SEGMENT DEFINITION AND CHARACTERISTICS OF COMPANIES HOW THEY REACTED TO CRISIS

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1. Aim of the data investigation

The main goal of the present study is to identify resilient companies from a dataset containing financial information of the firms at hand.

Since resilient attributes, reaction to economic crises and the simple identification of those subjects that had and survived such a negative scenario is gaining more and more attention, and it is deliberately desired to develop a technique for the fulfilment of this task. Scientific literature besides macroeconomic resilience (economic resilience of regions and countries in a broader sense) tends to expand towards microeconomic fields indeed that involves small- and medium sized enterprises and other company structures as well. Such companies are of great interest, since the present Covid-19 pandemic situation already brought negative economic impacts both on global- and local scale and presumably further, even greater negative impacts and turbulences are imminent that can easily have a perceivable effect on the individuals' level unlike any other economic downturn in the past few decades. Therefore, to protect companies and keep as many workplaces as possible is essential and tools are sought to promote decision- and policy makers to promote them in this.

One possibility to achieve this is to find those companies and participants that already have experience in economic recession periods, are familiar with the signs, actions to take and consequences. Best practices could be collected from various walks of life how to survive and even come out prosperous from such scenarios by further increasing competitive advantages compared to others.

Nevertheless, there are various factors that can cause troubles at an organization and lead to economic difficulties that cannot be attributed to any outer economic impacts or macroeconomic processes. Still these subjects go (or already have gone) through such periods with a unique and company specific solution and approach. Various industrial branches and firm sizes might have been affected differently and even geographical location can play significant role in surviving.

Companies that already survived turbulent periods might survive the following ones. Or not. It is even possible that resilient companies cannot contribute to the macroeconomic progress of nations, only in the short-run, resilient attribute can prevent bigger collapses on regional and national level and prevent larger economic crises that could drag other sectors with them via the subtle and complicated economic connections.

In order to have an objective and tangible result on which aspect resilient companies could contribute or utilized by economic experts from the above mentioned factors, is one of the main focuses of the present work for which the procurement of a database containing financial balance sheets and income statements were used.

2. Main characteristics of the database

The procured database contained financial balance sheets and income statements on little bit more than 26 000 Hungarian companies and 73 variables were involved in the dataset. The investigated time period covers 2002-2019 and mainly companies from processing sector have been involved, since these partakers contribute the most to the Hungarian economy according to the Hungarian Central Statistical Agency. With the financial information other meta-data, like company addresses, industrial branch information, numbers of employees in each year, predecessor-successor information and historical remarks on negative- and positive events that had an impact or influence on the active operation of the companies at hand were obtained.

2.1. Difficulties hidden in the database

During the exploratory data analysis several problematic anomalies were detected and had to be handled in order to be able to extract sensible input for the applied mathematical and further statistical processes. Within the framework of the present investigation, these anomalies and defects were handled in a robust way or were eliminated, however it has to be highlighted that number of variables offer a possibility for much wider economic-mathematical investigation that is obviously beyond the scope of the present study and therefore other abnormalities are to be expected that have to be handled case specifically if further approaches and methods shall be applied. Thus, the data preparatory phase shall be handled as a still open task that will inevitably be part of future data science or statistic related investigations.

Such observed abnormalities:

- There were variable names that were incorrectly given compared to official Hungarian financial statements.
- There were variables detected that contained no information after a certain year but could be worked out from the rest of the data.
- In case of some companies not just annual than half year (or for other time periods given) income statements were also provided.
- There were several inconsistencies among different data sets, under which we understand that different information (e.g.: employee data and financial data) did not overlap in time, which was a major issue to handle with robust solutions.
- The number of employees were given in some years with numbers (e.g.: 24) but in other years in a string format that represented a range (e.g.: 15-25).
- There was a huge amount of missing data cellwise independently from year and variable type.
- There were companies for which there were no income data provided for several years.
- There were companies with negative incomes.
- There were tax numbers to which absolutely no information pertained.
- There were companies with financial information for several years, but no industrial branch information or employee number information were provided or vice versa.
- Missing data were also observable in a form of zero-s. This means that in some years the accountants or other partakers wrote zero-s into the database when they did not have any data.
- Some companies had years of information completely missing, however there was clear evidence that the company existed and actively operated in the given year.
- etc.

It has to be mentioned that the above-described abnormalities shall be handled as defects and were treated accordingly. Nevertheless, in a broader mathematical sense, outlying data and non-normal distribution of each- and joint variables were also detected and naturally were forming an attribute of the data set.

Unlike measurement data, outliers and statistically a-typical data cannot be attributed to measurement error and therefore cannot be discarded on that basis. Similarly, the non-normal behaviour of the background distributions is a further characteristic that should not be approximated by normality and statistical procedures for conclusion withdrawal have to be chosen accordingly.

2.2. Applied transformations

Besides data handling that eliminated or reduced the undesirable effects of the missing values and other defects it had to be taken into consideration that the investigated data encompassed almost two decades during which several legal- and economic conditions changed. The most important transformations on the data that aimed to bring information from the given time-span to a common root were the following:

- The NACE numbering of the companies that coded the industrial branch information were synchronised and updated backward in time.
- The predecessor-successor information was utilized to unite companies that were technically the same organization just changed tax numbering due to some reason.
- Annual revenue has been selected for further investigations (in accordance with other relevant literature suggestions) since this variable had the least missing value among the financial variables.
- Financial statements where ambiguous information were given to a specific year have been corrected and unified.
- Financial information that were not given in HUF were discarded, since unrealistically large values were provided thus making such data unreliable (most probably the values were given in HUF but the currency was indicated in some other currency).
- Company NACE information were simplified to main NACE categories and companies were grouped accordingly into these main categories.
- Employee numbers were transformed to categories for every year in order to make data uniformized.

However, the applied transformations could lead to partial information loss they were inevitable for enabling the comprehensive and uniform handling of the companies without biasing the expected results.

3. Definition of economic shock of companies

Economic shocks of companies can be defined several ways that can be observed objectively from the financial indicators that can be deduced from the balance sheets and income statements. The selected approach relies on the investigation of the annual sales growth parameter that is literally the relative change in the annual revenue of the companies where the previous year is used as the basis of comparison. In case the sales growth is a positive number the company flourishes, has more revenue than in the previous year and this can correspond to a growing and expanding period. In case the sales growth is zero the company has the same revenue and in case of a negative sales growth the revenue shrinks compared to the previous year which can mean some kinds of fallback and distress in the operation, therefore can be characterised as a year of financial shock, since the incomes tend to decrease.

Based on this concept the economic setback of companies can be characterised and investigated on an individual manner regardless of any outer economic crisis. Such an approach serves information on companies that is only typical for themselves.

As it can be seen on Figure 1. and Figure 2. the selected variable is suitable to catch economic crises that took place in 2009 among the investigated companies (2020 clearly indicates some setback, however there are only a few data point available for this year, therefore it shall not be treated as representative).

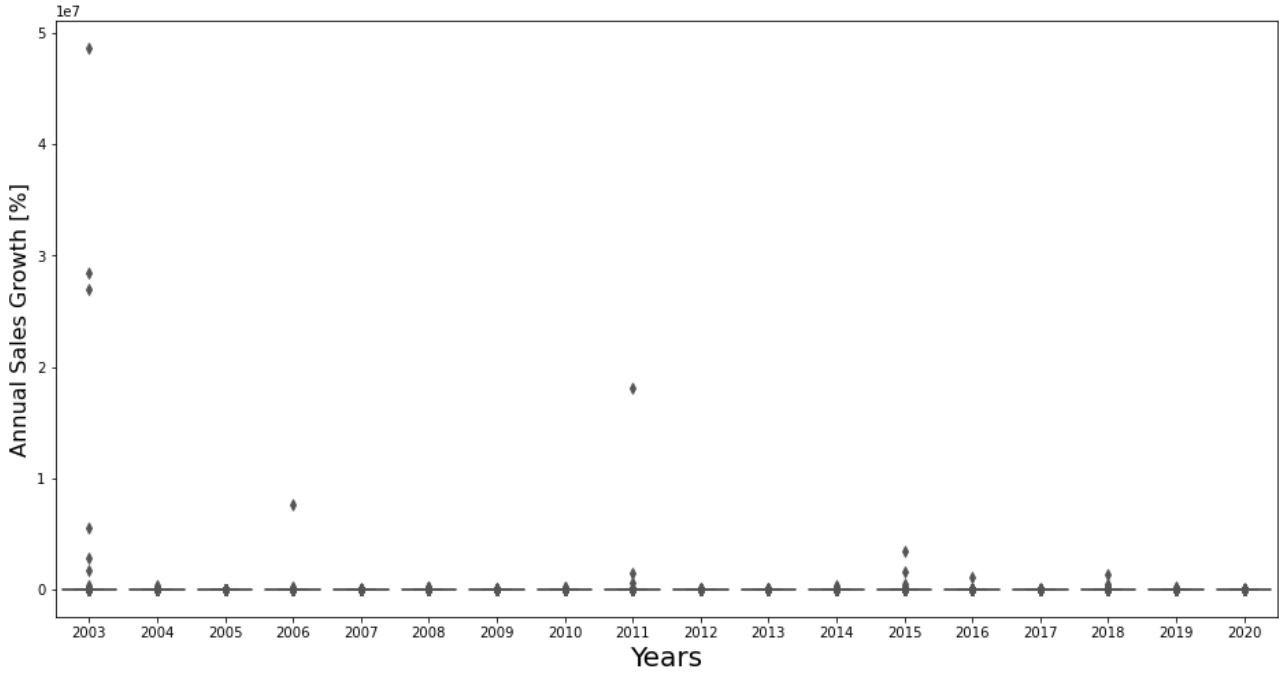

Figure 1: Box-plot of annual sales growth variable in each year.

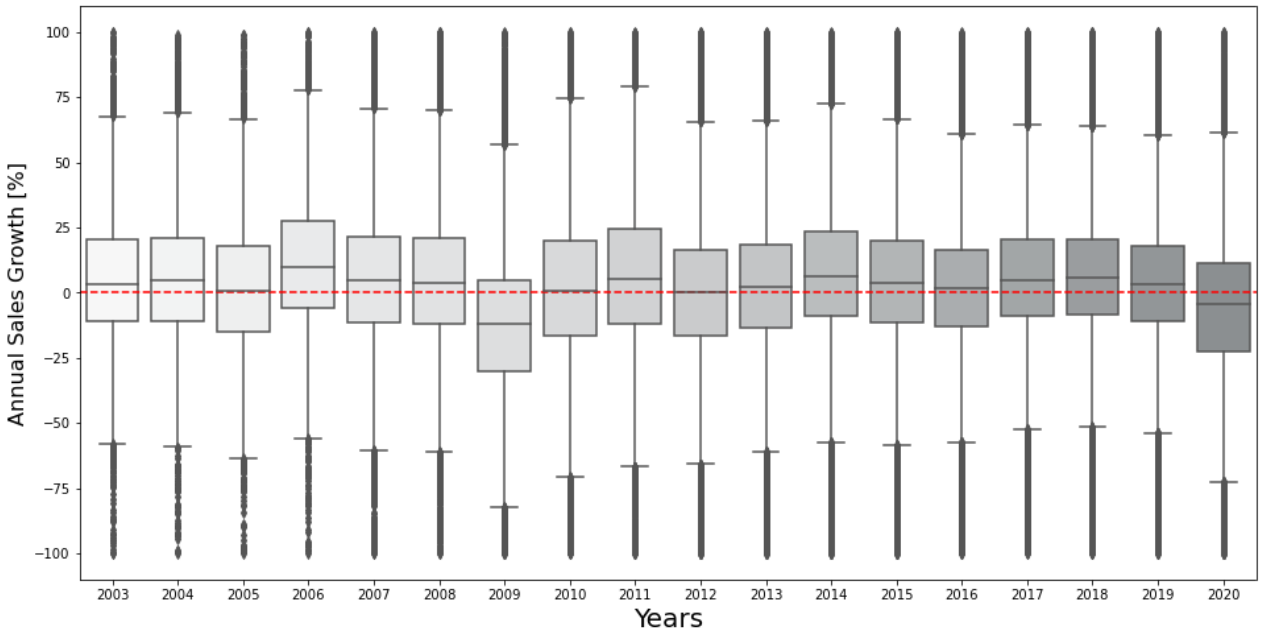

Figure 2: Box-plot of annual sales growth variable in each year with a focus on the majority of the data

A co-benefit of the investigation of annual sales-growth is that the wide range of financial revenue data can be transformed to a common percentage scale thereby the companies can be investigated on a common scale. Having investigated the selected variable for the whole population the subjects can be categorized in each year based on the strength of financial shock that they had to endure and the number of companies with a scale of economic setback can be given (see Figure 3.).

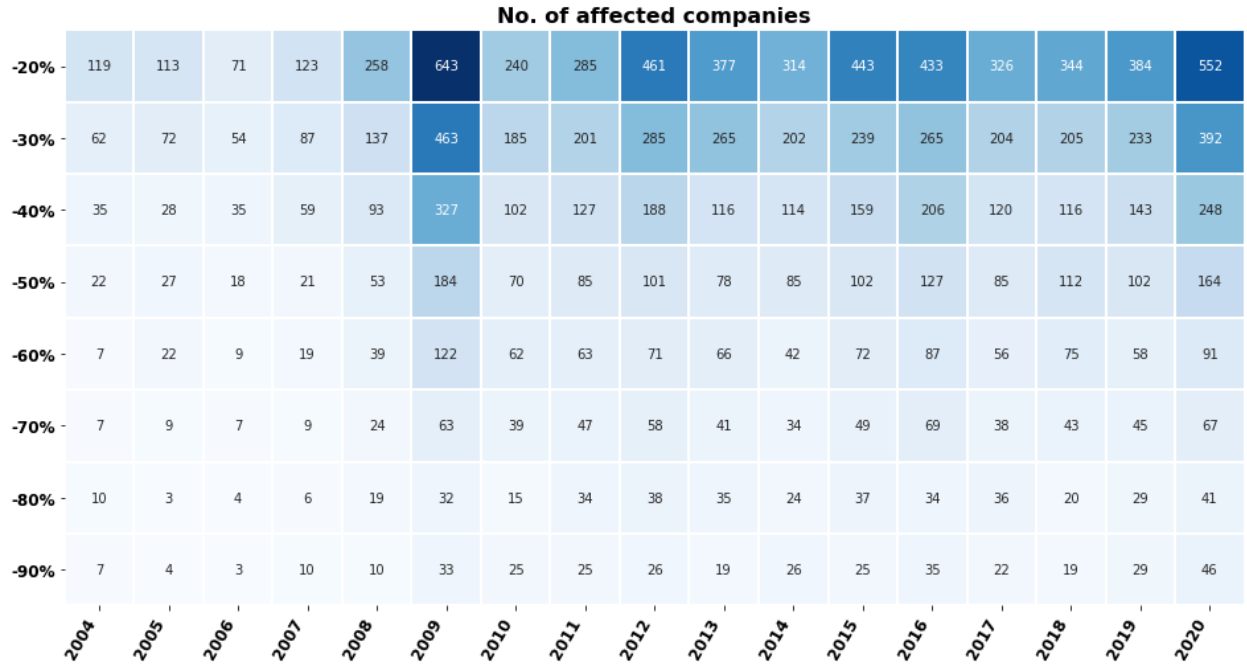

Figure 3: Number of companies exposed to economic shocks at different levels in each year.

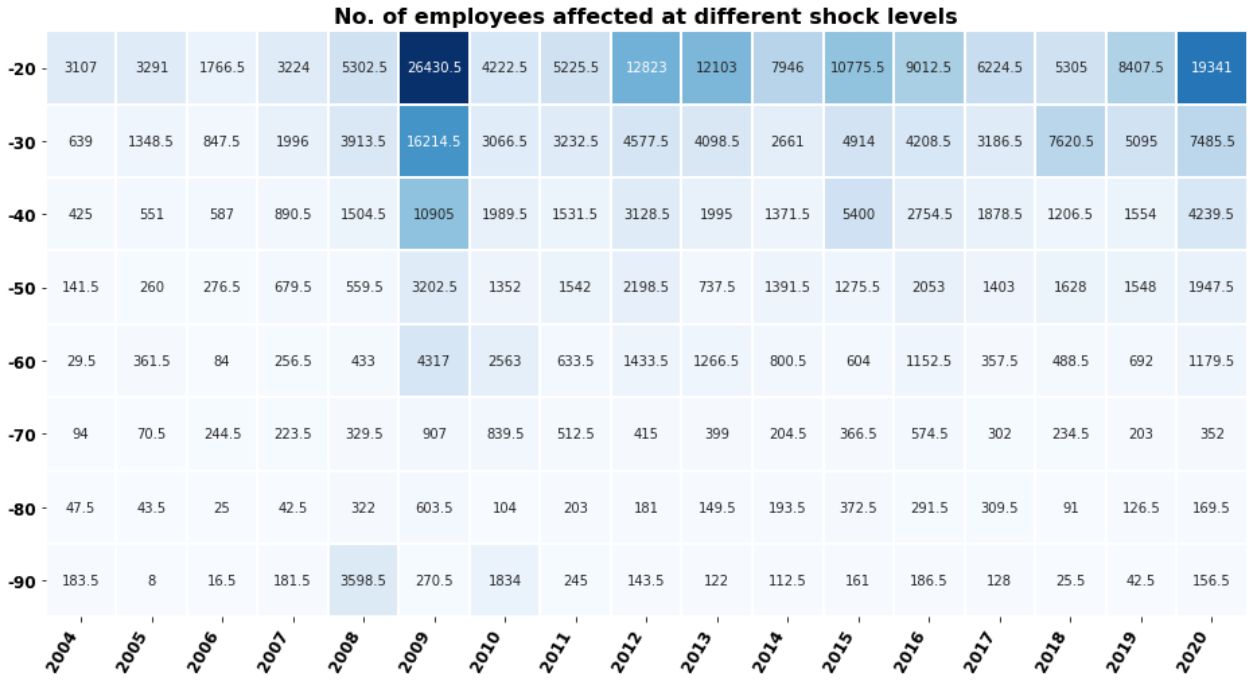

Figure 4: Corresponding average employee numbers at affected companies at different shock levels in each year.

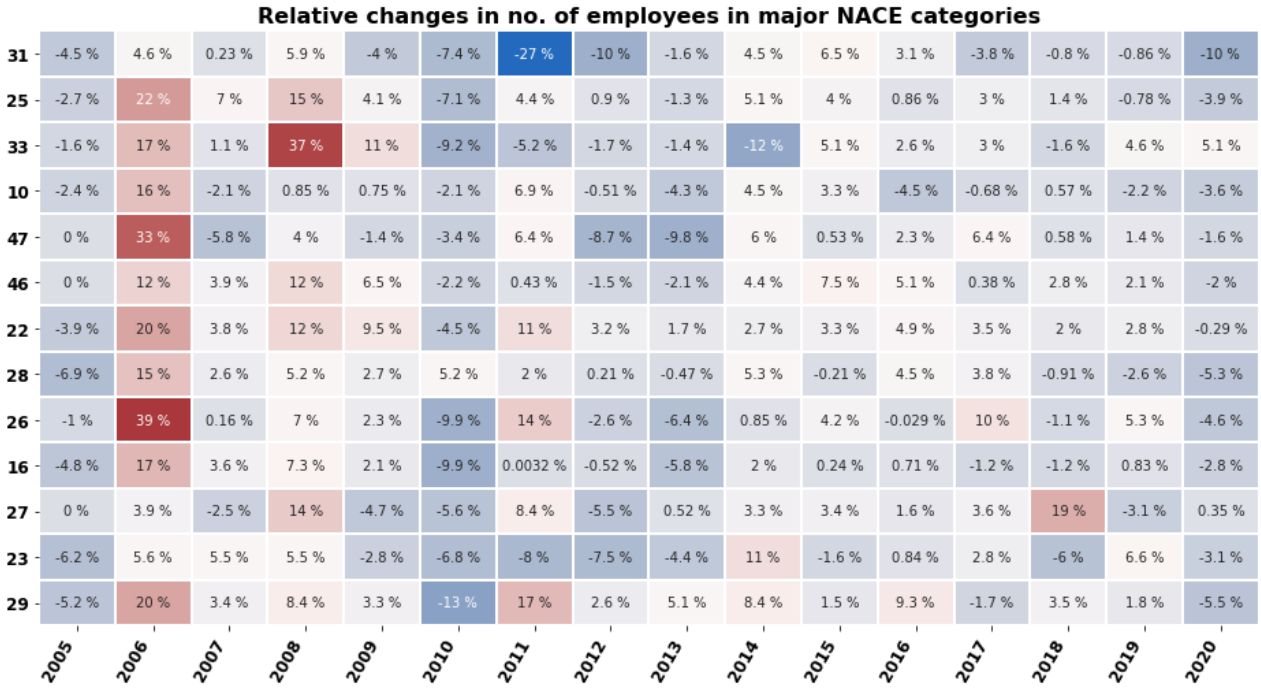

Figure 5: Relative changes in employee numbers in main industrial sectors in each year.

As Figure 1-5 reflect, based on the selected financial metric the impacts of the macroeconomic crisis of 2008 affected the most companies within the processing industry in Hungary a year later, so in 2009. The same holds regarding number of employees affected at those companies that were exposed to economic shock at a certain level, thus not just small companies with relatively small number of employees have been affected than this crisis truly hit a broad segment of society. Consequently, in 2010 a relatively comprehensive decrease in employee number is to be observed that is presented on Figure 5. The codes of the main NACE categories correspond to the following:

- 31: Furniture production
- 25: Manufacture of fabricated metal products
- 33: Repair and installation of industrial machinery, equipment and tools
- 10: Food production
- 47: Retail trade, except of motor vehicles and motorcycles
- 46: Wholesale trade, except of motor vehicles and motorcycles
- 22: Manufacture of rubber and plastic products
- 28: Manufacture of machinery and equipment n. e. c.
- 26: Manufacture of computer, electronic and optical products
- 16: Manufacture of wood and of products of wood and cork, except furniture
- 27: Manufacture of electrical equipment
- 23: Manufacture of non - metallic mineral products
- 29: Manufacture of road vehicles

4. Definition of resilient companies

Similarly to economic shocks, several variations exist for the definition of economic resilience. According to the scientific literature, resilience can be conceived as proactive, adaptive or reactive according to the relation of the company to the economic crisis at hand (where the economic crisis is at company level and independently understood from outer macroeconomic crises). Obviously, those companies would be the ideal to identify that has the methods and know-how to prepare for individual-level economic turbulences via financial instruments or production stock build-up etc., on the other hand these are hard to be differentiated from those companies that never had any kind of economic setback and was not exposed to such disturbances. The identification of these companies needs deeper economic considerations and besides objective data driven solutions the incorporation of background knowledge on managerial and entrepreneurial mindset, supply chain consideration etc. could be necessary that is beyond of the scope of the present study.

Thus, at present we settle for the identification of companies that actually did go through an economic downturn and investigate their reaction to the given phenomenon. Based on the former definition of economic shock, this can be done objectively in a numerical way since these companies are separable by investigating the annual sales growth.

In our examination we focused on companies that were exposed to an economic shock in a given year and right after the year of shock they managed to compensate and gain momentum to reach the economic status (or even overshoot it) as the year prior to the shock. Based on literature definition, we could denote these companies as “one-year-reactive-resilient” companies (later abbreviated as: OYRRC). Those companies which managed to steer back to the state prior to the economic shock only years later (more than one) are not considered as resilient in the present investigation due to their slower reaction, they could be denoted as “multiannual-reactive-resilient” companies (abbreviated as MRRC).

5. Classification of companies

It is important to note that resilience is a time dependent and volatile attribute of the companies, which means that being resilient at a certain level (corresponding to the shock level survived) does not necessarily indicate that the company remains resilient in the long-run and retain this characteristic for the whole of its operation. Therefore, resilience in our understanding is a temporal feature, a given company can be resilient only in case of facing an economic downturn and during its lifetime the company can be resilient several times at different “resilience-levels” when being exposed to various types of disturbances.

According to literature with respect to level of the economic indicator in the comeback year compared to the level of the year of the distress and prior to it the companies can be regarded as fragile, robust, resilient or antifragile.

Let us denote the year of economic disturbance as $year_i$, while the previous one with $year_{i-1}$ and the year of comeback with $year_{i+1}$. The exact definition of the 4 groups:

- **Fragile**: Annual revenue($year_{i+1}$) < Annual revenue($year_i$) or
  (Shock level)% > Sales Growth($year_{i-1}$ -> $year_{i+1}$) > -100%
- **Robust**: Annual revenue($year_i$) < Annual revenue($year_{i+1}$) < Annual revenue($year_{i-1}$) or
  0% > Sales Growth($year_{i-1}$ -> $year_{i+1}$) > (Shock level)%
- **Resilient:** Annual revenue($year_{i-1}$) < Annual revenue($year_{i+1}$) < 2*Annual revenue($year_{i-1}$)
  or 100% > Sales Growth($year_{i-1}$ -> $year_{i+1}$) > 0%

- **Antifragile:** 2*Annual revenue(year$_i$) < Annual revenue(year$_{i+1}$) or Sales Growth(year$_{i-1}$ -> year$_{i+1}$) > 100%

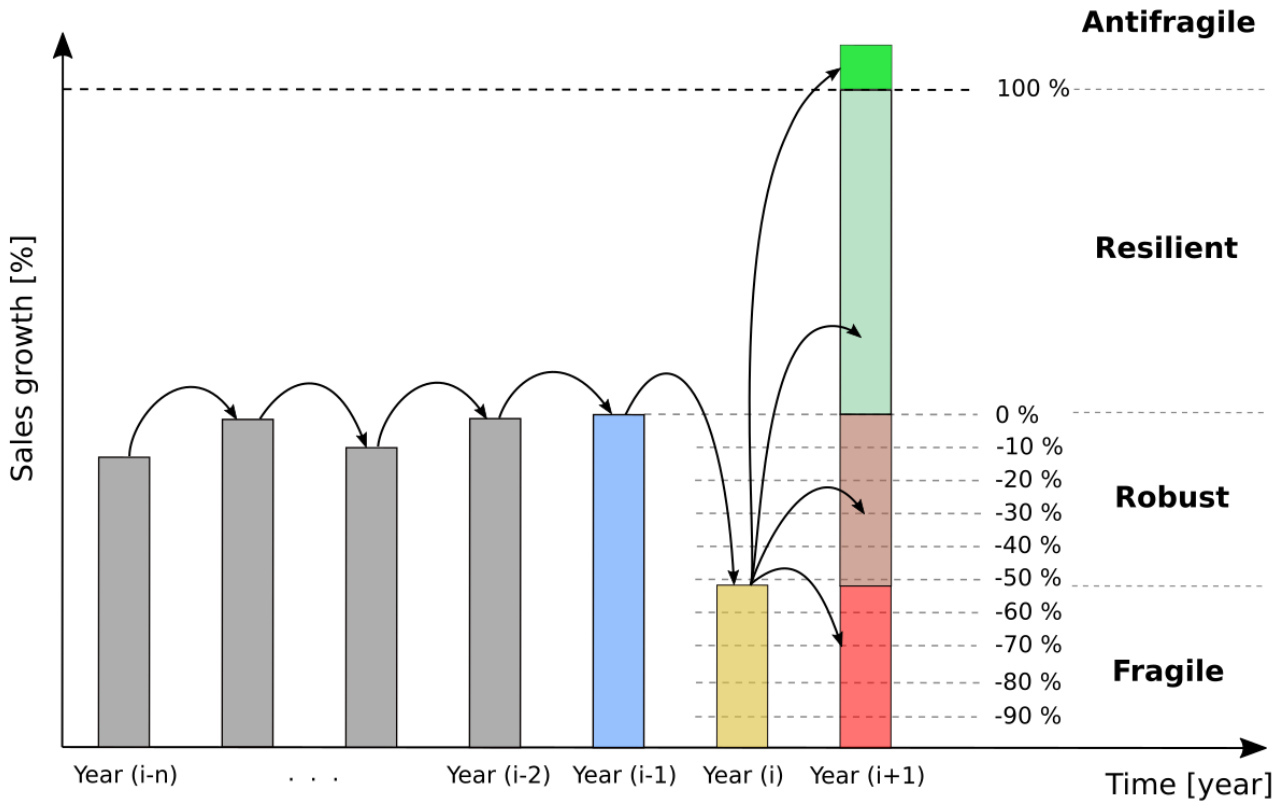

Figure 6: Basic concept for the classification of companies that were exposed to economic shocks.

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	class
189.0	198.0	188.0	145.0	382.0	687.0	845.0	533.0	579.0	630.0	506.0	506.0	607.0	534.0	475.0	492.0	684.0	Fragile
50.0	53.0	70.0	39.0	108.0	74.0	217.0	168.0	139.0	216.0	184.0	172.0	167.0	206.0	182.0	156.0	147.0	Robust
90.0	71.0	160.0	80.0	171.0	113.0	359.0	321.0	212.0	356.0	401.0	255.0	270.0	321.0	307.0	257.0	205.0	Resilient
5.0	2.0	5.0	6.0	9.0	16.0	19.0	35.0	15.0	24.0	29.0	21.0	17.0	27.0	28.0	21.0	9.0	Antifragile

Figure 7: Number of companies ordered into resilience-related classes in each year at 10% shock level they were exposed to.

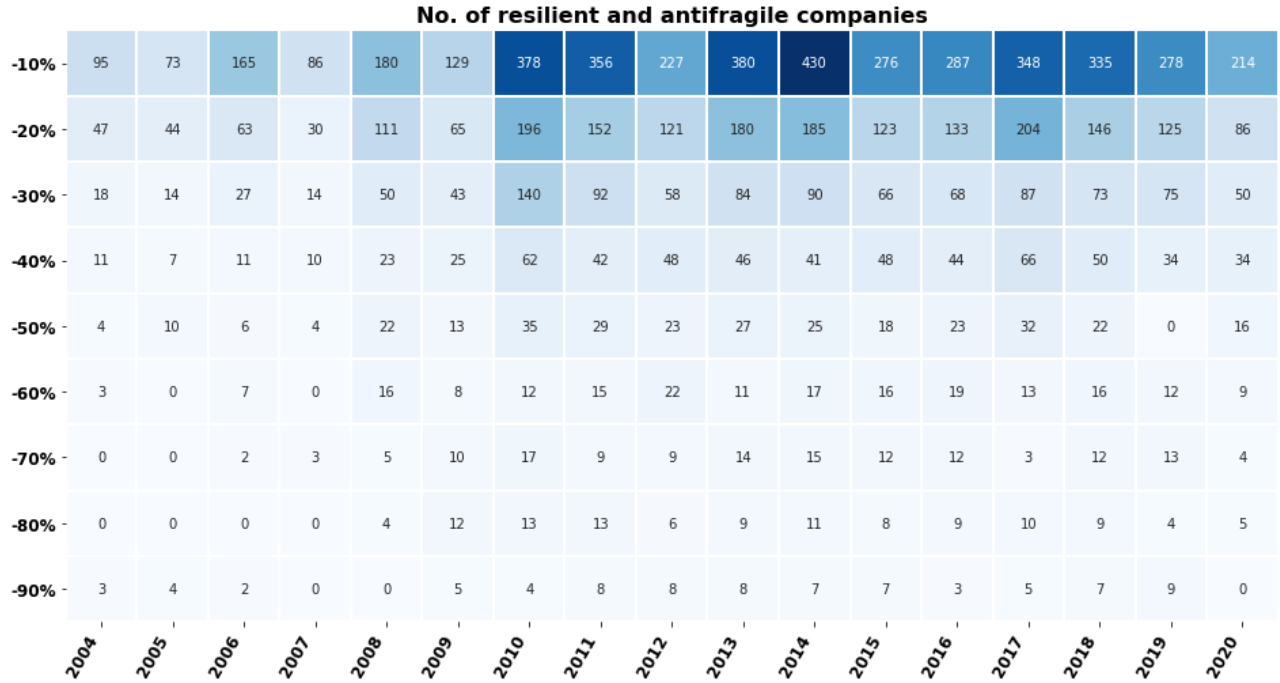

Figure 8: Number of resilient and antifragile companies at different resilience-levels in each year.

5.1. Characterization of companies involved in WPT1

There were 49 SMEs incorporated into the investigations of WPT1. These companies were also present in the present database and involved to the present analysis as well. The resilience related history of these firms based on the present concept could be analysed in case of 39 stakeholders where all the necessary data were available.

The corresponding results are listed in *4STEPS D.T3.7.1_resilience history of WPT1 companies.xlsx*.

6. Hypothesis tests with OYRRCs

During the investigation of resilient companies, the elemental question arises: *Does the temporal-resilient attribute contribute to the long-term survival, competitiveness or growth of the companies or not?*

In order to answer this question matched pair analysis has been performed on the classified companies and a quasi-experiment setup has been investigated, where the companies exposed to an economic shock were regarded as a “treated” sample, while an “untreated” sample has been selected from the population pairwise with similar features as a control group. Non-parametric signed Wilcoxon tests and odds ratio tests have been performed to find statistical evidence for the acceptance or rejection of the following H_0 null hypotheses:

- Resilient companies “live longer” counted from the year of economic disturbance than control group pairs.

(Resilient group: companies that faced economic disturbance at least once in their lifetime.
Control group: companies that never faced any kind of economic disturbance.)

- Resilient companies will be affected less by subsequent economic disturbances than control group pairs.
  (Resilient group: companies that faced economic disturbance at least twice in their lifetime.
  Control group: companies that faced economic disturbance only once in their lifetime.)
- Resilient companies will grow faster (measured by sales growth) after economic disturbance than control group pairs.
  (Resilient group: companies that faced economic disturbance at least once in their lifetime.
  Control group: companies that never faced any kind of economic disturbance.)
- Resilient companies will become bigger companies (measured in number of employees than control group pairs.
  (Resilient group: companies that faced economic disturbance at least once in their lifetime.
  Control group: companies that never faced any kind of economic disturbance.)

Based on the outlined mathematical procedure we found statistical evidence to reject all the above listed hypotheses that could also be graphically displayed and verified on Figure 9:

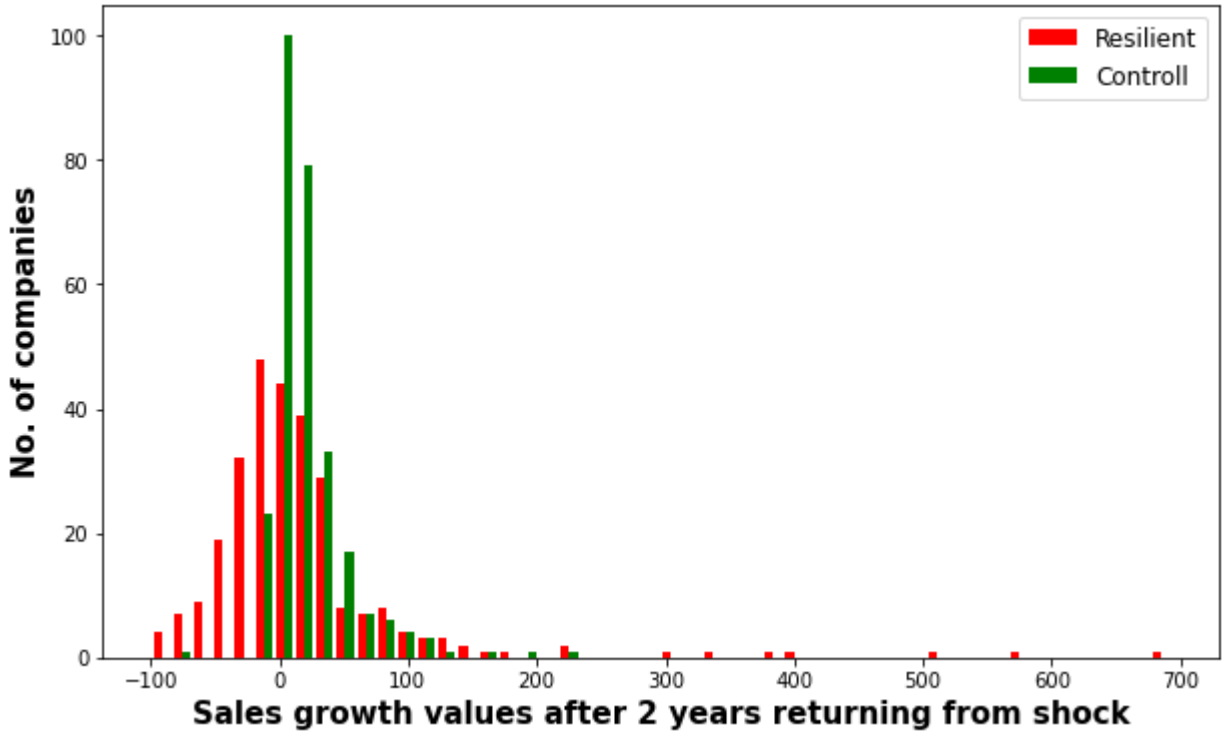

Figure 9: Distribution of sales growth among resilient and control group companies 2 years after the economic disturbance.

7. Conclusions

In the present work a quantitative approach of business resilience has been developed and applied. It can be concluded that the applied method can identify the aftermath of larger macroeconomic crises, like that took place in 2008.

After having identified crisis phenomena in the operation of Hungarian processing industry companies a definition of reactive resilient companies has been given, which companies have actually gone through economic turbulences and survived them. Based on the reaction to the crisis, a classification of the companies has been recommended and the number of companies has been counted in each year to the formed groups.

Based on non-parametric hypothesis testing the long-term aspects of resilience has been investigated, whether the once gained experience of surviving a turbulence period can contribute to the long-term survival and accelerated growth of companies compared to matched pairs that went through different paths and did not have the chance to collect such experience. Unfortunately, statistical evidence has been found that reactive resilience as a temporal characteristic of individual companies has no positive influence on long-term performance and survival rate and therefore shall be considered as a short-term positive attribute that helps alleviating larger macroeconomic crises or at least suppresses and prolongs the magnitude of such turbulences by keeping unemployment rate at a lower level etc. In the long-run once reactive-resilient companies on a statistical level shall be considered as wounded economic characters that might need to be identified and helped to bring them to the same level as the appropriate control groups.

In a future work other aspects of resilience beside reactive-resilience should be elaborated and models shall be worked out in order to numerically characterize companies and collect best-practices for preparing and avoiding negative impacts during operation. Further hypothesis tests could be figured out and performed and geographic data could be incorporated to the investigation. As a more advanced outlook from the present study, bankruptcy prediction models could be used to have a deeper understanding on economic resilience and form other (most probably still just a subset of) resilient groups and their features.