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Factors Introducing Industry 4.0 to SMES

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Abstract: The aim of the paper is to identify some of the factors that affect the introduction of Industry 4.0 elements to small and medium-sized enterprises (SMEs). The article is concerned with factors that can be impulsive for SMEs and factors that, on the contrary, are limiting for SMEs to integrate Industry 4.0 into the enterprises. These factors are the result of a short brainstorming with some employees of 72 selected SMEs for case studies. The analysis of 1018 Czech SMEs showed that the introduction of Industry 4.0 is related to the size of the enterprise. Fisher's Factorial Test based on a four-fold contingency table tested the data. The majority of medium-sized enterprises consider introducing digitization and robotization elements in the next 5 years, while in the case of micro-enterprises it was less than a half of the enterprises of the sample. At the same time, the relation between the enterprises with a written strategy and enterprises planning to implement Industry 4.0 was demonstrated.

Keywords: Industry 4.0; SMEs; factors; strategy

1. Introduction

Innovation is important driver of economic growth for both large enterprises and small and medium-sized enterprises (SMEs). The firms must still adapt to the new changes in the market to maintain their competitiveness. The main direction of innovation is focused on Industry 4.0. Industry 4.0 is a term covering industry automation, robotization and digitization. Industry 4.0 brings huge opportunities in terms of sustainability and increased productivity of industrial production by up to one-third (Poor and Basl 2018). The study of Deloitte from 2014 mentioned that large manufacturing firms already consider Industry 4.0 to be very important. To the contrary, small and medium-sized companies do not yet appear to consider it to be of great relevance to them. Nowadays, we can see a shift in small and medium-sized enterprises' access to Industry 4.0. This fact leads the authors to identify typical factors that influence the implementation of Industry 4.0 in SMEs.

An important role in the implementation of innovation technologies (Industry 4.0) is writing the innovation strategies of enterprises. This hypothesis is based on the study of Verbano and Crema (2016), which reported that firms with innovation strategies tend to integrate more new technologies.

2. Literature Review

Industry 4.0 is called the fourth industrial revolution (Park and Huh 2018). Industry 4.0 is based on the use of cyber-physical systems to improve computer and communication systems. New technologies are directed to distributed systems in this vision and work with methods of auto-optimization, intelligent worker support, self-diagnosis, machine perception and self-configuring. Based on sophisticated technologies, "smart factories" produce "smart products"—each easily identifiable and localizable (Stock and Seliger 2016; MacDougall 2014). The essential reason for introducing Industry 4.0 into real

practice is to increase business competitiveness. Industry 4.0 is no longer a topic discussed by large enterprises only. To the contrary, if we want small and medium-sized businesses to be able to produce more efficiently, it is necessary to fulfil the potential of Industry 4.0 (Ganzarain and Errasti 2016). The integration of the ideas of Industry 4.0 ideas will not only lead to changes in the production of SMEs but big changes can also be expected in other fields, such as labor markets and business models. Some authors, such as Faller and Feldmüller (2015), see that small and medium-sized enterprises (SMEs) have especially high difficulty in becoming skilled in the applications and technologies of Industry 4.0. The aim of this paper is to define some of the factors influencing the introduction of Industry 4.0 elements into the real-world production of small and medium-sized enterprises. Industry 4.0 represents a change of paradigm in production. Some authors admit that Industry 4.0 will become a global driving force for ensuring the sustainability of industry (Nieuwenhuis and Katsifou 2015). Industry 4.0, however, is associated with a high degree of abstraction and many enterprises do not exactly know what to think of it. This does not change the importance of the potential of Industry 4.0. Industry 4.0 and its components are expected to radically change the functioning of all enterprises, industries and, ultimately, the whole society (Ślusarczyk 2018). In general, there are many definitions of Industry 4.0. This paper uses the definition of PricewaterhouseCoopers (2016): "Industry 4.0 focuses on the end-to-end digitization of all physical assets and integration into digital ecosystems with value chain partners. Generating, analyzing and communicating data seamlessly underpin the gains promised by Industry 4.0, which networks a wide range of new technologies to create value." At a very general level, Industry 4.0 is a patronizing term for the current trends in digitization and automation in the society. As mentioned above, the technologies on which the Industry 4.0 concept is built have been in existence for a while and they are not completely new. What is happening today is the use all of these technologies together to connect the physical world with virtual and biological factors to create complex systems that exploit the synergies of each element and bring more added value than could be obtained if the elements were used separately (Gilchrist 2016).

Industry 4.0 is based on four key points, characterizing and distinguishing it from traditional production (Deloitte 2014): vertical integration of the production system, horizontal integration with the new generation of global value chain networks, flow production through the entire value chain and acceleration using Smart Technology. According to a study of the European Parliament, Smit et al. (2016) identified the main effects of the integration of the principles of Industry 4.0 in three dimensions and in areas of technological, social and business paradigm changes. In order to implement the changes mentioned above, it is necessary for the enterprise to address the main factors that can facilitate the implementation of Industry 4.0. Such factors include: employment, technology, IT level, finance and risk management. The factor that might have a significant impact on the introduction of Industry 4.0, as Wolf et al. (2018) pointed out, is employment. In the first phase, the number of jobs should decrease. Over time, jobs vacancies might increase and a high level of emphasis might be placed on highly skilled workers, becoming a competitive advantage for enterprises (Mura et al. 2017). History clearly shows that the growth in labor productivity has contributed to the release of employees from their activities. The introduction of Industry 4.0 will result in the disappearance of low-skilled jobs in the industry (assembly line production) and other activities. The role of the human factor for the introduction of Industry 4.0 is also perceived as the most significant; Hecklau et al. (2016) noticed that the experience and skills of the workforce are key to the success of a highly innovative factory. For this reason, companies should focus on developing a skilled workforce in human resources management. Employee qualification and skills requirements will be higher with Industry 4.0, as enterprises will use new technologies and intelligent media. However, Industry 4.0 implementation might uncover some issues, such as insufficient computer skills, as one of the most important issues (Wielki 2017). At the same time, a change in the existing processes is emphasized. New strategic approaches to comprehensive human resources management are in place for the easier and smoother implementation of new technologies, knowledge and competencies. The continuous automation of simple manufacturing processes will increase the number of workforce members with a high level of

complexity, leading to a high level of employee training. It will be necessary to qualify employees for more complex tasks (Hecklau et al. 2016).

Another aspect influencing the implementation of Industry 4.0, as noticed by Tupa et al. (2017), is related to risk management approaches due to the emergence of entirely new risk categories, in particular due to increased vulnerability and exposure to threats. The combination of cyberspace, sophisticated production, technology, features and the use of outsourcing services is the greatest factor in increasing the vulnerability of enterprises. The main newly identified types of risks are as follows: Production (information risk associated with data loss, loss of integrity and available information), Maintenance (problems with the availability and integrity of maintenance data), Used Methods and Tools (data processing errors), Machines and Production Technologies (sensitivity and vulnerability of a cybernetic attack data problem), Human Resources (low number of qualified workers), Machine Environment (internet network attacks, electromagnetic compatibility issues affecting production machines). The IT sector uses an "Information Security Management System" (ISMS) structure, including administrative security, technical security and physical security (Kim et al. 2019). The security of information is particularly related to the confidentiality of information. Implementation of this standard may be a solution for a particular manufacturing enterprise accepting Industry 4.0. Enterprises can use 5C architecture of cyber-physical systems to implement Industry 4.0 in manufacturing (Lee et al. 2015).

Another important factor is related to new robotic technology, machines and mechanisms. In particular, in mining and transport there are machines, robotic technologies, mechanisms with artificial intelligence elements and various automation devices (Tupa et al. 2017). This trend is also related to the manufacturing sector (Smater and Zieliński 2015). One of the main factors influencing the implementation of Industry 4.0 to enterprises is the initial investment associated with the acquisition of new technologies that make Industry 4.0 a reality. However, cost increase might as well be achieved by upgrading current technologies to optimize production. Such an investment might be rather expensive, as there is a question of financing the changes associated with the introduction of Industry 4.0. Users, in this case SMEs, mostly have long-term business relationships with national banks, and credit allocation occurs mostly without issue. Obstacles should also not arise while investing in technology (Nieuwenhuis and Katsifou 2015).

The expected impact of implementing Industry 4.0 for enterprises might be as follows. The biggest benefit of Industry 4.0 for industrial companies will be added cost efficiency and/or productivity (Kovács and Kot 2016). Manufacturing industry today must withstand increasing global competition in terms of product quality, productivity and production costs, and one of the ways to solve this situation is the application of the principles of Industry 4.0 (Brettel et al. 2014). On the other hand, there may be a slight increase in the cost of services associated with new technologies and machines. Other impacts include digitization (Lee et al. 2014), as well as ensuring and sustaining either organic (Müller et al. 2018) or social (Morrar et al. 2017) production. Other expected impacts of investment include digitization (Lee et al. 2014) and production and environmental sustainability (Müller et al. 2018)—both regional (Chmelíková and Redlichová 2012) and social (Morrar et al. 2017).

3. Methods

The aim of this paper is to identify typical factors that influence the implementation of Industry 4.0 in SMEs and, at the same time, to assess the impact of a defined written strategy and firm size on SMEs' innovation activity. The partial aim is to verify the hypothesis that firms that have written strategies will implement automation elements in the next 5 years.

We used the classification of SMEs by Commission Recommendation 2003/361/ESES (Commission Recommendation 2003) based on number of employees, turnover and balance sheet total. Attention was focused on such factors that can act impulsively in SMEs and on the factors which, on the contrary, are restrictive for SMEs. The analysis was carried through a questionnaire survey of a sample of 1018 small and medium-sized enterprises. In 2017, a questionnaire survey was carried out in small and medium-sized enterprises, where a sample of 40,000 SMEs out of a total of 413,157 in the Czech

Republic (2017) was created using a quota selection (based on CZ-NACE). Subsequently, data from 1018 SMEs were collected. After that, companies were selected from this group to plan the introduction of automation in the next 5 years, of which 100 were selected for case studies by random sampling. Overall, case studies were conducted in 72 SMEs, on the basis of which the factors defined by expert literature affecting the introduction of Industry 4.0 were modified. Based on short brainstorming with some employees of the enterprises selected for case studies, the most frequently occurring factors influencing the introduction of Industry 4.0 were identified. These factors were discussed in round tables with different executive managers. Subsequently, they were grouped into different categories. Further, the hypotheses were tested, assuming the dependence of the size of the enterprise (expressed in the number of employees) and willingness to invest in automation, on a sample of 1018 SMEs from the survey in the second half of 2017. Moreover, the hypotheses assuming the independence of the abovementioned factors were tested. The test statistics were based on a four-fold contingency table as you can see in Table 1, labelled as n11 = a, n12 = b, n21 = c, n22 = d (Freeman et al. 2017; Keller 2014).

Table 1. Four-fold contingency table (Budíková et al. 2010).

X	**Y**		**n*j*.**
	y[1]	**y[2]**	
x[1]	a	b	a + b
x[2]	c	d	c + d
n.k	a + c	b + d	n

The test statistics are summarized in Equation (1). If the hypothesis on the independence of variables X, Y applies, then K is asymptotically controlled by the distribution $\chi^2(1)$. Rejection hypothesis: $W = \langle \chi^2_{1-\alpha}(1),\ \infty)$. The null hypothesis is rejected at the α asymptotical level of significance if $K \in W$ under the condition of good approximation, proved before the test ($K \in W$).

$$K = \frac{n\,(ad - bc)^2}{(a+b)(c+d)(a+c)(b+d)}. \quad (1)$$

Regarding the outputs, the data were tested by Fisher's Factorial Test, by combinatorial considerations calculating the probability of marginal frequencies tables that deviate from null hypothesis, The sum of these probabilities is the p-value of the test, and the table of observed frequencies is the test statistics. The data were analyzed using the Statistica software, with the output p-value for Fisher's exact test. If the p-value $\leq \alpha$, the hypothesis of independence is rejected at the significant level of α, set at 0.05 in this paper (Devore 2015; Budíková et al. 2010).

4. Results and Discussion

Based on 72 case studies from SMEs supported by theory, the important factors significantly influencing the process of gradual digitization and automation in SMEs were grouped into categories according to the individual business activities (Figure 1).

Some factors reported by Figure 1 might encourage an enterprise to implement Industry 4.0 elements due to a competitive advantage and for the purpose of maintaining competitiveness in order to increase the value of the enterprise. Some factors might be limiting for small and medium-sized enterprises, preventing these technological changes from being introduced. The factors were grouped into six categories, based on business activities and areas: Employees, Machine, Finance Planning, Process Management, Know-How and External Factors. These factors concern all businesses that intend to implement automation in the next 5 years and therefore some common features of these SMEs can be expected.

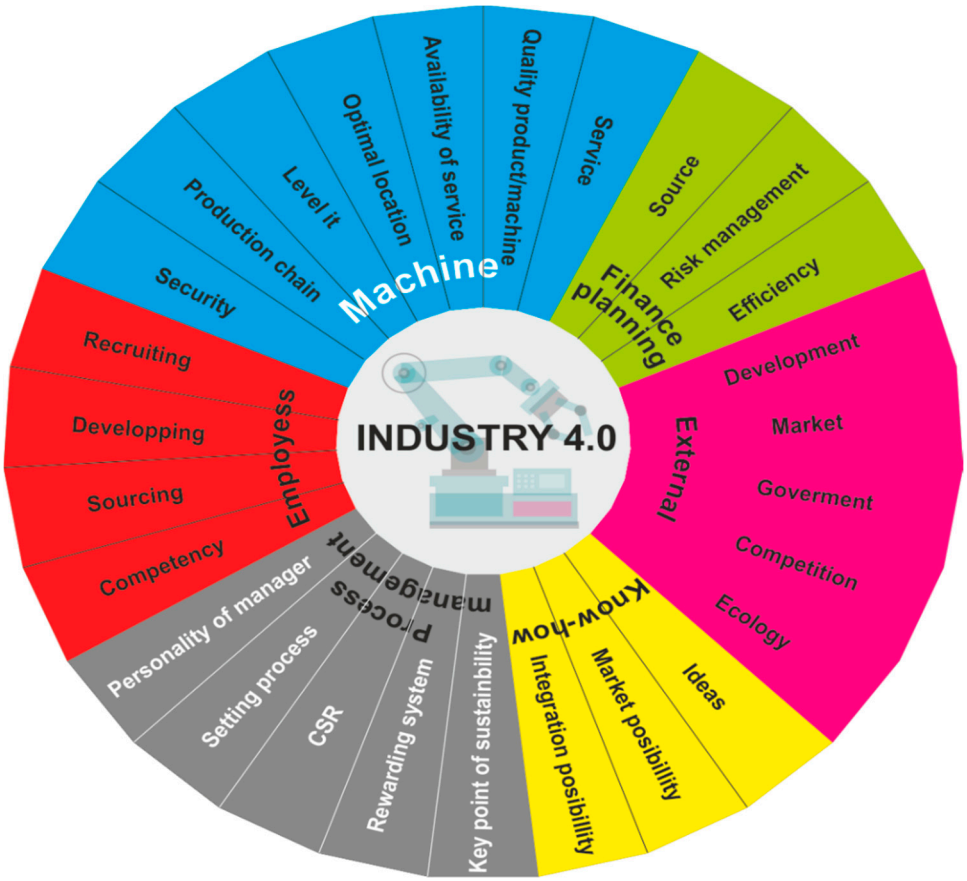

Figure 1. Factors influencing the introduction of Industry 4.0 elements in small and medium-sized enterprises (SMEs).

The category of Employees is divided into the following subcategories: recruiting, developing, sourcing, and competency. A limiting factor in the implementation of Industry 4.0 might be the issue of how to attract new employees to using new technologies (computer graphics, additive manufacturing, cybernetics, automation, artificial intelligence and cyber security) and workflows. The need to constantly develop employee knowledge and skills will require a different type of work, access to work and the creation of new jobs with different demands than the original production.

Poor and Basl (2018) added that it will also be necessary to change the education system. Other changes might be expected in human resources management. In the case of very low unemployment, this factor can considerably complicate the streamlining of business processes and activities.

The category of Process Management includes other factors, such as the key point of sustainability, the rewarding system, CSR, the setting process and the personality of a manager. The correct setting of the process of introducing innovations and changes to an enterprise is also the correct setting of the process benchmarks so that it is possible to continuously monitor and evaluate the process and its success, recognizing and terminating an unsuccessful project in time. For example, a newly created management system as the automatic generator of voltage control systems in power plants was shown to have a significant impact (Lee and Huh 2018).

The best choice for an enterprise is to combine new systems with a set line strategy with modern social responsibility trends. Even if all the factors evaluating the implementation of Industry 4.0 are set correctly, it always depends on the manager's personality—whether the manager is willing to risk their personal and professional success by introducing new systems and innovations that are in line with the agreed business strategy that plays an important role in planning itself.

The category of Know-How includes ideas, market possibility and integration possibility. Both tacit knowledge and key employees play major roles in creating innovation and introducing new

technologies. In general, the manager's management system, supporting new ideas and thoughts of subordinates that are subsequently developed, is highly influential. Another way to introduce innovation is to efficiently process information available on the market and respond flexibly to new trends and needs of customers, often providing useful innovation. The know-how of an enterprise is seen both as a competitive advantage due to the possession of patents and utility models, and as an access to technology, extending the supply chain thanks to information sharing.

SMEs can respond flexibly to customer requirements (impulsive factor), and they are often able to hinder the availability of the necessary know-how, both financial and informational, in realization. Large enterprises usually have their own development centers as well as employees dealing with specific areas, which cannot be guaranteed for SMEs.

Into the category of Machines, the following factors are included: security, production chain, IT level, optimal location, availability of service, quantity of product to machine and services. The level of technology utilization (machines, equipment) and technologies in an enterprise, their renewal and their optimal use are the fundamental factors for the integration of Industry 4.0. In order to increase competitiveness, it is desirable for enterprises to use new technologies, digitize and speed up production processes, increase efficiency, have a flexible production of multiple types of products (Wang et al. 2016) and exhibit customer orientation. Industry 4.0 efforts are also centered on making everything in real time, which requires that the production process, the collection of data and the feedback is achieved in real time (Gilchrist 2016). A prerequisite for the integration of Industry 4.0 is the availability and speed of service and the availability of data center services. The essential requirements for its use are the digital security of systems and the security of data processing in enterprises. Most SMEs have to deal with security and maintenance through outsourcing. The cost of safety and maintenance have to be taken into account when analyzing the effectiveness of an investment.

When deciding to invest in new technologies, it is necessary to assess both the method of financing, the efficiency of the investment and the economic effect (Huh and Lee 2018). The category of factors influencing this decision is called Finance Planning and includes the source of financing, risk management and efficiency. It is necessary to assess whether enterprises have sufficient resources to finance an investment. The subsequent decision-making process deals with the question of whether to use external or internal resources for funding. A decisive factor influencing whether or not Industry 4.0 is introduced is its effectiveness (return on investment and recovery rate). A necessary part of the distribution process is risk analysis. The critical stage of the risk management process is the choice of the optimal solution. After that, the decision on the implementation of the risk mitigation measures and the decision on its further monitoring in the case of a high degree of uncertainty follow. Risk management uses the principle of feedback compared to the current situation and possible threats to provide the fullest possible information about the possible course of their fulfilment. Without this analysis, the implementation of new technologies in connection with the introduction of Industry 4.0 would be rather risky.

During the course of its operation, an enterprise is influenced by changes resulting from the surrounding environment. Factors that affect the integration of Industry 4.0 into real business practice can be divided into internal and external. The external factors were classified into the External category, divided into the following subcategories: Development, Market, Government, Competition and Ecology. The external factors that have a significant impact on the use of new Industry 4.0 technology include technological development and the speed at which new technologies are adopted in real practice. Another important factor is the willingness of governments and communities of nations (e.g., the EU) to support the introduction of new technologies into production. This support can be both methodical and financial (subsidies). Frequent drivers of introducing new technologies to lower costs and higher productivity are competition in the market—a competitive environment. These are, in particular, factors affecting an enterprise within the industry in which the enterprise performs its operations. It also includes market position compared to competitors, development and its trends in a competitive environment and business mood. At the same time, trends in automation and the

robotic automation of production are leading to a greener industry, through the more efficient use of materials and the reduction of environmental burdens. An important factor is also related to the reduction of environmental impacts of production and the use of technologies that reduce burden on the environment (Carter 2018).

Further analysis was aimed at the identification of factors and the actual possibilities of introducing Industry 4.0 into small and medium-sized enterprises in the Czech Republic. The sample consisted of 1018 SMEs. There are 629 enterprises planning to increase automation and thus integrate technological change in the next 5 years, representing 62% of the participants. The sample of enterprises was further categorized and analyzed by their size as you can see in Table 2. There were 213 micro-enterprises in the sample size, 46% of which plan to automate in the next 5 years. However, it is necessary to add that 71% of them do not have a written strategy. The same percentage was reported for the enterprises that are not going to automate. These conclusions were confirmed by Fisher's exact two-sided test, where the p-value is 0.85317. At a level of significance of 0.05, the null hypothesis that the written strategies for micro-enterprises and the introduction of automation in the next 5 years are unrelated is not rejected. In micro-enterprises, the strategy has no impact on the introduction of automation, supporting the idea that micro-enterprises are managed more operationally. The test results are shown in the right-hand side of Figure 2.

Table 2. Frequency comparison in SMEs.

Company Size	Written Strategy	Automation in 5 Years—No	Automation in 5 Years—Yes	Sum
Micro	No (%)	82 (38.50%)	70 (32.86%)	152 (71.36%)
	Yes (%)	33 (15.49%)	28 (13.15%)	61 (28.64%)
	Total (%)	115 (53.99%)	98 (46.01%)	213 (100.00%)
Small	No (%)	127 (25.76%)	162 (32.86%)	289 (58.62%)
	Yes (%)	67 (13.59%)	137 (27.79%)	204 (41.38%)
	Total (%)	194 (39.35%)	299 (60.65%)	493 (100.00%)
Medium	No (%)	42 (13.46%)	74 (23.72%)	116 (37.18%)
	Yes (%)	38 (12.18%)	158 (50.64%)	196 (62.82%)
	Total (%)	80 (25.64%)	232 (74.36%)	312 (100.00%)

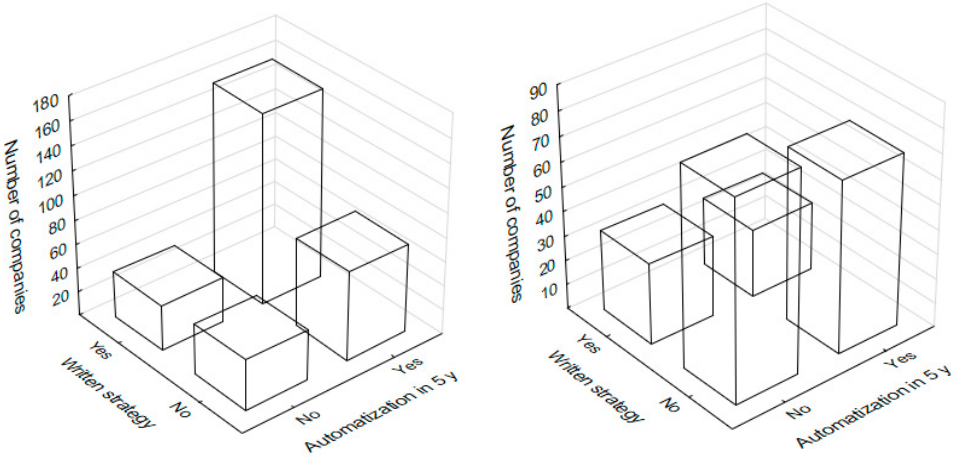

Figure 2. Frequency of medium-sized and micro-enterprises according to written strategy and approach to implementation of automation in 5 years. Medium-sized on the left, micro-sized enterprises on the right.

In the sample, there were 493 small enterprises, among which less than 59% were without a written strategy. However, there were more than 60% that are not going to increase automation. This amounts to 289 small enterprises without a strategy, of which 44% do not plan to introduce or expand automation in the next 5 years, compared to 67% of the enterprises with a strategy that are going to

increase automation. The results are supported by a p-value of 0.01492 for Fisher's test, rejecting the null hypothesis that the written strategies for small enterprises and the introduction of automation in the next 5 years are unrelated at a significant level. There is a relation between both variables.

In total, there were 312 medium-sized enterprises in the sample, 232 of which are going to increase automation, compared to 26% that are not going to increase it. A written strategy was reported by 63% of enterprises, 81% of which are planning to implement automation.

The written strategy was reported by 63% of enterprises, 81% of which are going to implement automation, compared to 64% without the strategy. In general, it is assumed that medium-sized enterprises will face problems with the introduction of Industry 4.0 more often in the next 5 years compared to small enterprises and micro-enterprises.

A general relation of the strategy and the planned increase in automation is also confirmed by Fischer's test, as it was possible to reject the null hypothesis that the two factors are not related at the significance level of 0.05. The value of p-value here is 0.00127. The test results are also shown in the left-hand part of the box-plot above.

5. Summary

This paper discussed the factors influencing the implementation of Industry 4.0 into SMEs. It identified some factors that might be an incentive for Industry 4.0 use. In the sample of 1081 enterprises, it was proved that there is a relation between Industry 4.0 implementation and the size of an enterprise. The same results were found by Sommer (2015), who reported that large enterprises are better prepared for Industry 4.0 than small enterprises. More medium-sized enterprises (around 59%) are considering introducing digitization and robotic automation elements in the next 5 years, compared to less than half of the micro-enterprises in the sample. A written strategy plays an important role. A statistically significant association of Industry 4.0 elements with the written strategy formulation was proved. This factor (a written strategy), as a part of the abovementioned category of Process Management, might be considered as one of the factors supporting the implementation of Industry 4.0. A possible difficulty might be related to the fact that the enterprises do not have assigned responsible people who would take care of further deepening the principles of Industry 4.0 (Basl 2017). Thus, the limiting factor is related to the structure of the employees (insufficient educational structure and professional level), the financial difficulty and the return on investment projects. The solution may be found in different approaches to employees, as a number of authors have suggested in terms of talent management (Egerová et al. 2015), and in a well-defined strategy (Chladkova and Formankova 2016; Rolinek and Řehoř 2008). In spite of the above limits, the Industry 4.0 concept offers great potential for the future, particularly for medium-sized enterprises.

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