

Managing complexity in the era of Industry 4.0

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Complexity is one of the biggest barriers to success in organizations, whether in the business or nonbusiness sectors. Despite this fact there is very little research into the causes and consequences of this rapidly growing problem in the era of Industry 4.0. Similarly, there is very little practical information that provides actionable advice on how management in organizations can attack this problem.

Internal complexity challenges like economic turbulence, understanding changes in customer needs, coping with economic crises, successfully launching innovative new products or services, dealing with regulatory changes, and finding and keeping talent are all major issues of management. In coordinating internal complexity with a complex competitive external environment, management of organizations needs to continually respond in order to succeed.

We define complexity as the number of components in a system plus the variety of relationships among these components plus the pace of change in both the components and the relationships.

Larger systems are often more complex – but they may just be more complicated if their behavior is unpredictable. Based on the database of the Global Entrepreneurship Index (GEI) we compared the EU-member countries (especially Hungary) and how prepared they are for management of growing complexity. Simplicity in business exists when we have exactly the right number of essential components and connections to achieve a successful result – no more, no less. That means everybody has to find an optimal level of complexity, which is called simplicity, or good complexity, so we can talk about good or bad complexity, and their respective levels are changing continuously.

Investigating the countries, we have identified three clusters of displaying different management challenges: balanced, flexible, and vulnerable countries with regard to their capacity to face and manage growing complexity. Hungary is among the latter group.

Keywords: complexity challenges, management 4.0

1. Introduction and literature

Complexity will be one of the biggest barriers to success of organizations in the foreseeable future. There are many growing challenges like economic turbulence, understanding changes in customer needs, coping with emerging economies, successfully launching innovative new products or services, dealing with regulatory change, and finding and keeping talent, which are all major issues that preoccupying company leaders. In combination these amount to a complex competitive environment, which firms need to continually respond to in order to succeed (Bockelbrink et al. 2018).

We know that the competitive environment is becoming more complex, turbulent and unpredictable, and managers have little or no control over the underlying

trends, from globalization, to increasingly segmented markets, to technological change. The most damaging kinds of complexity, however, come from within. More products and services, more strategic initiatives, more layers of management, more processes, procedures, disrupting innovations – until managers are overwhelmed (Dinya 2012).

We can see a natural evolution of the business models, driven by technological opportunities, new management practices, and the growing diversity of customer needs. The external complexity, which is called Industry 4.0 drives internal complexity.

We define the term complexity based on the literature as follows. **Complexity** is the **number of components** in a system, plus the **variety of relationships** among these components, plus the **pace of change** of both the components and the relationships. Complex systems are characterized by diversity, ambiguity, and unpredictability of outcomes relative to inputs, or changes in conditions. The interaction of three dimensions – number of components, variety of relationships and pace of change in both – means we cannot easily tell what a complex system is going to do. It also means it is more difficult to control. As a general rule, the more a system is made up of people, the more complex it is. The **simplicity in business** exists when you have exactly the **right number of essential components** and **connections** to achieve a successful result. No more, no less. This is the good complexity (Heywood et al. 2010).

These definitions are useful as they can be applied to most business systems, at any level: from firms in a supply chain, functional departments in a firm, machines in a production line, or people in an organization. In fact, you can look at any complex system and identify whether the overall complexity is being driven by the number of components, the variety of different components, the number of connections, the pace of change, or a combination of these factors. Once you know what type of complexity you are dealing with, the solution for the complexity problem becomes much clearer.

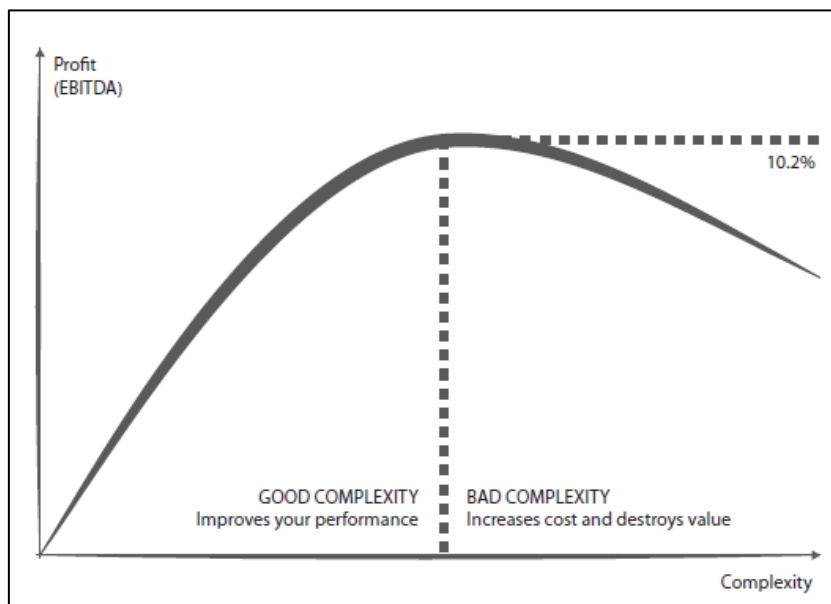
We have to talk about external and internal complexity specifically in relation to firms. Companies succeed, fail, or simply survive in complex competitive environments full of opportunities and threats, which they have to continually respond to. The scale of complexity facing organizations alone represents a significant challenge. It drives greater uncertainty, and unpredictability and makes decision-making more difficult. Firms have a broader range of options to choose from, but a more confused information picture on which to base decisions. Effective allocation of scarce resources becomes more challenging.

Two main forms of complexity relevant to business organizations are commonly discussed: **strategic complexity** and **organizational complexity**. Strategic complexity is about the positioning of the firm in a changing external competitive environment, and the management decision-making processes that try to navigate the best path through this environment. Focusing on dynamic capabilities managers have to improve agility and responsiveness in the face of chaotic or turbulent environments address this kind of complexity and the firm's ability to survive (Gottfredson 2012).

Organizational complexity refers to internal sources of complexity stemming from the evolution of business divisions, processes, procedures and rules, and changing structural characteristics. Both forms are associated with positive (good) and negative (bad) performance effects of complexity. Managerial decisions are about finding the right balance – between ‘good’ complexity and ‘bad’ complexity. As successful firms grow, they add new products and services to their portfolios, enter new markets, engage in joint-ventures and acquisitions, and add new business units and lines of management; these strategic initiatives adding value and profits also growing. This is good complexity. At some point (we predictably called it the ‘tipping point’) added complexity – a new line of products, one more acquisition, an extra layer of management – does not add proportionate value. The firm does more things and the number of components and/or interrelationships grows, but the added value is outweighed by the added cost of the complexity. Bad complexity is costly complexity – and if it becomes too overwhelming, it can kill not just profits but the entire business (Kerr 2012).

A group of experts developed a complex indicator (called Global Simplicity Index, or GCI) some years ago and investigated hundreds of companies among the Top 500 (Collinson and Jay 2012). In total, they applied 18 proxy measures: nine for performance and nine for complexity – these being combined into the GCI. They found that a profit loss of companies with higher complexity (bad complexity) than the optimum was 10.2% (approx. 1.2 Billion USD) (Figure 1).

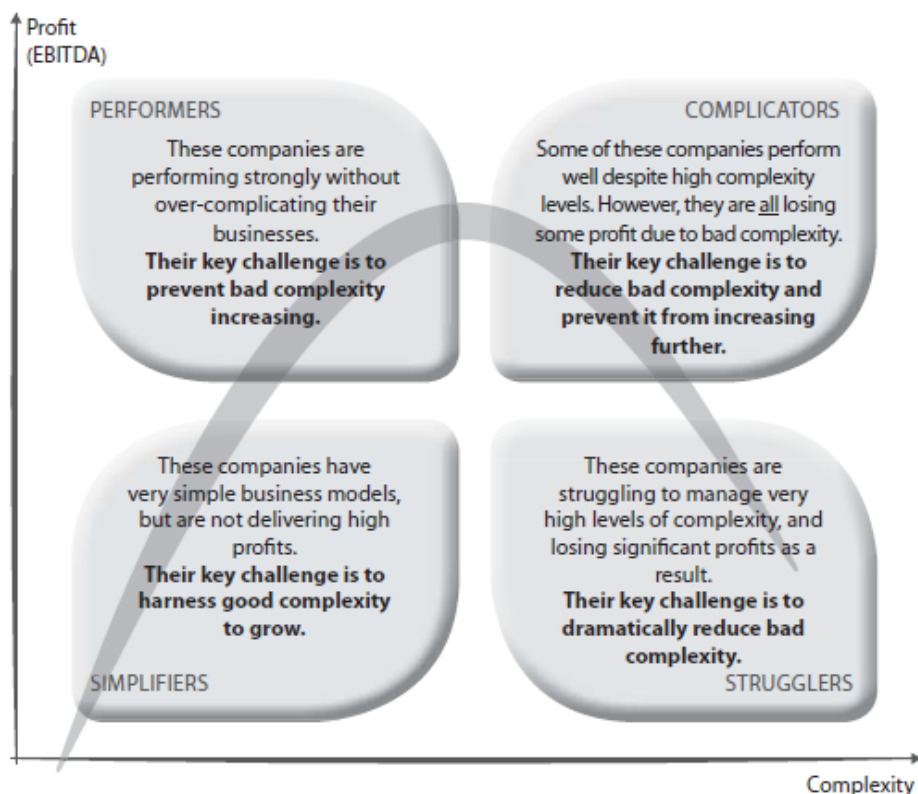
Figure 1 The relationship between performance and complexity



Source: Collinson and Jay (2012). Remark: EBITDA is the earnings before interest, taxes, depreciation, and amortization.

Investigating the top 200 companies globally they could identify four groups displaying different management challenges: simplifiers, complicators, struggles, and performers concerning their focus on complexity (Figure 2). They defined that complexity of organizations has six dimensions (internal: people – strategy – process – product – structure, plus external environment) and their priorities must be redefined in the era of Industry 4.0.

Figure 2 The performance–simplicity matrix – characteristic types of companies



Source: Collins and Jay (2012)

This led us to the idea that studying the challenges of complexity management should be started at the macro-level in order to take into account the differences of environmental (external) complexity. The potential proposed solutions and principles must be in harmony with the local (national) environment – there can be no best practice, just different good practices depending on the local situation. Familiar with the results of the Global Entrepreneurship Index (GEI), we thought that their database of 137 countries could be a good basis for our research for several reasons (Ács et al. 2017, Lafuente et al. 2019):

The Global Entrepreneurship Index (GEI) is a composite indicator of the health of the entrepreneurship ecosystem in a given country measuring the quality (level) of entrepreneurship and the extent and depth of the supporting entrepreneurial ecosystem.

- It gives excellent and detailed information on 137 countries concerning their level of entrepreneurship, which is a relevant pointer to the future competitiveness of their economy.
- But the indicators applied in the GEI have another dimension too: they are characterizing their relationship with future changes in the world of business. Namely: the lower the level of entrepreneurship in a country is, the more threatened they are by changes of growing complexity, in accordance with the literature.
- Each indicator of the GEI (see later) has some pertinence to the environmental and/or internal complexity. Companies and their management must be ready for continuous reconfiguration of their business model, for more and more disrupting innovations in every field of operation.

2. Investigation and results

We have elaborated a model to investigate the readiness of countries to manage the growing complexity of global business environment (Figure 3). It based on the combination of the international experiences and literature of complexity management over the last few years, and the database of the Global Entrepreneurship Index (GEI). As a first approach we have collected a database of 27 EU-member countries (only Malta has not been included) and the 14 indicators describing them as follows. The values of 14 indicators of GEI-database are normalized (their average is 0, standard deviation is $\pm 1,0$). It would be possible to widen the focus of investigation globally in future, but firstly we tried to investigate the EU and especially the position of Hungary. We conducted a factor analysis of the 14 indicators to check their interdependence (if existent) and to form complex indicators (factors) from them for later use. Every group of interdependent indicators (variables) forms a certain factor (complex indicator), also with normalized values. After defining the professional meaning (content) of the factors (as complex indicators) we conducted cluster analysis based on the factor-weight matrix of the 27 countries. Investigating the different clusters (classes) of the countries it was possible to characterize the distribution of the EU-countries by their position regarding growing complexity.

Figure 3 The model of the investigation



Source: Own construction

We used these 14 variables (“pillars”) for measuring the position of countries at 14 areas of internal conditions and external environment, and we characterized them (additionally to the original definition in the GEI) from the point of view of complexity management, as follows:

1 - Entrepreneurial Attitudes: This gives a picture of how a country thinks about entrepreneurship, or talking about quickly growing complexity, how familiar the culture is (value range) with the higher complexity of challenges.

1.1: *Opportunity Perception.* This pillar captures the potential “opportunity perception” of a population by considering the state of property rights and the regulatory burden that could limit the real exploitation of the recognized business opportunity.

1.2: *Startup Skills.* Launching a successful venture requires the potential entrepreneur to have the necessary startup skills, including how to deal with the complex environment?

1.3: *Risk Acceptance.* Of the personal entrepreneurial traits, fear of failure is one of the most important obstacles to a startup. Aversion to high-risk enterprises can retard nascent entrepreneurship.

1.4: *Networking*. Networking combines an entrepreneur's personal knowledge with their ability to connect to others in a country and the whole world.

1.5: *Cultural Support*. This pillar is a combined measure of how a country's inhabitants view entrepreneurs in terms of status and career choice, and how the level of corruption in that country affects this view.

2 - Entrepreneurial Abilities: It measures the level of how people are prepared for future uncertainties, do they have the necessary skills or competencies?

2.1: *Opportunity Startup*. This is a measure of startups by people who are motivated by opportunity but face red tape and tax payment. An entrepreneur's motivation for starting a business is an important signal of quality.

2.2: *Technology Absorption*. In the era of Industry 4.0, information and communication technologies (ICT) play a crucial role in adapting to complexity.

2.3: *Human Capital*. The prevalence of high-quality human capital is vitally important for ventures that are highly innovative and require an educated, experienced, and healthy workforce to continue to grow.

2.4: *Competition*. Competition is a measure of a business's product or market uniqueness, combined with the market power of existing businesses and business groups and the effectiveness of anti-monopoly regulation.

3 - Entrepreneurial Aspirations: This is for measuring the readiness and ambition of people to survive in global competition, in other words, are they clear with what is meant by continuous and disruptive innovation.

3.1: *Product Innovation*. New products play a crucial role in the economies of all countries. While countries were once the source of most new products, today developing countries are producing products that are dramatically cheaper than their Western equivalents. The high level of this indicator is a typical sign of affinity to rapid exchange of company portfolio, which is fundamentally important in a time of unpredictable (complex) environmental changes.

3.2: *Process Innovation*. Applying and/or creating new technology is another important feature of businesses with high-growth potential. It is another important dimension of readiness for disrupting renewal of the business model, or the operation.

3.3: *High Growth*. High Growth is a combined measure of the percentage of high-growth businesses that intend to employ at least 10 people and plan to grow more than 50 percent in five years with business strategy sophistication and the possibility of venture capital financing. It is a characteristic indicator of competition focus, not just the survival struggles.

3.4: *Internationalization*. Internationalization is believed to be a major determinant of growth. A widely applied proxy for internationalization is exporting. Exporting demands capabilities beyond those needed by businesses that produce only for domestic markets. We should not forget, that companies in more open (globalized) economies – like Hungary – are more vulnerable to the threats of complexity.

3.5: *Risk Capital*. The availability of risk finance, particularly equity rather than debt, is an essential precondition for fulfilling entrepreneurial aspirations that are beyond an individual entrepreneur's personal financial resources, even in the time of unpredictable challenges.

As a first step of factor analysis we wanted to ensure the homogeneity of the dataset to provide the most characteristic representation of the assumed interrelationships. Taking into account the values of $MSA > 0.5$ and $KMO > 0.8$, all of the 14 variables seemed to be important. So, it was advisable to involve these indicators into the investigation. The results of the factor analysis are summarized in Table 1. The names of indicators are abbreviated. The findings are:

- Based on the intrinsic values greater than 1, we found of the four factors that they had a high level of explanation: compressing 81.4% of the information content of the 14 indicators. Based on the Kaiser-test we found the first three factors to be the best approach, because they contain all 14 variables. Communality of the original indicators was also appropriate: each of the values ranging from 0.734 to 0.903 is well above the empirical rule of min. 0.25, and the Bartlett test was significant (0.00). Thus, the results of the factor analysis based on the database are methodologically correct.
- The maximum factor weights at the 14 indicators are higher than the expected min. 0.3 (between 0.614 and 0.926). According to this, the professional interpretation of the factors (based on the respective indicators) is as follows:
- *F1: Complex (socio-economic) readiness level*. With the exception of three of the 14 original indicators, 11 indicators are mutually synchronous and intertwined in this factor. It suggests that these indicators should be considered and treated as a complex, common changing system, and for example must be dealt with together in macro-level decisions aiming to increase readiness to manage the threats of growing complexity.
- *F2: this is related to one indicator that changes independently of all others, the level of internationalization*. This suggests that the degree of internationalization is independent from how companies (and the business ecosystem) are prepared for managing increasing complexity. Otherwise: companies could be prepared for it, or not, in an opened or a closed economy.
- *F3: we find two variables here – the level of start-up skills (0.656) and the risk capital (-0.614) changing independently from the rest*. Because their sign is opposite, this suggests that in countries where the start-up skills are higher there is less demand (or supply) of risk capital (and vice versa). And another message is: readiness for managing complexity is independent of start-up background. The *F4* is just a residual complex indicator without professional content.

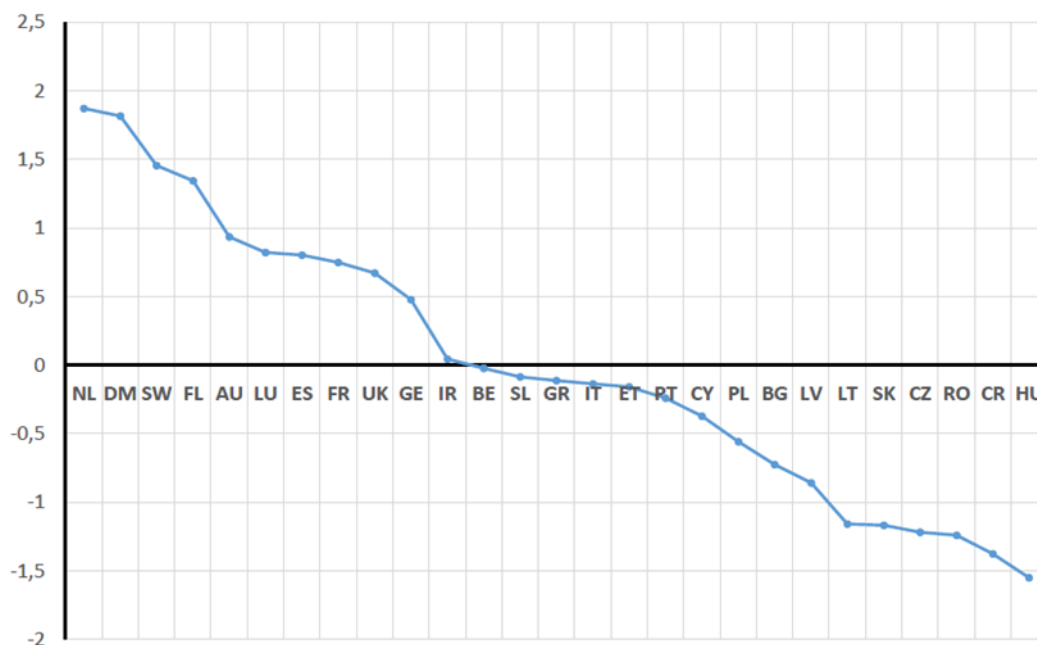
Table 1 Results of factor analysis

INDICATORS	Components			
	F1	F2	F3	F4
OPPORTPERCEPT	.918	-.158	-.007	.121
STARTUPSKILLS	.101	-.481	.656	.250
RISKACCEPT	.798	-.091	.326	-.176
NETWORKING	.688	-.507	-.138	-.130
CULTSUPPORT	.884	-.246	-.048	.094
OPPORTSTARTUP	.889	-.201	-.039	.137
TECHABSORP	.926	.056	.146	-.143
HUMANCAPITAL	.673	.143	-.251	.457
COMPETITION	.922	.065	-.052	-.061
PRODUCTINNOV	.724	.337	-.207	.103
PROCESSINNOV	.669	.086	.333	-.538
HIGHGROWTH	.624	.458	.192	.460
INTERNATIONAL	.327	.787	.245	-.211
RISKCAPITAL	.552	-.073	-.614	-.295
LOADINGS (%) $\Sigma = 81.4\%$	53.4	11.5	9.1	7.4

Source: Own calculation

If we take the F1 as the *complex readiness level* of a country (business ecosystem) to face the *threats of increasing complexity it seems to be useful for ranking* (Figure 4). *Decision makers* at every (macro- and micro-) level have to think through what the weakest (last) place of Hungary in the ranking means from the perspective of solving complexity management tasks! The vertical axis shows the normalized values of F1 factor in each country, where the average performance is 0, the positive values represent above average performance, while the negative ones are under average.

Figure 4 Ranking of EU-members based on their level of complexity management

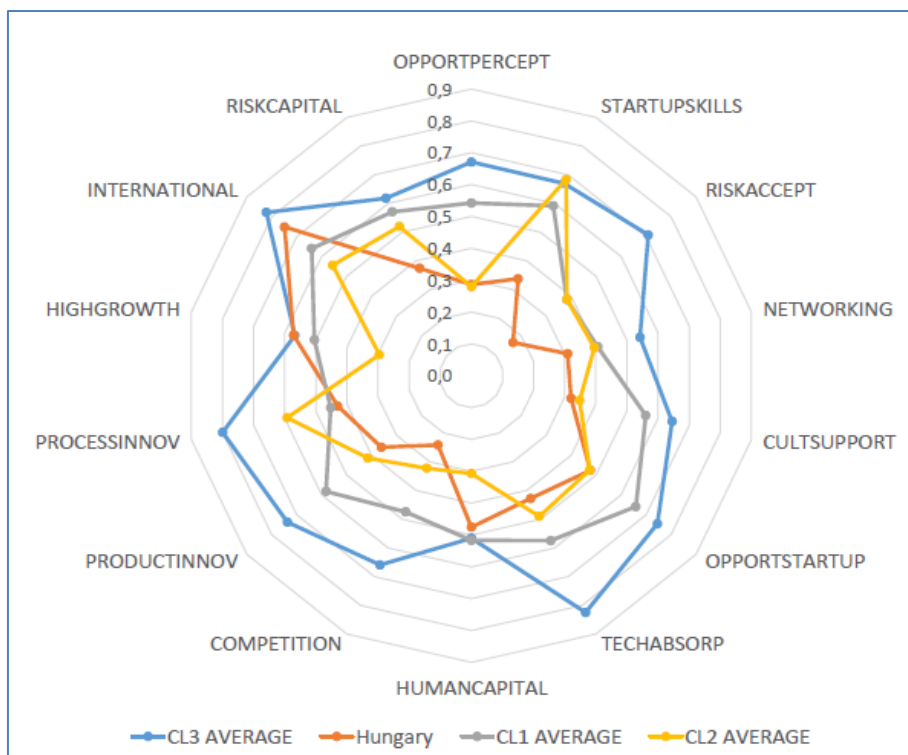


Source: Own construction

The cluster analysis with the four factors (as complex indicators) was performed on the 27-member database, and we determined the number and characteristics of the countries belonging to a distinct type (CL1, CL2, CL3 clusters) (Figure 5).

By trying different numbers of clusters, finally, three clusters gave the most definite results. Cluster member countries are referred to by their abbreviated names. The CL3 cluster of so-called "Prepared countries" (SW, FR, NL, FL, AU, GE, BE, LU, SL, SK, CZ) has the highest value of F1 (0.468) – they seem to be the most „robust” countries in the face of complexity challenges. The CL2 cluster (UK, DM, IR, ET, LV, PL, CY, LT, RO, including Hungary too, but not in Figure 5, because we wanted to show its profile separately) is the group of “Strongly threatened countries” based on their lowest value (–0.336) of F1. The CL1 cluster of "Vulnerable countries" (PT, ES, IT, GR, CR, BG, where F1 = –0.298) is practically the group of moderately threatened economies is characterized by some readiness (F1) and the least developed financial market (F2) among the three clusters.

Figure 5 Comparing the cluster profiles and Hungary



Source: Own construction

Hungary is a special case – its F1 value is the weakest in the EU (–1.549). Its weak points are:

- Concerning entrepreneurial attitudes: opportunity perception, risk acceptance, networking, cultural support
- Concerning entrepreneurial abilities: technology absorption, competition
- Concerning entrepreneurial aspirations: product innovation, process innovation
- Besides the above-mentioned, but independent of the F1 complex indicator, there are also weak points in start-up skills and risk capital.

The value (level) of these indicators are weaker than the average level of the CL3 cluster ("Prepared countries") or the CL1 cluster ("Vulnerable countries"), even the average level of our CL2 cluster ("Strongly threatened countries"). Only the level of high growth and the human capital could be termed acceptable – if we could maintain these levels into the future, but certain dangers can be ascertained in the growing crises of the education and healthcare systems, the continuous migration of qualified workforce into Western Europe, and the possible future decrease in EU-subsidies.

3. Conclusion

We often meet with good-news reports in the media about the growing performance of the Hungarian economy. With the benefit of careful selective immersion, these reports can be supported by some indicators. But the statements can only be taken seriously if they stand in international comparison and in a broader context. Above all, the overall picture must be balanced, and provide sufficient guarantees for the country to respond effectively to the challenges of the future. This time we have studied one of these challenges, namely the threats of the accelerating global complexity in the economy as a consequence of the industrial revolution 4.0, and how countries are prepared for facing it.

As a result of our research, we have found that the pool of the EU member states shows a very mixed picture in this respect. A significant group of the 27 investigated countries (those with the most advanced business ecosystem, cluster CL3) are at a relatively acceptable level for all of the indicators examined. Some of the indicators in another group (cluster CL1) are weaker and that's why these are more vulnerable, but there is a chance for them to find the right answer to more complex challenges. However, there is a very vulnerable group of member states (cluster CL2) – which, if they do not try to build (rebuild) a viable, flexible, and entrepreneurial business ecosystem as quickly as possible, will not be able to successfully negotiate the maze of the fourth industrial revolution.

Hungary's situation is very specific: it is a member of the CL2 cluster, so in many respects it is highly threatened. Unfortunately, however, even in this cluster it differs in a negative sense, because most of those indicators are weaker (in some cases significantly) compared to the cluster average - indicators which are essential for the future competitiveness of the business ecosystem.

Finally, all EU member states (and all players in the globalized economy) face big and rapidly growing complex challenges. Countries whose business ecosystems are weaker than average (for various reasons) seem particularly vulnerable. All this underlines the responsibility of macro-level decision-makers and organizational-level managers to form business ecosystems by working together in the right direction and in a timely manner, as soon as possible.

The results of our research are a kind of diagnosis that draws attention to the points of business ecosystems where significant improvements and transformations are needed to survive in an era of growing complexity. The results also point to the fact that, because of the complex context of the ecosystem's characteristic features, it is pointless to find a single best rescue measure - the viable solution and the path to it may vary from country to country. And this is especially true in Hungary, because its position is very specific as our results show.

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