EMPLOYEE TECHNOLOGY ACCEPTANCE OF INDUSTRY 4.0 IN SMES

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ABSTRACT

The integration of the digital into the physical world is called Industry 4.0 and transforms manufacturing. In the future, smart factories collect more data than ever to empower artificial intelligence in cyber-physical production systems. Employee acceptance was identified as one of the most critical aspects for a successful introduction of I4.0 in any company. The design of such an I4.0 introduction process needs further research, not only for big corporations but also for small- and medium-sized enterprises as those are just as crucial for economies around the globe. Companies can use various “maturity” or “readiness” models for self-assessment of their current I4.0 capabilities and progress towards successful I4.0 introduction. We use the technology acceptance model to improve the employee dimension in our questionnaire. It is conducted in Germany and Spain with a focus on smaller and medium-sized enterprises. The results find statistically significant differences for smaller companies with significantly fewer technologies used, less systematic technology management, fewer investments made, and also earlier stages of I4.0 introduction for smaller companies. The collaboration with a bigger partner on the I4.0 introduction leads to a significantly more positive attitude towards I4.0, including employees, who look towards the changes with confidence.

KEYWORDS: Industry 4.0, Artificial Intelligence, Technology Acceptance Model, SME.

1. INTRODUCTION

Industry 4.0 (I4.0) transforms manufacturing by the integration of the digital into the physical world. In the future, smart factories collect more data than ever to empower artificial intelligence (AI) in cyber-physical production systems (CPPS). Extensive networks of humans and machines are the result, which eliminates company borders and redefines work within a plant but also the collaboration between business partners. However, in 2018, just 14% of 1.600 executives, who participated in a study conducted by Deloitte, believed that their organization is prepared for I4.0 and able to profit from this new potential (Deloitte, 2018). While Gartner predicts that additional automation and the use of artificial intelligence will create more jobs than it destroys, the new jobs will mainly be in fields such as healthcare and education. At the same time, manufacturing will probably see most job losses, so employees are skeptical about the introduction of the new technology (Pettey & Meulen, 2017).

This work examines the technology acceptance by employees and the overall status of I4.0 introduction in small- and medium-sized manufacturing companies (SMEs). Several studies and questionnaires investigate the introduction of I4.0 and AI in manufacturing companies but

mostly target big multi-national companies. Therefore, they provide the basis for our questionnaire that focuses on SMEs and analyses the employee's feelings in more detail.

1.1. Employee acceptance of I4.0 introduction

Employees help companies realize their digital transformation and are the ones most affected by the changes in the digital workplace. Their direct working environment is altered, requiring them to acquire new skills and qualifications. Abel, Hirsch-Kreinsen and Steglich explain the worker's doubts not only with their fear of job losses but also the technological changes being digital and no longer immediately comprehensible to the individuals, which results in insecurities and skepticism (Abel, Hirsch-Kreinsen, Steglich, & Wienzek, 2019). Kagermann, Wahlster, and Helbig similarly report a "growing tension between the virtual world and the world of workers' own experience. This tension could result in workers experiencing a loss of control and a sense of alienation from their work as a result of the progressive dematerialization and virtualization of business and work processes" (Kagermann, Wahlster, & Helbig, 2013). They also agree that through extensive human-machine interactions, the work content, and processes, as well as the working environment, will be radically transformed and thus also the worker's job and competence profiles. Other researchers perceive the introduction of I4.0 not only as a challenge but also as a chance to improve the work environment by creating learning systems, which "dynamically detect and adapt to the context of the support situation and the worker's actions" (Gorecky, Schmitt, Loskyll, & Zühlke, 2014).

In conclusion, for a successful introduction of I4.0 in any company, employee acceptance got identified as one of the most critical aspects. The introduction process requires communication and transparency as "acceptance is a fragile construct, which needs constant cultivation" to convert employee resistance into acceptance or even support (Abel et al., 2019). The design of a successful I4.0 introduction process needs further research, not only for big corporations but also for small- and medium-sized enterprises.

1.2. Industry 4.0 for SMEs

Small and medium-sized enterprises are just as important for economies around the globe as big multinational enterprises. In the 28 European countries, two-thirds of employees in the non-financial sector are employed by SMEs. All three sizes of SMEs are contributing nearly equally to value added with 20.3% for micro enterprises, 17.6% for small enterprises and 18.5% for medium-sized enterprises (Airaksinen, Luomaranta, Alajääskö, & Roodhuijzen, 2015). In 2015 they employed 91 million people in total and generated 3.934 € billion of value added (Eurostat, 2018). Therefore "SMEs are the backbone of the European and many other economies" (*Future Image Industry 4.0*, 2012; Kraemer-Eis & Passaris, 2015). This is also especially true for manufacturing, where European SMEs provide around 45% of the value added and around 59% of employment (Vidosav, 2014).

Even though SMEs are an essential factor to economies, the I4.0 methods are developed mainly in larger enterprises and have to be adapted to the specific requirements of SMEs (Rauch et al., 2018). Currently, the spread of I4.0 depends on company size, and large companies are more likely to deploy relevant I4.0 technologies than SMEs (Schröder, 2016). Several scientists investigated the reasons for this observation. In 2017 Decker used case study research to evaluate the I4.0 readiness of Danish SMEs from the metal processing sector with the result that

SMEs at this time were not sure if or how they should introduce I4.0 in their companies (Decker, 2016). Wuest et al. confirmed the struggle of SMEs to adopt I4.0 in a study conducted with manufacturing SMEs in West Virginia in 2018 (Wuest, Schmid, Lego, & Bowen, 2018). Both studies seem to support the claim made by Lutz Sommer in an article from 2015 that, "actually most of SMEs are not prepared to implement I4.0 concepts" (Sommer, 2015). Further research suggests various challenges for SMEs in I4.0 introduction:

- Different prerequisites regarding the integration of their production plants in higher-level IT systems, which is much more advanced in bigger companies (Lichtblau et al., 2014).
- Using a self-assessment tool is not easy as I4.0 concepts are still too little known (Rauch et al., 2018)
- SMEs often lack resources to evaluate new technologies and their business uses. Thus it is hard for them to develop an appropriate strategy, including a cost-benefit analysis (Schröder, 2016).

Those challenges need to be verified and addressed because "successful implementation of an industrial revolution I4.0 has to take place not only in large enterprises but in particular in SMEs" (Sommer, 2015).

1.3. Industry 4.0 Self-Assessment

Companies can use various "maturity" or "readiness" models for self-assessment of their current I4.0 capabilities and progress towards successful I4.0 introduction. Schumacher, Erol and Sihn created an overview of existing models in 2016 and found that many models lack details regarding the development process or assessment methodology (Schumacher, Erol, & Sihn, 2016). They highlight the "Industry 4.0 Readiness Model" (Lichtblau et al., 2014) as "scientifically well-grounded and its structure and results explained in transparent manners" but the model contains just a single question for the employee dimension. In this question, they assess if the workers have the required skills to accomplish their future tasks[1]. Schumacher, Erol and Sihn propose their own "Industry 4.0 maturity model", which also asks for the openness of employees towards new technologies. However, we introduce the technology acceptance model in our study to further improve the employee dimension.

1.4. Technology Acceptance Model

The "Technology Acceptance Model" (TAM), developed by Fred D. Davis 1986 and published in 1989, is used to acquire additional insights into the factors that influence adoption of new technology (Davis, 1986). The two main variables are "perceived usefulness" (PU) and "perceived ease-of-use" (PEU). Im, Kim, and Han extended the TAM by introducing "perceived risk" (PR) as an additional variable that negatively affects adoption (Im, Kim, & Han, 2008). Those factors influence the "attitude towards usage" (ATU) and finally also the "behavioral intention

[1] Industry 4.0 Readiness Model Questionnaire: https://www.industrie40-readiness.de/ retrieved 14-04-2020

to use" (BIU) and the questionnaire contains items to investigate every component. To this day TAM is one of the most popular models to assess user acceptance of new technologies and was successfully used to evaluate the adoption of related technologies, e.g., smartphones and wearables (Chang, Lee, & Ji, 2016; Roy, 2017).

2. METHODOLOGY

The questionnaire is conducted in Germany and Spain with a focus on smaller and medium-sized companies. The German manufacturing companies are all members of the "Innovation Hub Oberbergischer Kreis", a regional association that focuses on the exchange of I4.0 knowledge and possible applications. The Spanish companies belong to the industrial service sector, working on optimization, logistics and manufacturing technologies for their national and international clients.

The questionnaires are sent to the executives, who are responsible for the introduction of I4.0 and AI in their companies. This work examines the following hypotheses:

H_1: Smaller SMEs need more assistance for the evaluation of I4.0 technologies than bigger

H_2: Smaller SMEs need more assistance to assess I4.0 introduction costs and benefits than bigger SMEs. SMEs.

H_3: Smaller SMEs need more assistance to formulate an I4.0 strategy than bigger SMEs.

H_4: SMEs that collaborate with a big company feel better prepared for I4.0 introduction and have a higher technology acceptance rate than SMEs who do not collaborate with a big company.

H_5: Employees from SMEs with internal motivation to introduce I4.0 have a higher technology acceptance rate than employees from SMEs with an external motivation to introduce I4.0.

H_6: SMEs with internal motivation to introduce I4.0 expect a higher increase in productivity than SMEs with an external motivation to introduce I4.0.

H_7: There is a significant difference in the answers between Spanish and German SMEs.

3. RESULTS

Overall, 14 companies participated in the survey, with 11 completing the questionnaire. Seven of those companies were from Germany (63.6%) and four (36.4%) from Spain. The companies were also grouped by the size of their workforce: "less than 10 employees" (9.1%), "10 to 49 employees" (18.2%), "50 to 249 employees" (45.5%) and "more than 250 employees" (27.3%). The Mann-Whitney U test was used to evaluate the results and find statistically significant differences in the answers of different groups (Mann & Whitney, 1947). The test was independently developed in 1947 by Mann-Whitney and Wilcoxon. Thus it is also known as the Wilcoxon-Mann-Whitney rank-sum test. It is one of the most commonly used non-parametric tests, which means it does not depend on a normal distribution and provides reliable, statistically significant results when used with small sample sizes of 10-20 observations (Landers, 1981). The Mann-Whitney test verifies the null hypothesis (H_0) based on the comparison of each

observation from the first group with each observation from the second group and identifies if the two independent groups are homogenous and have the same distribution (Nachar, 2008). If there is a statistically significant difference between the two populations, the determined p-value is small and the H_0 is rejected in favor of the alternative hypothesis. The commonly accepted thresholds for p are ≤ 0.05 for significant differences and ≤ 0.01 for highly significant differences and also used for this analysis (Fisher, 1992). All results stem from the two-sided test, which examines both ends of the distribution. Anova and similar techniques have not been used as normal distribution could not be guaranteed and the sample size is too small. Only the relevant questions to the particular hypothesis are shown. The complete questionnaire is available online in Spanish, English and German for further reference[2].

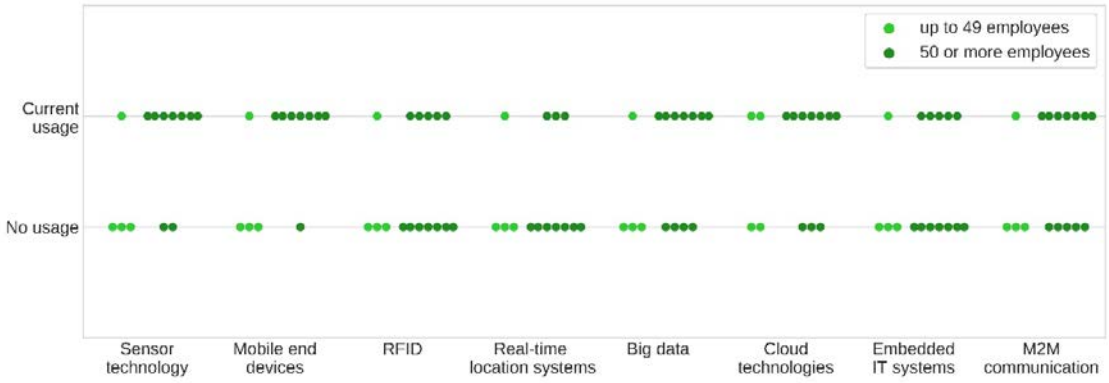
H_1: Smaller SMEs need more assistance for the evaluation of I4.0 technologies than bigger SMEs.

Q16 Technology usage in companies

Statistically significant differences in technology usage (Q16) comparing "Companies with up to 10 employees" with the other participants for all of the eight technologies: Sensor technology (p=0.009, highly significant), mobile end devices (p=0.004, highly significant), RFID (p= 0.027), real-time location systems (p=0.030), big data (p=0.018), cloud technologies (p=0.011), embedded IT systems (p=0.027) and M2M communication (p=0.022).

Splitting the participants into "Companies with up to 49 employees" and "others" identified significant differences for the following three out of eight technologies: Sensor technology (p=0.014), mobile end devices (p=0.006, highly significant) and big data(p=0.038).

Figure 1. Technology usage in companies with up to 49 vs more than 49 employees.



[2] Jan Strohschein, Github Repository: https://github.com/janstrohschein/Industry-4.0-readiness-for-SMEs-Questionnaire Retrieved at 10-04-2020

Q17 Past and future investments

The analysis of investments in the past 2 years found significant differences for “Research and development” (p = 0.020) and “Production / manufacturing” (p = 0.023).

The planned investments over the next 5 years also show significant differences in “Production/ manufacturing” (p = 0.035). The analysis shows several significant differences and confirms H_1.

H_2: Smaller SMEs need more assistance to assess I4.0 introduction costs and benefits than bigger SMEs.

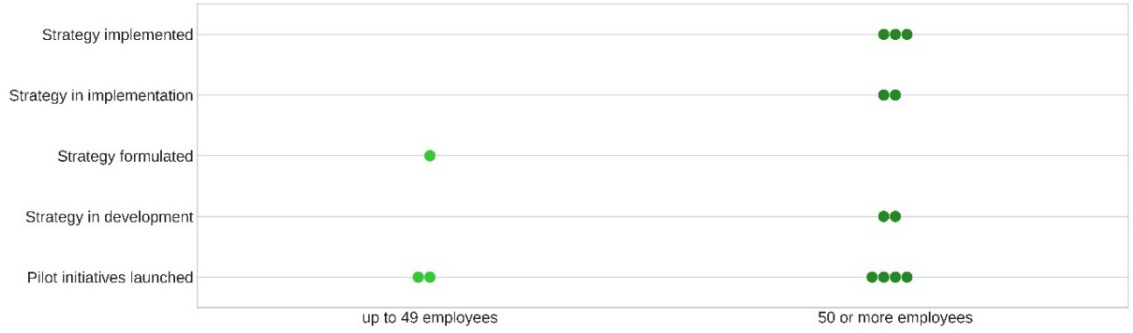
Analysis of Q12 “The benefits of I4.0 introduction are well known to our company and clearly evaluated” and Q13 “The costs of I4.0 introduction are well known to our company and clearly evaluated” yielded no significant differences between companies of different sizes. Thus H_2 is rejected.

H_3: Smaller SMEs need more assistance to formulate an I4.0 strategy than bigger SMEs.

Q14 Industry 4.0 strategy implementation status

Significant results for all splits, i.e. “Companies with up to 10 employees” | “others” (p = 0.030), “Companies with up to 49 employees” | “others” (p = 0.012) and “Companies with up to 249 employees” | “others” (p = 0.008, highly significant).

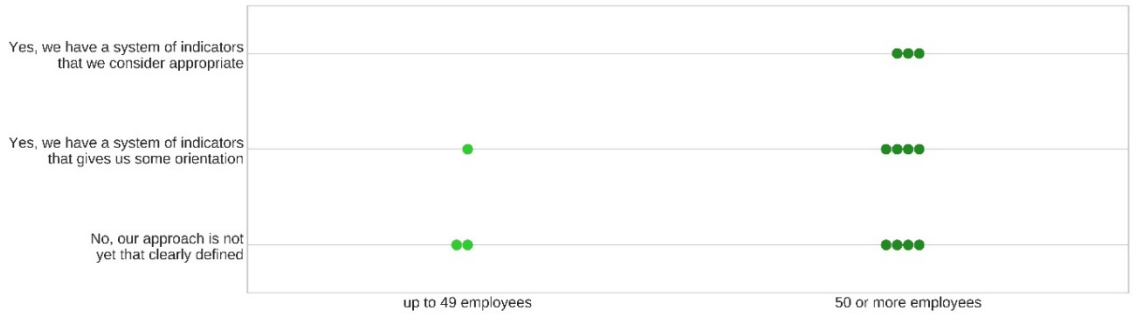
Figure 2. Q14 Industry 4.0 implementation status comparing companies with up to 49 employees and companies with more than 50 employees.



Q15 Industry 4.0 indicators

Statistically significant differences for all splits, i.e. “Companies with up to 10 employees” | “others” (p = 0.029), “Companies with up to 49 employees” | “others” (p = 0.010) and “Companies with up to 249 employees” | “others” (p = 0.008, highly significant)

Figure 3. Industry 4.0 indicators comparing companies with up to 49 employees and companies with more than 50 employees.



Q18 Systematic technology and innovation management

Split with “Companies with up to 10 employees” | “others” found significant differences in the technology and innovation management for IT ($p = 0.025$), production technologies ($p = 0.029$), product development ($p = 0.018$), services ($p = 0.031$) and in the amount of centralized innovation management ($p = 0.031$).

The split between “Companies with up to 49 employees” and “others” yields highly significant results ($p < 0.01$) for production technologies ($p = 0.003$) and product development ($p = 0.001$). Significant differences were found for services ($p = 0.044$) and the implementation of a centralized innovation management ($p=0.015$). The analysis shows significant or even highly significant differences and verifies H_3.

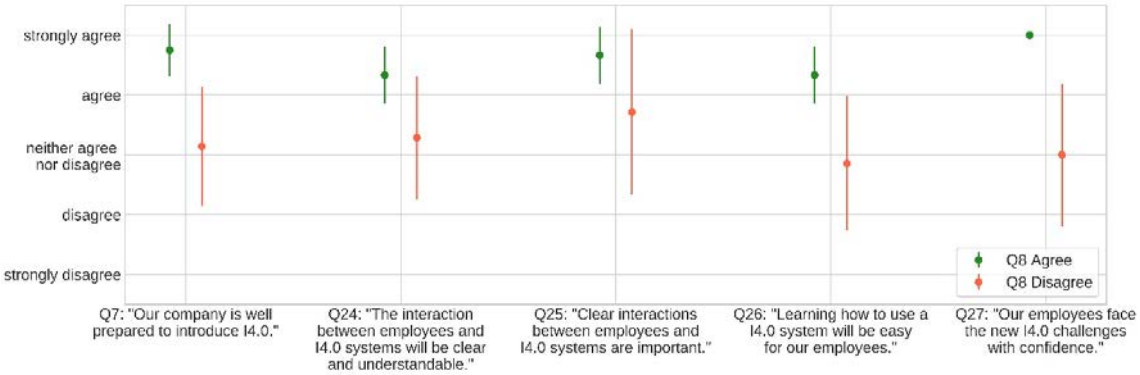
Figure 4. Systematic technology and innovation management in companies with up to 49 and more than 50 employees.

H_4: SMEs that collaborate with a big company feel better prepared for I4.0 introduction and have a higher technology acceptance rate than SMEs who do not collaborate with a big company.

The samples are split based on their answer to question Q8 "Our company adopts the I4.0 strategy of a (bigger) partner".

Significant differences exist for Q7 “Our company is well prepared to introduce I4.0” ($p = 0.042$) and Q27 “Our employees face the new I4.0 challenges with confidence” ($p = 0.042$), thus H_4 is accepted.

Figure 5. Comparing companies that agree/disagree to Q8 (mean + std.).

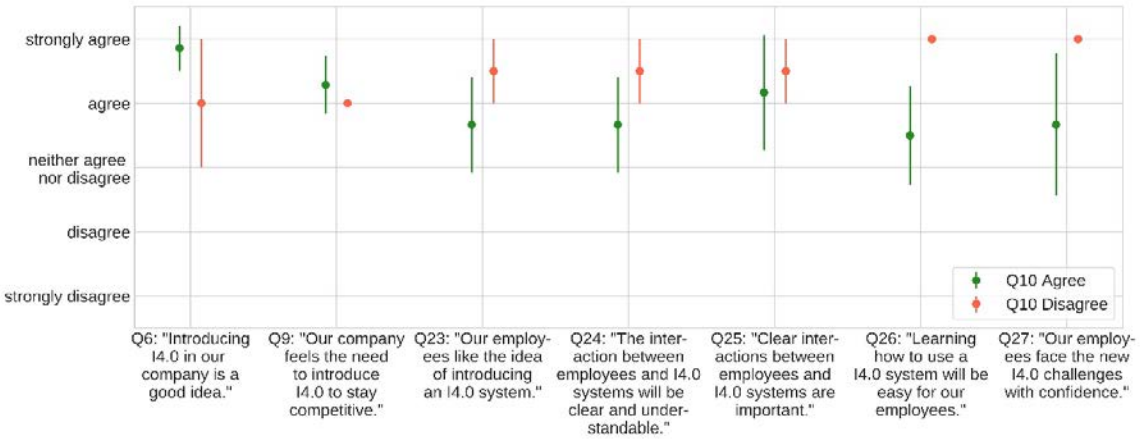


H_5: Employees from SMEs with internal motivation to introduce I4.0 have a higher technology acceptance rate than employees from SMEs with an external motivation to introduce I4.0.

The samples are split based on their answer to question Q10 "Our company feels the need to introduce I4.0 to continue collaboration with (bigger) partners.". The split was chosen, as the other possible splits based on Q6 "Introducing I4.0 in our company is a good idea" and Q9 "Our company feels the need to introduce I4.0 to stay competitive" had uniformly agreeing answers.

Results are shown in an overview but are not statistically significant, and therefore H_5 is rejected.

Figure 6. H_5 overview with companies grouped based on their Q10 answers (mean + std.).

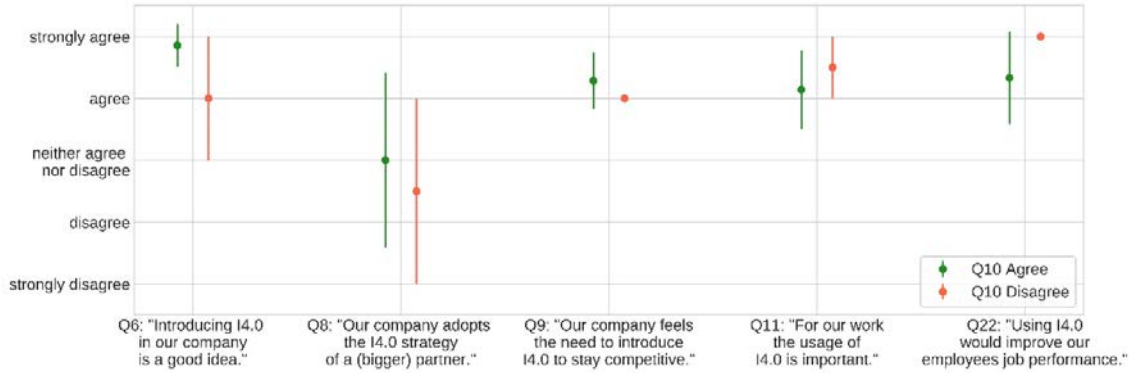


H_6: SMEs with internal motivation to introduce I4.0 expect a higher increase in productivity than SMEs with an external motivation to introduce I4.0.

The samples are split based on their answer to question Q10 "Our company feels the need to introduce I4.0 to continue collaboration with (bigger) partners.". The split was chosen, as the other possible splits based on Q6 "Introducing I4.0 in our company is a good idea" and Q9 "Our company feels the need to introduce I4.0 to stay competitive" had uniformly agreeing answers.

Results are shown in an overview but are not statistically significant, and therefore H_6 is rejected.

Figure 7. H_6 overview with companies grouped based on their Q10 answers (mean + std.)



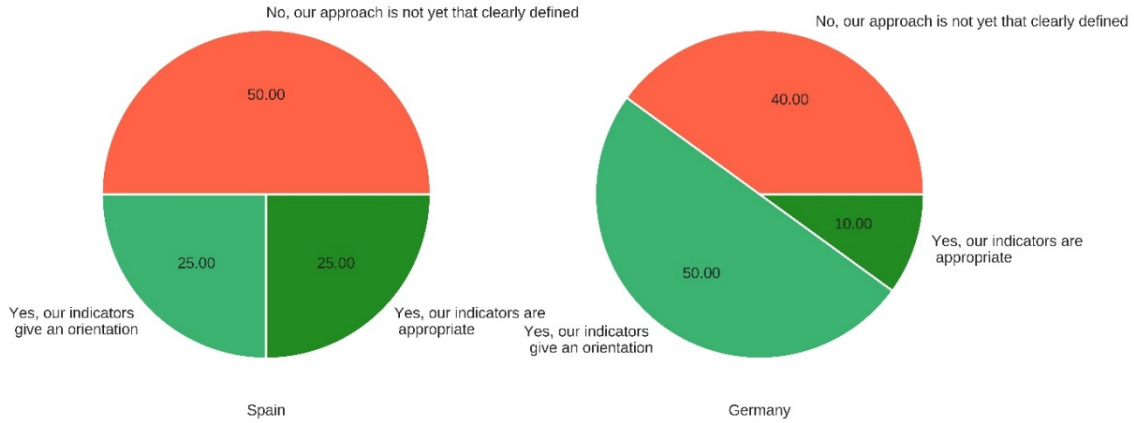
H_7: There is a significant difference in the answers between Spanish and German SMEs.

While 60% of German SMEs planned to increase the employees from leadership working on I4.0 introduction, none of the Spanish SMEs plan additional workers (p = 0.007, highly significant). The situation is similar for an increase of employees in HR working on I4.0 introduction. 40% of German companies plan to increase the current number of employees and none of the Spanish SMEs (p = 0.038).

A significant difference (p = 0.050) was also found between Spanish and German companies for Q9 “Our company feels the need to introduce I4.0 to stay competitive”. Spanish companies tended to agree strongly (avg.: 4.75, std.: 0.43), while German companies agreed (avg.: 3.9, std.: 0.53).

The current status of I4.0 implementation (Q14, p = 0.016) and the indicators used to track the progress (Q15, p = 0.013) also differed significantly between the two countries. Half of the German and 25% of the Spanish companies stated that they have indicators that give them some orientation. However, just 10% of the German and 25% of the Spanish companies think that their indicators are already appropriate.

Figure 8. Q15 I4.0 indicators with companies grouped by country.



Surveying the existing technologies (Q16) in companies of both countries showed significantly more usage of mobile end devices ($p = 0.025$) in Germany In contrast, companies in Spain utilized more real-time location systems ($p =. 0.030$). Unfortunately, there was also a highly significant difference in Spanish companies that use none of the inquired technologies ($p = 0.002$).

The results for technology and innovation management (Q18) also highlight differences between the two countries. The German companies focus on innovation management for production technologies ($p = 0.038$) and product development ($p = 0.012$) while the Spanish companies possess significantly more innovation management for their services ($p = 0.008$, highly significant) or use a centralized approach ($p = 0.002$, highly significant). The Spanish participants also declared significantly more companies without any technology or innovation management ($p = 0.040$). As the analysis found several statistical significant differences H_7 is accepted.

4. DISCUSSION AND CONCLUSION

$H_{1\text{-}3}$ regard additional assistance required by smaller companies to formulate an I4.0 strategy (H_1), assess costs and benefits (H_2) and evaluate the related technologies (H_3). H_1 and H_3 could be validated with significantly fewer technologies used, less systematic technology management, fewer investments made and also earlier stages of I4.0 introduction for smaller companies. Those findings may confirm claims by Christian Schröder that SMEs often lack resources to evaluate new technologies, which makes the development of an I4.0 strategy harder (Schröder, 2016). The results suggest that SMEs, five years after the survey by Lichtblau et al. (Lichtblau et al., 2014), could not catch up regarding the integration of their production plants in higher-level IT systems, a precondition for many I4.0 use cases. Apart from those differences, all companies declared that they could evaluate the benefits but have problems assessing the associated costs of I4.0 introduction, thus H_2 is rejected.

The collaboration with a bigger partner on the I4.0 introduction led to a significantly more positive attitude towards I4.0, which confirmed H_4. Even though “many of the I4.0 methods are developed mainly in larger enterprises” (Rauch et al., 2018), there is potential for the SMEs to profit from the groundwork done by the bigger partner, especially when the SMEs own resources are rather scarce. Five years after Lutz Sommer (Sommer, 2015) stated that “most SMEs are not prepared to implement I4.0 concepts” the collaboration with a bigger partner leads to SMEs who feel well prepared for the I4.0 introduction.

$H_{5\text{-}6}$ examine the influence of internal and external motivation to introduce I4.0 towards the technology acceptance rate and expected increases of productivity but could not be statistically verified, thus both hypotheses are rejected.

The comparison of Spanish and German SMEs highlighted various statistically significant differences, which leads to acceptance of H_7. Most noticeably are Spanish companies that use none of the new technologies and also do not possess technology or innovation management. It is not possible to determine if it is a regional difference or if it is caused by the small sample size where Spanish companies are smaller on average.

The small sample size is the main limitation of this work and stems from the specific requirements for the participants, but also the world-wide COVID-19 pandemic where SMEs had to shut down their production. It would be interesting to conduct the questionnaire again with more participants to get more insights into the differences between Spanish and German SMEs,

even though the results are already statistically significant. Future research should work on concrete methods to assist SMEs with the development of an I4.0 strategy and the evaluation of the associated new technologies. Best practices of successful I4.0 adoption, which are currently not available (Matt & Rauch, 2020), will also provide great value to SMEs.

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