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Industry 4.0 holds a great potential for manufacturers, so why haven't they started?

A multiple case study of small and medium sized Danish manufacturers

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Abstract. Despite the potential of Industry 4.0 and the increasing interest from the manufacturing industry, the adoption of Industry 4.0 is still lacking behind in SMEs in the manufacturing industry. In this paper, we explore why this is happening. The research is based on a multiple case study of 24 small and medium sized Danish manufacturing companies, which have all started their Industry 4.0 journey. We analyze the case data from the perspective of dynamic capabilities. Our findings show that the companies experience multiple barriers related to the sensing and seizing capabilities, which hinder their engagement with Industry 4.0. The lack of capabilities to sense and seize opportunities in relation to Industry 4.0 leads us to question whether manufacturers understand Industry 4.0 as a strategic asset or a set of disconnected technology improvements which may bring benefits to the operations, but do not utilize the systemic potential of Industry 4.0.

Keywords: Industry 4.0, SME, barriers, dynamic capabilities, case study.

1 Introduction

The manufacturing industry is entering its fourth industrial revolution, and with this follows a potential for creating both incremental and radical process innovations in the production by exploiting emerging Industry 4.0 technologies [1-4]. Especially in high wage countries, such as Denmark, Industry 4.0 is expected to boost the industry's competitiveness by using digitalization as a tool to increase productivity and enable new opportunities for manufacturers. These expectations are also recognized by both small, medium and large Danish manufacturers, who show much interest in Industry 4.0. However, despite indications of interest to innovate for Industry 4.0, the actual adoption

of Industry 4.0 innovations in Danish SMEs in the manufacturing industry is very slow [5]. This indicates that something is stopping the conversion of initial interest into initiatives. Barriers for Industry 4.0 are well studied in general (see e.g. Agostini and Filippini [6], Hoyer et al. [6], and Kumar et al. [7]). However, research aiming to understand why SMEs in the manufacturing industry do not succeed in introducing lasting Industry 4.0 innovations in their organizations in spite of their willingness and initiatives is limited. In previous research, Horváth and Szabó [8] found that SMEs experience more and higher barriers in adopting Industry 4.0 than large companies, which indicates that SMEs in general might find it more challenging to introduce Industry 4.0. Examples of barriers faced by SMEs in adopting Industry 4.0 are lack of expertise [9, 10], difficulty in forming an Industry 4.0 innovation strategy [10], and lack of resources [11]. However, given that Industry 4.0 is introducing a shift in paradigm, underlying assumptions of how to operate the manufacturing system changes which means that targeting and overcoming individual barriers may not improve SMEs adoption of Industry 4.0, as it is the fundamental thinking of how to operate the manufacturing system that changes. Consequently, we argue, that it is lack of capabilities which keep the companies from adopting Industry 4.0 rather than isolated barriers. In this paper, we, therefore, study the lack of Industry 4.0 innovations in SMEs from the perspective of dynamic capabilities, implying that the lack of Industry 4.0 adoption may be caused by a lack of capabilities. According to Teece [12] dynamic capabilities are:

- **Sensing** (and shaping) new opportunities through search and exploration of new markets and technologies
- **Seizing** the opportunities resulting in new products, services, or processes, and
- **Transforming** (and reconfiguring) the organization's assets to remain competitive as technologies and markets change [12]

The three dimensions of dynamic capabilities have previously been coupled to a three phase innovation process of Industry 4.0 [13]: In phase one, which represents the sensing capability, actions related to identifying new Industry 4.0 opportunities take place; in phase two, which represents the seizing capability, valuable opportunities identified in phase one are seized and refined; and in phase three, which represents the transforming capability, the identified opportunity is implemented in the company [13-15]. We apply this relation between the three dimensions of the dynamic capabilities and the innovation process of Industry 4.0 to the research presented in this paper.

To explore the impact of lack of Industry 4.0 innovations in SMEs from a dynamic capability perspective, further we aim to answer the research question: *Which barriers hinder Danish small and medium sized manufacturers from adopting Industry 4.0?*

The remaining part of this paper is structured as follows: Section 2 presents the research methodology, section 3 presents our findings, section 4 contains a discussion of the findings, and section 5 concludes on our research.

2 Methodology

This research is based on a multiple case study of 24 small and medium sized Danish manufacturers. The companies have participated in the research programme Innovation

Factory North at Aalborg University aiming to boost Industry 4.0 innovation in SMEs in the manufacturing industry. The research programme is structured as an innovation process to support the Industry 4.0 journey of the manufacturers. Activities for the companies in the programme include forming an Industry 4.0 innovation strategy, making a digital maturity assessment, making a prototype of an Industry 4.0 innovation, and forming an implementation plan. The participants from the companies are mostly top managers involved in the decision-making of Industry 4.0 innovations in their organization. The data used in this study consists of observations and notes from activities with the companies in the research programme.

In total, we have used data from 19 seminars and 17 engagements with a total participation of 24 companies in our analysis. The data consisted of extensive notes and observations of the progress of each company. Additionally, as barriers were not the specific topic of the seminars and engagements, we subsequently conducted in-depth interviews with a key responsible employee or manager in eight purposively selected companies participating in the research programme. We conducted the interviews as semi-structured interviews, which were all transcribed for analysis. With the interview data, we triangulated the findings from the seminars and engagements in relation to the most central barriers experienced in the companies, and developed in-depth understanding of such barriers.

To analyze the data, we used the Gioia methodology, which is a systematic approach for qualitative data analysis. In the Gioia methodology data is first organized into 1st and 2nd order categories in order to generate a structure of the large amounts of data. The 1st order categories stay true to terms e.g. applied by the interviewees. To define the 2nd order categories, we searched for similarities and differences among the 1st order categories, and applied our theoretical knowledge to create a higher-order meaning to the 1st order categories and define the 2nd order categories.[16] In our analysis, the 2nd order categories were the identified barriers. Lastly, the 2nd order categories were aggregated into what Gioia et al. [16] refer to as aggregated dimensions. In the aggregated dimensions we grouped the 2nd order categories according to the three dynamic capabilities sensing, seizing, and transforming. This allowed for analysis of the relation between the experienced barriers and the underlying capabilities. An extract of the analysis is shown in Table 1.

From the data analysis we identified several problems related to Industry 4.0 adoption experienced by the companies. However, several of the problems could be overcome by the companies with some effort, such as companies finding it difficult to find and choose the right technologies. As the aim of this paper was to explore and identify which problems were hindering the companies in progressing and thereby became a barrier for adopting Industry 4.0 we excluded problems, which were manageable for the companies to overcome with a relatively low effort.

Table 1. Extract of data analysis

Quote	1 st order	2 nd order (Barrier)	Aggregated dimension (Dynamic capability)
<i>"Industry 4.0 is odd. Do we even have [Industry] 2.0 or 3.0?"</i>	Difficult to understand what Industry 4.0 covers and is defined as.	Lack of understanding of what Industry 4.0 is and the value of it for the company	Sensing
<i>"I miss the relation to our working day so that we would have something tangible to get started."</i>	Miss being able to relate to everyday work to get something that is manageable in order to get started		
<i>"We have had problems with making a positive business case. Here [Industry 4.0 investments] we should look beyond the ordinary two years [for return on investment]."</i>	Have had difficulties in making a positive business case if only evaluating over two years. We need to evaluate based on more than two years.	Difficult to make a business case that can justify value upfront	
<i>"Another challenge we are facing is that, we know this [solution] will help us with some things, but we have a hard time quantifying it [the value] so it is difficult for us to be specific about required investments towards our owners."</i>	Difficult to quantify the value of an idea.		

3 Findings

From our data analysis, we identified 10 barriers towards adopting Industry 4.0 experienced by SMEs in the manufacturing industry. The barriers are listed in Table 2 and categorized according to the three dynamic capabilities sensing, seizing, and transforming.

Table 2. Industry 4.0 barriers categorized according to the three dynamic capabilities.

Dynamic capability	Barrier
Sensing	Difficult to formulate an Industry 4.0 innovation strategy or have not made one yet
	Difficult to make a business case that can justify value upfront
	Do not actively work with Industry 4.0
	Lack of understanding of what Industry 4.0 is and the value of it for the company
Seizing	Existing governance structure does not support Industry 4.0 projects
	Lack of competences
	Lack of commitment from management/owners
Transforming	Lack of time or funds to support Industry 4.0 projects
	Getting the organization onboard to ensure support and commitment in the transformation process
	The road to fulfilling the Industry 4.0 innovation strategy is uncertain and unclear

As the categorization in Table 2 shows, the barriers are primarily centered around two of the three dimensions of dynamic capabilities, namely sensing and seizing. Referring back to the three dimensions of dynamic capabilities and their relation to the innovation process, the findings indicate that the companies' adoption process of In-

dustry 4.0 is obstructed very early on by several kinds of barriers, and that the companies therefore do not reach the state of transforming which may explain why only two of the 10 barriers are related to this capability.

The three most reoccurring barriers expressed by the companies are 1) *lack of understanding of what Industry 4.0 is and the value of it for the company*, 2) *lack of competences*, and 3) *getting the organization onboard to ensure support and commitment in the transformation process*. These findings are not surprising, as Industry 4.0 is still new to the industry, and thus lack of understanding of it and competences to manage it are expected. Furthermore, as Industry 4.0 will initiate a transformation process of the organization, getting the organization onboard is needed to ensure a successful implementation of Industry 4.0.

10 of the 24 companies had expressed 1) *lack of understanding of what Industry 4.0 is and the value of it for the company* as a barrier to the company's adoption of Industry 4.0. The lack of understanding of Industry 4.0 implies that the companies are not able to identify and transform its value into their own operations. In one company, the manager decided to explore the opportunities of Industry 4.0 by experimenting with a software robot. The manager expected that a software robot would be valuable in several applications in the company but had not identified these beforehand, as he was not certain about which problems the technology would be able to solve. The application of the first software robot was therefore purchased to introduce the organization to the technology and through this let the employees identify other potential applications for software robots. To support this, the manager expected that the company would purchase software for developing their own software robots later on and thereby exploit the potential of software robots as an Industry 4.0 technology.

Of the 24 companies, 11 stated 2) *lack of competences* to be a barrier. To overcome this some of the case companies decided to hire a new employee to run Industry 4.0 initiatives, whereas others chose to build up the capabilities within the existing staff. For instance, in one company, they chose to build a product configurator from scratch even though they might had been able to buy a solution from a supplier, which could do the same. They chose to build it in-house instead in order to build up the competences and to learn what their requirements were for the solution as their knowledge levels improved. Furthermore, the idea is to expand the configurator continuously as the maturity level in the organization increases and thereby is able to absorb solutions that are more advanced. Another company was interested in exploring the potential of 3D printing metal components as an alternative production process, but no one in the company had experience with 3D printing. Therefore, to build up these competences, the company bought a 3D printer for plastics, which was cheaper than buying one for metal printing. With this, the company built up the competences and knowhow to decide whether to make an investment in the right 3D printer for metal without investing too much in technologies in the first place. This also assisted the company in drawing up a business case for investing in 3D metal printing.

In total, 13 companies found 3) *getting the organization onboard to ensure support and commitment in the transformation process* to be a significant barrier. To get the organization onboard, one company ran a project where they installed screens and introduced apps in the production to reduce paper and thereby showed fast results of the

value of digitalization to the organization. In another company, the COO and co-owner of the company emphasized that it is important to explain the company's strategy of Industry 4.0 in a way so that shop floor employees are able to retell it and relate to the strategy. Similar to this, the CEO of a third company expressed that he is not concerned about resistance from the organization in the adoption of Industry 4.0. He also spends much effort on explaining why a digitalization initiative makes sense, as he like in the other company, believes that if the employees can see that an initiative makes sense and it may even make their workday easier, then everyone will get onboard with it. Furthermore, the CEO has chosen to take a "trial-and-error" approach to digitalization projects where he clearly communicates to the organization, that they cannot expect that everything will work from day one but eventually things will work as planned.

Despite some of the companies having found ways of overcoming the barriers, long time may pass from the initial idea of how to overcome a barrier, to planning to implement it, and lastly implementing it successfully. Consequently, time passes and many resources both in the form of time and money may be spend on overcoming barriers before being able to build the technical Industry 4.0 solution. This has the consequence that the digital transformation will take a long time, and is highly affected by the barriers prolonging the process.

As our findings show, the small and medium sized manufacturers experience multiple barriers towards achieving a successful adoption of Industry 4.0. Furthermore, the barriers are mainly related to two of the three dimensions of dynamic capabilities; sensing and seizing opportunities. In the following section, we discuss our results.

4 Discussion

Barriers and challenges related to the adoption of Industry 4.0 in SMEs in the manufacturing industry has been widely studied (see e.g. [7, 17, 18]). Though, much of this research is considering barriers to Industry 4.0 in the whole innovation process, that is from idea generation to implementation of final solution (see e.g. [17, 19, 20]),. However, many small and medium sized manufacturers are in particular challenged early in the process, and may even have difficulty in getting started with generating an idea and seeing the potential of Industry 4.0. In this paper, we have therefore introduced a focus solely on the first phase of Industry 4.0 adoption in industry by focusing on the barriers that hinder the companies in adopting Industry 4.0 in the first place. By studying and thereby better understanding what hinders their adoption of Industry 4.0, we can create initiatives that assist the companies better in the process in the future. Our findings suggest that future initiatives should focus especially on developing the dimensions related to the two dynamic capabilities sensing and seizing opportunities to better equip organizations for adopting Industry 4.0, which means that companies may need better support to identify and choose opportunities of Industry 4.0. Furthermore, the systemic nature of Industry 4.0 may also challenge the companies' adoption of Industry 4.0 in full scale which may imply that many companies do not utilize the systemic value of Industry 4.0 but instead break it into separate, smaller projects which are easier to manage. However, this may affect the results, which the companies may achieve.

The aim of the introduction of Industry 4.0 in Germany was originally to ensure the German industry's competitiveness in the long term among others by improving decision-making, productivity, and flexibility in the production [2]. In spite of this great potential, as our findings show, SMEs lack the capabilities of sensing and seizing such opportunities, and the strategic value these companies make from Industry 4.0 technologies may therefore be questioned. These results contrast the theoretical expectations of Industry 4.0 which argue that the industry will benefit remarkably by Industry 4.0 (see e.g. [3, 4, 9]) and may indicate that companies are not considering manufacturing to be a strategic resource in strengthening the company's competitiveness despite the entry of Industry 4.0. This misalignment in expectations needs to be aligned to ensure that theory development and applications in practice are consistent.

5 Conclusion

The purpose of this paper was to explore why SMEs in the manufacturing industry have not started their digital transformation towards Industry 4.0 by answering the following research question: *Which barriers hinder small and medium sized Danish manufacturers from adopting Industry 4.0?* To answer the research question, we conducted a case study of 24 small and medium sized Danish manufacturers from which we identified 10 barriers keeping the companies from adopting Industry 4.0. We analyzed the barriers from a dynamic capabilities perspective and concluded that eight of the 10 barriers were related to the sensing and seizing capabilities, which indicates a need for more support in the industry to build these capabilities. Furthermore, the lack of these capabilities, and the presence of the barriers related to these two capabilities may indicate that manufacturers are not considering Industry 4.0 to be a strategic initiative that can strengthen their company's competitiveness despite this being a key motivation in research on Industry 4.0.

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