequently it is easier to read and interpret.

Ratio name	Ratio abbreviation	Details
Inventory turnover	INVTUR	INVTUR=total revenues/inventories
Receivables turnover	RECTUR	RECTUR=total revenues/short term receivables
Asset turnover	ASTUR	ASTUR=total revenues/total assets
Cash ratio	L1	L1=cash/short term liabilities
Quick ratio	L2	L2=(cash+short term receivables)/short term liabilities
Total liquidity	L3	L3=(cash+short term receivables+inventories)/short term liabilities
Debt ratio	DEBTRAT	DEBTRAT=total liabilities/total assets
Insolvency	Insolv	Insolv=current liabilities/current receivables
Return on assets	ROA	ROA = EBT/total assets
Return on equity	ROE	ROE=EBT/total shareholder equity
Return on sales	ROS	ROS=EBT/total revenues
Current ratio	Curratio	Curratio=current assets/current liabilities

Table 1. List of FPU

The aim of CA is to categorize companies into homogenous groups. Hence companies with similar FPU or factors are classified into the same cluster. Vice versa, companies in different clusters should vary. Euclidean distance was employed.

Now the focus will be on the hierarchical Cluster Analysis (HCA) and Non - hierarchical Cluster Analysis. At the beginning of HCA each cluster consists of only one company. Later the clusters integrate into groups with more companies and in the end all companies are in the same cluster. Graphical result of HCA is dendrogram. The advantage of this procedure is that the exact number of clusters is not necessary. Example of Non- hierarchical CA is k-means clustering where the exact number of clusters is required. SPSS 18 program will be used for the execution of the analysis.

## 5 RESULTS

At the beginning of FA interdependences of FPU should be analyzed. The structure of interdependence

will be measured by correlation matrix (Tab. 3).

The range of correlation coefficient is between -0,510 and 0,924. Consequently it is possible to state there is a strong relationship among the variables.

	1	2	3	4	5	6
1	1,000	0,207	0,456	0,239	0,278	0,104
2	0,207	1,000	0,149	0,129	-0,097	-0,022
3	0,456	0,149	1,000	0,066	0,272	0,327
4	0,239	0,129	0,066	1,000	0,857	0,706
5	0,278	-0,097	0,272	0,857	1,000	0,924
6	0,104	-0,022	0,327	0,706	0,924	1,000
7	-0,130	-0,028	-0,105	-0,373	-0,467	-0,501
8	-0,097	0,637	-0,297	-0,160	-0,471	-0,510
9	0,426	0,240	0,269	0,350	0,320	0,230
10	0,345	0,222	0,208	0,193	0,158	0,092
11	0,307	0,173	-0,030	0,371	0,295	0,176
12	0,099	0,001	0,211	0,614	0,805	0,879

Table 3. Correlation matrix

Notes:

- 1 INVTUR
- 2 RECTUR
- 3 ASTUR
- 4 L1
- 5 L2
- 6 L3
- 7 DEBTRAT
- 8 Insolv
- 9 ROA
- 10 ROE
- 11 ROS
- 12 Curratio

	7	8	9	10	11	12
1	-0,130	-0,097	0,426	0,345	0,307	0,099
2	-0,028	0,637	0,240	0,222	0,173	0,001
3	-0,105	-0,297	0,269	0,208	-0,030	0,211
4	-0,373	-0,160	0,350	0,193	0,371	0,614
5	-0,467	-0,471	0,320	0,158	0,295	0,805
6	-0,501	-0,510	0,230	0,092	0,176	0,879
7	1,000	0,313	-0,324	-0,049	-0,306	-0,496
8	0,313	1,000	-0,041	0,018	0,000	-0,464
9	-0,324	-0,041	1,000	0,845	0,882	0,279
10	-0,049	0,018	0,845	1,000	0,806	0,136
11	-0,306	0,000	0,882	0,806	1,000	0,277
12	-0,496	-0,464	0,279	0,136	0,277	1,000

Table 3. Correlation matrix (cont)

Results of correlation analysis are not very surprising as the relations among financial ratios are given by their formulas, for example RECTUR and ASTUR are positively correlated because total revenues are in numerator. An opposite situation is between Insolv and L3, where receivables are in Insolv in numerator and in latter one in denominator. Factor analysis is performed using PCA. As twelve input variables were considered, the maximum number of factors could be twelve. The aim is to extract as small

number of dominant factors as possible. These factors ought to explain most of original variance. The dominant factors will be selected those, which the total eigenvalue is greater than 1 (Table 4).

Other factors explain less than 1, i.e. they explain less than the original variable (the fifth factor only 0,734). New four factors explain 82,478% of original variance. Thus a substantial reduction in dimension of the original space has been achieved, i.e. from 12 to 4 dimensions in sustaining a good degree of explanation of the original variance. Theory of FA contends that explained variance could be lower than one (from 70% to 90%), [11] assert that 60% explanation of variance is believed to be sufficient in social sciences. As a result first two factors are perceived as satisfactory. First two factors explain more than twice as the second pair of factors does so.

Initial Eigenvalues			
	Total	% of Variance	Cumulative %
1	4,667	38,894	38,894
2	2,603	21,690	60,584
3	1,351	11,255	71,840
4	1,277	10,638	82,478
5	0,734	6,120	88,597
6	0,633	5,271	93,868
7	0,301	2,511	96,379
8	0,154	1,283	97,662
9	0,124	1,035	98,697
10	0,080	0,669	99,367
11	0,066	0,548	99,915
12	0,010	0,085	100,000

Table 4. Extracted factors

	Component			
	1	2	3	4
INVTUR	0,082	0,331	0,101	0,725
RECTUR	0,046	0,127	0,917	0,200
ASTUR	0,136	0,001	-0,063	0,910
L1	0,840	0,191	0,170	0,002
L2	0,927	0,113	-0,139	0,180
L3	0,936	-0,010	-0,135	0,177
DEBTRAT	-0,607	-0,182	0,091	0,007
Insolv	-0,380	0,028	0,845	-0,236
ROA	0,219	0,910	0,072	0,222
ROE	0,018	0,909	0,056	0,191
ROS	0,228	0,942	0,057	-0,065
Curratio	0,883	0,086	-0,124	0,081

Table 5. Rotated Component Matrix, Extraction method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization.

The original FPU could be matched with four dominant factors by the highest regression coefficient (Table 4). Based on the above selection criteria the

factors can be named as follows: factor of liquidity, factor of profitability, factor of activity without RECTUR and mixed factor. DEBTRAT has not been matched with any factor as it has a quite low regression coefficient. Last factor comprises of FPU that they have receivables in denominator.

## 5.1 RESULTS OF CLUSTER ANALYSIS

Cluster analysis has been conducted based on four financial ratios. Financial ratios with the highest regression coefficients were selected, i.e. L3, ROS, RECTUR and ASTUR. Correlation matrix of four out of them is presented of illustration (Tab. 6).

		RECTUR	ASTUR	L3	ROS
RECTUR	Pearson Correlation	1	0,149**	-0,022	0,173*
	Sig. (2-tailed)		0,002	0,654	0,000
	N	421	421	421	421
ASTUR	Pearson Correlation	0,149**	1	0,327**	-0,030
	Sig. (2-tailed)	0,002		0,000	0,543
	N	421	421	421	421
L3	Pearson Correlation	-0,022	0,327**	1	0,176*
	Sig. (2-tailed)	0,654	0,000		0,000
	N	421	421	421	421
ROS	Pearson Correlation	0,173**	-0,030	0,176**	1
	Sig. (2-tailed)	0,000	0,543	0,000	
	N	421	421	421	421

Notes: \*\*. Correlation is significant at the 0.01 level (2-tailed).

Table 6. Correlation matrix of four financial ratios

Table 6 shows that correlation coefficients are in range from -0,030 to 0,327. If a test of significance is used at 5% level, between L3 and RECTUR or between ROS and ASTUR does not have to be any relation. The presented range indicates this group of financial ratios is “more orthogonal” than the group of all used ratios. Cluster centers are presented in next tables and its member companies. Cluster analysis is conducted by the four financial ratios.

The companies are sorted by the distance from the cluster center from the closest to the furthest. The number of clusters was determined aiming they are equally numerous. If five cluster were determined, in some occasions there would be one company in the cluster. [13] points out a theory of CA and FA. She confirms the idea of [14] that states the problem of optimal number of clusters is as old as clustering itself.

The number of clusters selected a priori has a major impact on the result. Only 2008 – 2012 are presented for illustration. The most numerous clusters

demonstrate the trend of the whole industry.

Cluster 1	Maanshan, Mechel
Cluster 2	ARCMITT ,SDI ,CSN ,NUCOR ,EVR ,ISCOR
Cluster 3	ISTEEL ,POSCO ,Essar ,THYSS ,VOEST ,Nippon ,USSKE ,Vizag ,Metinves,JSW ,HYUNDAI ,TATA ,Kobe ,Outokump, Shougang, NLMK ,WORTH ,RUUKKI ,CMC ,Sumitomo
Cluster 4	BLUE ,MMK ,Nisshin ,SSAB ,EVRAZ SA,Erdemir ,USS ,Angang ,SEVER ,Metallo ,SAIL ,Dongkuk ,GERD ,Baosteel,SALZG

Table 7. Member companies in 2008

	Cluster			
	1	2	3	4
RECTUR	21,782	17,470	6,423	10,170
ASTUR	0,942	1,216	1,036	1,028
L3	0,662	1,930	1,459	1,636
ROS	0,069	0,166	0,109	0,101

Table 8. Cluster centers in 2008

Cluster 1	Mechel ,CSN ,ARCMITT ,ISCOR ,WORTH
Cluster 2	SDI ,GERD ,ISTEEL ,SEVER ,EVR ,SALZG ,CMC ,BLUE ,Hyundai ,Baosteel,NUCOR
Cluster 3	Nisshin ,SAIL ,VOEST ,Vizag ,THYSS ,Nippon ,RUUKKI ,SSAB ,Ezz ,Dongkuk ,POSCO ,MMK ,Metallo ,NLMK ,USSKE ,Kobe ,Outokump, AHMSA ,EVRAZ SA,Erdemir ,USS ,Maanshan
Cluster 4	Metinves,Angang ,Sumitomo,JSW ,TATA ,Shougang

Table 9. Member companies in 2009

Values of RECTUR demonstrate that destocking of inventories took place in 2008. Also values of ASTUR were higher in 2008. This indicates selling of other assets not only inventories. Another explanation is shutting down of inefficient mills. A decrease of ROS was observed.

	Cluster			
	1	2	3	4
RECTUR	12,492	9,511	6,286	2,997
ASTUR	0,836	0,849	0,681	0,521
L3	1,371	1,864	1,361	1,403
ROS	0,071	0,050	0,042	0,081

Table 10. Cluster centers 2009

Cluster 1	CSN ,Hyundai ,MMK ,GERD ,AHMSA ,NUCOR ,BLUE ,Erdemir ,Baosteel, SDI ,ARCMITT ,SEVER
Cluster 2	Ezz ,ISCOR
Cluster 3	POSCO ,THYSS ,VOEST ,ISTEEL ,WORTH ,NLMK ,Nippon ,Angang ,Metallo ,TATA ,CMC ,Nisshin ,Mechel ,EVRAZ SA,RUUKKI ,EVR ,USS ,SALZG
Cluster 4	Kobe ,Dongkuk ,Vizag ,SAIL ,Shougang, Maanshan, Outokump, USSKE ,SSAB ,JSW ,Metinves,Sumitomo

Table 11. Member companies in 2010

	Cluster			
	1	2	3	4
RECTUR	10,635	18,101	7,067	4,405
ASTUR	0,757	0,903	0,920	0,721
L3	1,499	1,794	1,543	1,114
ROS	0,067	0,052	0,044	0,059

Table 12. Cluster centers in 2010

A decrease of L3 has been witnessed. It could be a consequence of destocking of inventories. In other words, mainly amount of inventories diminished. Mostly RECTUR decreased. It can be interpreted that a recovery occurred and amount of receivables increased. ASTUR increased. It can be understood that revenues rose.

Cluster 1	EZZ ,JSW
Cluster 2	Metallo ,EVR ,ISCOR ,SEVER ,ARCMITT ,MMK ,NUCOR
Cluster 3	Tata ,BLUE ,THYSS ,USS ,AHMSA ,GERD ,SAIL ,ISTEEL ,Nippon ,Angang ,CMC ,CSN ,Erdemir ,NLMK ,Sumitomo, EVRAZ SA,SDI
Cluster 4	POSCO ,Maanshan, Mechel ,Hyundai ,Dongkuk ,Baosteel, USSKE ,Outokump, WORTH ,VOEST ,Nisshin ,RUUKKI ,Vizag ,ESSAR ,Kobe ,Metinves, SSAB ,SALZG ,Shougang

Table 13. Member companies in 2011

EZZ and JSW might destock their inventories. ASTUR increased due to higher revenues but the interpretation should be cautious if these revenues rose only because of destocking inventories or real economic activity.

	Cluster			
	1	2	3	4
RECTUR	22,376	13,492	8,994	5,884
ASTUR	0,788	0,926	0,942	0,896
L3	0,637	1,572	1,426	1,281
ROS	0,060	0,070	0,040	0,031

Table 14. Cluster centers in 2011

Zhluk 1	Metallo ,NUCOR ,AHMSA ,GERD ,SEVER ,SAIL ,MMK ,SDI
Zhluk 2	JSW ,EZZ ,ISCOR ,ARCMITT
Zhluk 3	NLMK ,ISTEEL ,RUUKKI ,BLUE ,THYSS ,NSSMC ,EVR ,EVRAZ SA,USSKE ,SSAB ,Erdemir ,USS ,Baosteel,VOEST ,Nisshin ,Hyundai ,CSN ,Tata ,CMC ,Mechel ,POSCO
Zhluk 4	Outokump,Angang ,Kobe ,Dongkuk ,Metinves,Shougang,Maanshan,ESSA R ,SALZG ,WORTH ,Vizag

Table 15. Member companies in 2012

	Cluster			
	1	2	3	4
L3	1,731	1,207	1,399	1,104
RECTUR	11,736	18,306	8,185	4,861
ASTUR	0,845	0,852	0,929	0,768
ROS	0,057	-0,006	-0,014	-0,051

Table 16. Cluster centers in 2012

Destocking of inventories continued in some companies in 2012. Profitability was the worst since 2003. Many companies incurred losses. It should be emphasised that Metallo is not only steel but also mining company and it owns one of the largest reserve base in the world.

## 6 TWO DIMENSIONS

Another way how to observe a trend in global steel industry is to apply multidimensional statistical methods, i.e. two factors that have explained most of variance. Liquidity and profitability factors are presented in following figures.

In 2003 it can be seen that companies are deployed relatively equally from profitability axis. An extreme value was USS, it had biggest losses. Some companies had higher values of liquidity factor.

In 2004 an improvement of situation can be observed in terms of profitability, i.e. an increase of values of profitability factor. On the other hand, decrease of liquidity factor was observed. However, Salzg and NLMK had relatively high values.

In 2005 it can be seen that companies are deployed mostly in positive part of profitability factor. Tata and CSN had highest values of profitability. NLMK had relatively high value of liquidity factor.

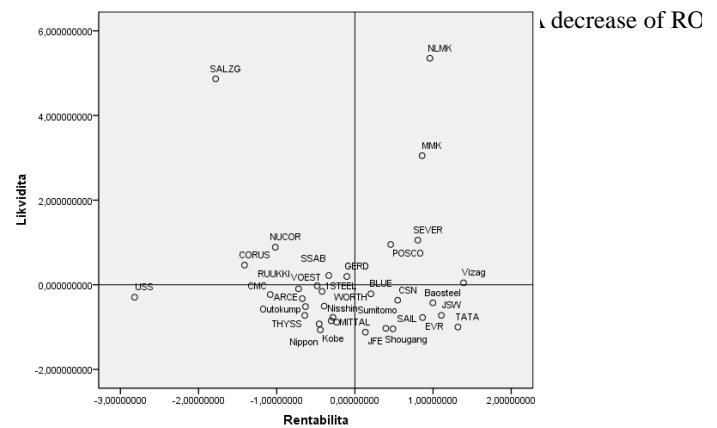


Figure. 1 Situation in industry in 2003  
Notes: likvidita – liquidity factor Rentabilita – profitability factor

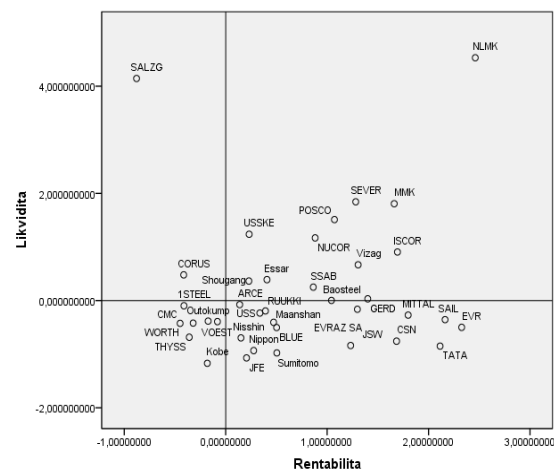


Figure 2. Situation in industry in 2004

In 2006 it can be seen that most of companies had positive values of profitability factor and various values of liquidity factor. ISCOR and Salzg had extreme values of liquidity factor. In 2007 it can be seen that companies are deployed throughout the figure with high values of profitability factor. The year was the most successful over the period, although in last quarter financial crisis started.

In 2008 it can be seen that companies are deployed are the origin. In that year economic recession expanded worldwide. South African companies reached relatively high values of profitability factor. This figure can be misleading since inventory and receivables turnover are not presented. In 2009 economic crisis had the biggest impact on steel industry. Numerous companies incurred losses.

In 2010 a small recovery has been observed but slight majority of companies had negative values of profitability factor. There are also companies that incurred losses and higher values of liquidity factor.

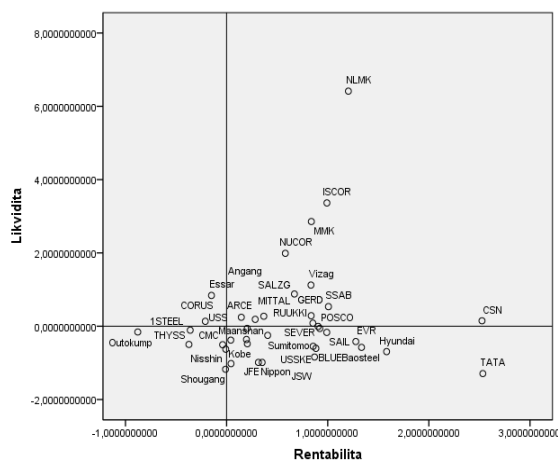


Figure 3. Situation in industry in 2005

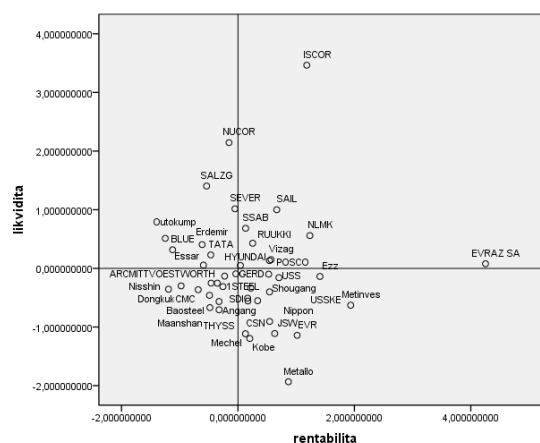


Figure 6. Situation in industry in 2008

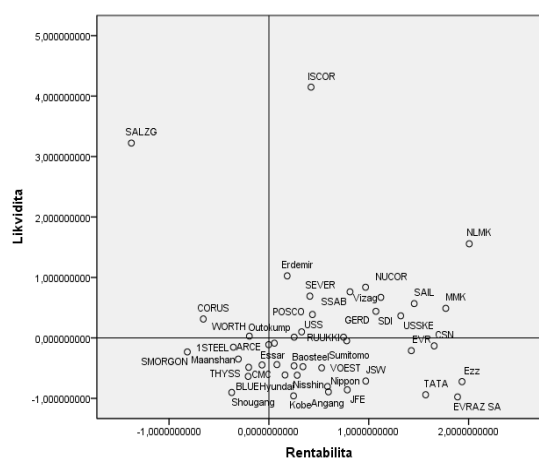


Figure 4. Situation in industry in 2006

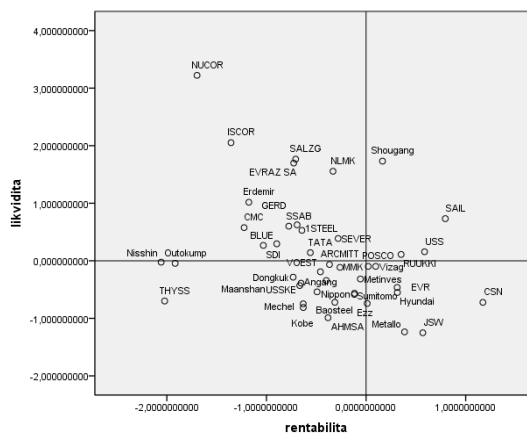


Figure 7. Situation in industry in 2009

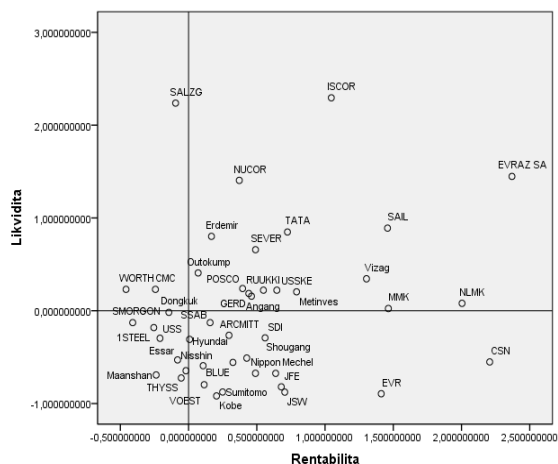


Figure 5. Situation in industry in 2007

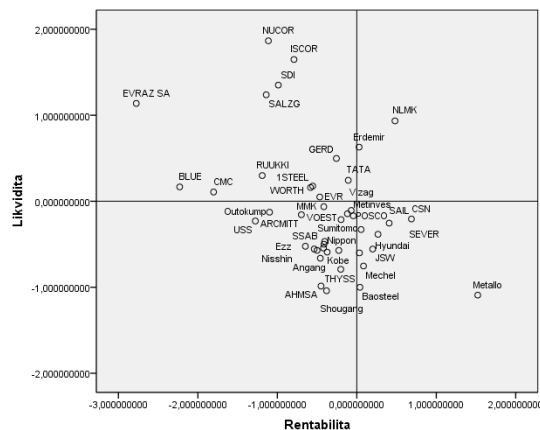
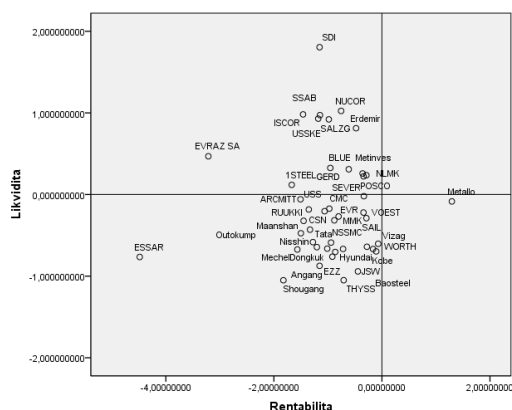
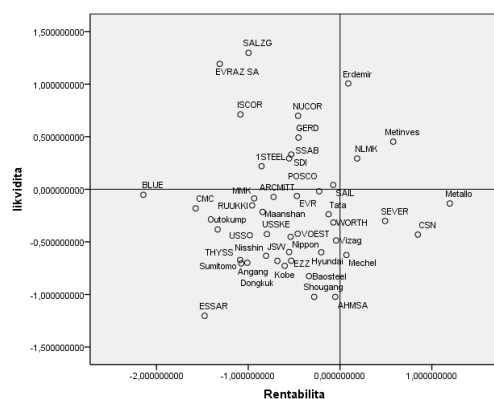


Figure 8. Situation in industry in 2010

In 2011 it can be seen that there is even larger number of companies with negative values of profitability factor.



In 2012 a majority of companies incurred losses even Chinese ones. This situation is the worst one of the observed period. Some of companies have been shown as extreme one ones. For instance Metallo as a mining company has been profitable. Essar should be considered as global and especially its Canadian subsidiary incurred huge losses.

## 2 CONCLUSION

Evolution of financial health in steel industry has been presented in this paper. Financial crisis started in late 2007, extended in 2008 and the greatest impact on metallurgy segment was in 2009. An economic recovery can be seen in 2010. Last two years were not successful in the industry. Multidimensional methods have been used. Factor analysis reduced drastically the dimension of space (from 12 to 4) and the factors explained 82,478%. Therefore it is perceived as a good result since the sample has been analyzed by four variables with a good explanation of the original variance. Chinese companies' production grew the whole period whereas European companies declined. Cluster analysis categorized the companies into four groups by financial ratios. As a trend of membership of companies has been monitored, a prediction could be performed which companies are creditworthy and other ones could have financial difficulties. Companies were allocated to clusters by factors that demonstrate

financial situation. Two-dimensional figures and k-means clustering were compared. In 2012 companies incurred losses even Chinese ones.

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 <<http://www.metinvestholding.com/en>>  
 <<http://www.nsc.co.jp>>  
 <<http://www.nssmc.com/en>>  
 <<http://www.nisshin-steel.co.jp>>  
 <<http://nmlk.com>>  
 <<http://www.nucor.com>>  
 <<http://metalloinvest.com/eng/ir>>  
 <<http://severstal.com>>  
 <<http://www.onesteel.com>>  
 <<http://www.ruukki.com>>  
 <<http://www.shougang-intl.com.hk>>  
 <<http://www.onesteel.com>>  
 <<http://www.sail.co.in>>  
 <<http://www.sumitomocorp.co.jp>>  
 <<http://www.ssab.com>>  
 <<http://www.tatasteel.com>>  
 <<http://www.thyssenkrupp.com>>  
 <<http://www.ussteel.com>>  
 <<http://www.vizagsteel.com>>  
 <<http://www.voestalpine.com/group/en>>  
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### Appendix

Name of company (1)	Code
Ahmsa Altos Hornos de México	AHMSA
Al Ezz Steel Rebars S.A.E.	EZZ
Angang Steel Company Limited	Angang
Arcelor S.A	Arce
Arcelormittal S.A	ARCMITT
Arcelormittal South Africa	ISCOR
Baoshan Iron & Steel Co., Ltd	Baosteel
BlueScope Steel Limited	BLUE
Commercial Metals Company	CMC
Companhia Siderúrgica Nacional	CSN
Corus Group	CORUS
Dongkuk Steel	Dongkuk
Erdemir Group	Erdemir
Essar steel	Essar
Evraz group S.A.	EVR
Evraz Highveld Steel and Vanadium Limited	EVRAZ SA
Gerdau S.A	GERD
Hyundai steel	Hyundai
JFE steel corporation	JFE
Jindal South West Steel	JSW
Kobe steel	Kobe
Maanshan iron and steel company Limited	Maanshan
Magnitogorsk Iron & Steel Works Open Joint Stock Company	MMK
Mechel OAO	Mechel
Metinvest Holding B.V.	Metinves
Mittal Steel Company N.V.	Mittal
Nippon steel Corporation	Nippon
Nippon steel Metals Corporation	NSSMC
Nisshin steel co. Ltd.	Nisshin
Novolipetsk Iron and Steel Corporation	NLMK
Nucor Corporation	NUCOR
OAO Holding Company Metalloinvest	Metallo
OAO Severstal Group	SEVER
Onesteel limited	1STEEL
Outokumpu	Outokump
Pohang Iron and Steel Company	POSCO
Rautaruukki Corporation	RUUKKI
Salzgitter AG	SALZG
Shougang Concord International Enterprises Company Limited	Shougang
Smorgon Steel	Smorgon
Steel Authority of India limited	SAIL
Sumitomo Metals Corporation	Sumitomo
Swedish Steel AB	SSAB
Tata steel	TATA
Thyssenkrupp AG	THYSS
United States Steel Corporation	USS
United States Steel Košice s.r.o.	USSKE
Visakhapatnam Steel Plant	Vizag
Voestalpine AG	VOEST
Worthington industries	WORTH

Table 17. List of companies in database