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Industrial Internet of Things in the Food Industry

Understanding the readiness of incumbents ahead of a technological change

Master's thesis in the Management and Economics of Innovation Programme

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SUMMARY
When technological change affects an industry, incumbent firms sometimes fail and give way to new entrants, and sometimes they thrive. Ex post studies suggest factors inside and outside the firms that have influenced the outcome of such technological changes. This thesis aims to review these factors. The factors are then applied to a change where the outcome is not yet clear. The chosen change is the Industrial Internet of Things (IIoT) entering the food industry. The aim is to enable firms in the food industry to assess their readiness for the change.

An extensive literature review compiles five factors that could determine an incumbent's readiness for technological change. The factors are the incumbent's existing competences and strategic beliefs, the type of innovation, the incumbent's incentives to invest, its complementary assets, and its relationships in its value chain. This set of factors is then related to incumbents in the food industry in the case of a technological change due to IIoT, using supporting interviews with experts for further context. For each of the factors, a set of assessments is proposed for firms in the industry so they can understand their relative readiness ahead of the change.

The five factors could each affect the food industry in nuanced ways during a transition due to IIoT. Firstly, investing in IIoT competences is required for incumbent firms, while it is possible to enhance the expertise within food production. If the industry shifts towards mass customization, new architectural knowledge might be needed, harming incumbents. The firms' lack of willingness to invest is deemed a significant challenge for them, opening for new entrants to win market share. Most existing systems are considered complementary assets, potentially protecting firms while they adapt. Finally, firms might need to switch suppliers while maintaining their strong relationships with customers and consumers in order to perform well during the transition.

Since not all factors align in terms of advantage or disadvantage for incumbent firms, no prediction is made regarding the outcome of this technological change. However, the framework could provide nuanced guidance for firms when preparing for this change. By collecting more data from the industry, the framework could be extended further, for example by including additional complementary assets. Future research into mass customization, consumer transparency, and the effect of regulations could provide additional context for the framework. Finally, the set of factors identified in the literature review along with the general manner of analysis provide research progress as they could be applied to other industries and technologies.

Keywords: technological change and industrial transformation, Industrial Internet of Things, food industry, production systems.

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1 INTRODUCTION

The global economy keeps growing. Since the World Bank started collecting data about the global GDP in 1960, the yearly per capita growth has only been negative on five occasions (World Bank, 2019). One source of this sustained growth is *creative destruction* as coined by Joseph Schumpeter in 1942. Creative destruction describes the industrial changes initiated by innovative entrepreneurs who find radically different ways of doing business (Schumpeter, 1942). The profits earned during the temporary market leaderships established by such entrepreneurs have since been named *Schumpeterian rents* after the economist, and can be seen as a key incentive for innovation (Sautet, 2014).

New technologies are a major source of innovation. They can be a provider of growth for incumbent firms but also a force of destruction that creates openings for new entrants (Utterback, 1994). Some waves of change drastically shift the competitive situation in an industry, while others barely make a difference. Incumbents might be able to keep ahead of the new entrants and keep their market share, or they might end up out of business entirely. The new technology itself is not the lone reason for this. The outcome of any industrial transformation is affected by factors both inside and outside the firms, for example the type of innovation and its effect on the firms' competences (Sandström, 2016; Tripsas, 1997).

One ongoing transformation is the digitalization of the manufacturing industry. In Germany, the term Industry 4.0 was proposed by the government in 2011, referring to a fourth industrial transformation (Boyes, Hallaq, Cunningham, & Watson, 2018). Similar initiatives can be found around the world, such as the Industrial Internet term in the US and Smart Industry in Sweden. The general purpose is to use digital technologies to increase industrial efficiency, productivity, safety, and transparency (Boyes et al., 2018). Firms have not come that far in this transformation, however (Åkerman, 2018). One industry where this transformation can have a large impact is food manufacturing. The UK Government (2017) estimates that applying digital technologies to its food and drink sector would result in benefits of £56 billion over 10 years largely due to automation of labor, decreased waste, and more efficient processes.

In parallel, the concept of *the Internet of Things (IoT)* has emerged. Coined in 1999, the term contains technologies that enable devices to collect and communicate data about the physical world around them (Xu, He, & Li, 2014). In 2018, the 31 billion IoT devices globally exceeded the population threefold (IHS Markit, 2019). The devices range from smart light bulbs to cars with cellular connectivity. Naturally, IoT technologies also become useful for industrial purposes and create an intersection with the Industry 4.0 transformation. The resulting set of technologies is *the Industrial Internet of Things (IIoT)*. IHS Markit (2019) estimates that IIoT devices will account for nearly 50% of all new IoT devices between 2018 and 2030.

IIoT entering the food industry is the topic of this thesis. The outcome of this change is not yet clear, in contrast to previous works by Sandström (2016) and Tripsas (1997) that look at other technological change ex post. Additionally, no major previous research has been conducted about technological change and industrial transformation in the food industry. Finally, IIoT is a set of technologies and not one single technology, which has been the case for previous research.

1.1 Purpose

The purpose of this thesis is to fill the above research gaps. This is done by connecting literature about technological change with the change induced by IIoT in the industrial context of food manufacturing. Further, the aim is to create an ex ante framework for assessing firms in the industry.

1.2 Research Questions

The key questions that this thesis will answer are as follows.

RQ1: Which factors could determine an incumbent's readiness for technological change?
RQ2: How do these factors relate to incumbents in the food industry and the technological change caused by IIoT?
RQ3: Which factors should a food manufacturer assess when implementing IIoT?

1.3 Scope and Limitations

The scope of the context and topic for this thesis has been selected to enable meaningful insights for the reader.

The industrial context for this thesis is the food industry. The terms *food industry* and *food manufacturing* are used interchangeably. As used in this thesis, the terms refer to the group of firms that produce food items that are sold to consumers through own or third-party distribution channels such as grocery stores. Where possible, the context is narrowed even further to focus on firms that produce ready meals. Ready meals refer to food products that contain an entire frozen or chilled meal that can be eaten after reheating. The Swedish ready meals market is large and fragmented compared to other Swedish food industries (see Appendix A) and has a higher variance of product prices. The entry barriers are therefore seemingly lower. Additionally, as the product contains an entire meal there is less interdependency with other food products. This additional focus enables a clearer look at the market and the technological change.

IIoT technologies entering the industrial context is the topic of this thesis. The term IIoT is defined further in section 2.1.1 ("Industrial Internet of Things") based on the literature review. During the interviews conducted in this thesis, this definition was used to set the scene. Additionally, the definition is used to properly fit related literature to the theoretical framework. Other related trends such as digitalization, Industry 4.0 or IoT are not further discussed in this thesis, other than where they overlap with IIoT.

As further described in the definition of IIoT, IIoT technologies aim to improve production value. Therefore, the intersection of IIoT and the food industry is in and around the production systems at the firms. In this thesis, the production systems themselves and any surrounding systems are considered subjects of the technological change. The overall performance impact to these systems due to this technological change is considered the performance impact of IIoT. While the implementation of IIoT technologies in manufacturing is the change in focus, this thesis will not attempt to define a future version of a production site. As the possible transformation has not yet occurred it is not possible to know what an "IIoT-integrated" production site could look like.

Finally, the thesis includes interviews with representatives from production system and IIoT supplier firms, experts and researchers. Firms in the food industry have declined interviews and any analysis from an internal perspective is therefore instead based on the other interviews. All of the interviews have been conducted with people living and working in Sweden. As such, the findings from this thesis are based on the conditions of the Swedish food industry and might not be applicable in other countries.

1.4 Thesis Outline

The thesis begins with a literature review. This review will define IIoT, which is considered the technological change in focus. Additionally, it will provide a further understanding of the food industry and its current state, which is considered the industrial context in focus. Existing works regarding technological change are then used to build an initial theoretical framework that answers the first research question and provides further context for the second and third research questions.

The main content of this thesis is the analysis. This will expand the initial framework using additional literature and interviews. The data from the interviews comes from two experts from two different vendors of industrial automation and IIoT solutions, one production system researcher and one food manufacturing automation expert.

The results of the analysis will be summarized by presenting a second version of the framework that is specific for IIoT in food manufacturing, providing an answer to the third research question.

Finally, reflections are made in the conclusion along with suggestions for future research.

2 CONTEXT & THEORETICAL FRAMEWORK

This chapter sets the scene for exploring the research questions and results in an answer to the first research question. First, literature is used to provide more context for the technological change and the industry in focus. Second, the theoretical paradigm of technological change and industrial transformation is explored further in order to provide an initial analytical framework.

2.1 Context

The technological change in focus for this thesis is the Industrial Internet of Things entering the food industry. Below, IIoT is defined further followed by a look at current literature about the food industry. Additionally, the current automation standard ISA-95 is explored to provide an overview of the current state of technology in manufacturing.

2.1.1 Industrial Internet of Things

The *Industrial Internet of Things (IIoT)* is often defined as the industrial application of the *Internet of Things (IoT)* (Boyes et al., 2018). For the purposes of this thesis, a stand-alone definition will be used instead to avoid confusion of the two terms. Boyes et al. (2018) conducts a literature review of various definitions and proposes a definition that is stand-alone and describes the system, how the system can be used, and the reasons why.

An *IIoT system* includes networked smart objects, cyber-physical assets, generic IT, and optionally cloud or edge computing platforms (Boyes et al., 2018). Smart objects refer to sensors, actuators or devices that have at least basic connectivity and computing capabilities. They can with minimal human intervention generate and communicate data (Boyes et al., 2018). Another component is cyber-physical assets as IIoT relies on these. These assets can be production machines and systems that make up and control the physical production processes. The systems work in real-time and largely autonomously (Boyes et al., 2018). Generic information technologies are the third component of the system. These are not unique to manufacturing systems and so enable flexibility in the choice of devices and systems between different suppliers. The fourth and optional component is a cloud or edge computing platform that the objects and assets are connected to (Boyes et al., 2018).

The system, in turn, enables various *capabilities* within the production system. The process, product and/or service data can be accessed, collected, analyzed, communicated, and exchanged. This use can be real-time, intelligent, and/or autonomous (Boyes et al., 2018). Further, these capabilities are not purely for the production system itself but also enable more power for the users and the consumers (Boyes et al., 2018). The capabilities are therefore similar to the Industry 4.0 development path proposed by Schuh, Anderl, Gausemeier, ten Hompel, & Wahlster (2017). Its purpose is to help firms understand where they are on the path and decide where they want to end up. The path consists of six stages of development: computerization, connectivity, visibility, transparency, predictive capability, and adaptability. Computerization and connectivity can be related to simply implementing an IIoT system. The following stages are synonymous with the capabilities listed above. Visibility, for instance, concerns connecting the various data sources to build a single source of truth for the status of the production process (Schuh et al., 2017).

Finally, the purpose of IIoT is improving production *value* for the implementing firms, which could be done in various ways (Boyes et al., 2018):

> "This value may include; improving product or service delivery, boosting productivity, reducing labour costs, reducing energy consumption, and reducing the build-to-order cycle." (Boyes et al., 2018).

The value could be achieved by applying the capabilities that the system enables. Lee & Lee (2015) has a similar outlook. It suggests that better monitoring and control capabilities bring lower costs and higher productivity. Additionally, better data analysis helps increase customer satisfaction and value provided to customers (Lee & Lee, 2015).

Using the above three perspectives, the definition of IIoT that is used in this thesis is summarized in Table 1.

Table 1: Definition of IIoT

Industrial Internet of Things (IIoT): A system that enables the use of certain capabilities within the industrial environment to improve production value.	
System	Smart objects, cyber-physical assets, generic IT, optional cloud or edge computing platforms (Boyes et al., 2018)
Capabilities	Use of process, product and/or service data to advance along the Industry 4.0 development path: visibility, transparency, predictive capability, and adaptability (Boyes et al., 2018; Schuh et al., 2017)
Value	Improved delivery, higher productivity, lower labour costs, lower energy consumption, faster build-to-order cycle (Boyes et al., 2018) Lower costs, higher productivity, higher customer satisfaction, increased value provided to customers (Lee & Lee, 2015)

2.1.2 Food Industry

The food industry is a pillar of civilization. It is one of the biggest industries in every country, for instance, it employs an eighth of the UK workforce (Fryer & Versteeg, 2008). In comparison to other large industries such as pharmaceutics, it is however not dominated by a few global firms as Fryer and Versteeg (2008) claim that small and medium enterprises (SMEs) take up 99% of the European market. Acosta, Coronado, & Ferrándiz (2013) look at the food industry from an innovation perspective. It points out distinct characteristics that apply to the firms. Firstly, that the industry is relatively mature and low-tech. When food innovations are developed, it is often in smaller firms that struggle in commercializing them. The innovations are generally incremental, improving or changing existing products. Finally, the industry tends to not conduct own research but rather bring in knowledge and technologies from others (Acosta et al., 2013).

Grunert, Harmsen, Meulenberg, and Traill (1997) propose a framework for understanding innovation in the food industry. It suggests that there are three different orientations that a firm could have: product, process, and market. Having a product or process orientation leads to developing technical competences within the respective areas. A successful innovative firm would then need to combine its technical competences with an understanding of the market to develop product or process innovations (Grunert et al., 1997). It is in general not possible to have both a product and a process orientation. Fryer & Versteeg (2008) suggests that most firms in the food industry have a product orientation as the food industry is responsive to customer and consumer needs and highly innovative in terms of products. However, it is much less innovative in terms of processes, which is attributed to a low margin mindset in the firms. Investments in the production system are rare unless they have a clear business case (Fryer & Versteeg, 2008).

One trend driving innovation in the food industry is consumer convenience, which has led to an increase in ready meal consumption (Fryer & Versteeg, 2008). The ready meals segment also contains some of the more innovative firms (Traill & Meulenberg, 2002). This thesis focuses on the ready meals segment of the food industry where possible. Ready meals are defined as prepared complete meal food products that only need minimal preparation before eating (Muhamad & Abdul Karim, 2015). Muhamad & Abdul Karim (2015) further defines five types of ready meals: chilled, frozen, dried, canned, and ambient. This thesis mainly considers chilled or frozen ready meals. For both of these types, a meal is portioned, cooked and then either chilled or frozen for transportation and retail (Muhamad & Abdul Karim, 2015). They are cooked at around 65-80 °C and then chilled or frozen to slightly above or below freezing temperatures respectively (Elansari & Bekhit, 2015). Additionally, sous-vide type ready meals are packaged under vacuum before the cooking step, extending their shelf life. All three types should then be reheated to their cooking temperatures before eating (Elansari & Bekhit, 2015).

2.1.3 Current State of Manufacturing

Since IT was introduced into manufacturing automation systems in the 1960s, all automation has become IT-driven (Sharma, 2017). Today, the systems used in a manufacturing firm can be separated into operational control systems and enterprise business systems. These have been developed separately in many cases, where the operational systems have been focused on the product and controlling the production, and the enterprise systems have been used for resource planning and customer relations (Sharma, 2017). A major reason for this gap is the requirements for stability, security, and safety of the operational systems that are not present for enterprise systems. However, there are many reasons for converging these systems, such as cost and risk reduction as well as better operational transparency (Sharma, 2017).

One standard developed for enabling this convergence of systems is ISA 95 (Sharma, 2017). It describes manufacturing automation by categorizing it into four levels. Level 1 is the lowest and contains subsystems for instrumentation such as sensors and valves that work in real-time. Level 2 contains control subsystems and machine operator interfaces. The third level is a Manufacturing Execution System (MES). The MES is the interface between the operational systems at levels 1-2 and the enterprise systems at level 4. MES controls the production layout, product recipes, and tracks materials. Level 4 is the enterprise systems that manage orders, scheduling and inventory. Sharma (2017) suggests that the standard has led to lower costs and durations for system integration projects, as well as enabled cross-industry solutions to emerge.

2.2 Theoretical Framework for Technological Change

Factors both inside and outside the firms affect the outcome of any industrial transformation (Sandström, 2016; Tripsas, 1997). The factors that these two papers identify are used as starting points for the framework in this thesis. For each of the factors, a further literature review has been conducted. The results from the literature review are summarized in Table 2 and constitute the answer to RQ1: *Which factors could determine an incumbent's readiness for technological change?*

Table 2: Factors that could determine an incumbent's readiness for technological change

Factor	**Description**
Existing competences and strategic beliefs	Existing competences could be either enhanced or destroyed during a technological change (Tushman & Anderson, 1986) Changes to strategic beliefs might be required, causing difficulties and hierarchical inertia (Tripsas & Gavetti, 2000)
Types of innovation	If the innovation is architectural, new architectural knowledge is needed (Henderson & Clark, 1990) Organizational structure affects the development of architectural knowledge (Henderson & Clark, 1990)
Incentives to invest	Firms are prone to waiting during uncertainty (Hall & Khan, 2003; Jensen, 1982) Firms are prone to invest in incremental or sustaining innovations (Tripsas, 1997; Christensen & Bower, 1996) Firms are prone to stay on the path that they are already on (Brian Arthur, 1989)
Complementary assets	Complementary assets could protect or harm a firm while it adapts to an industrial transformation (Teece, 1986; Tripsas, 1997)
Relationships in the value chain	A firm’s relationships to other actors in its value chain can affect its performance during a transformation (Afuah & Bahram, 1995) Firms that switch suppliers perform better (Afuah, 2000) A strong customer base and commitment improve performance (Helper, 1995; Hall & Khan, 2003)

2.2.1 Existing Competences and Strategic Beliefs

When Schumpeter (1942) coined the term creative destruction he described the disassembly of existing processes in order to replace them with new, innovative means of production. During such a transformation, each incumbent firm possesses different competences that they bring with them into the new paradigm. Tushman and Anderson (1986) categorize these technological discontinuities as being either *competence-enhancing* or *competence-destroying*. The former is described as a shift in technology that permits the transfer of know-how and knowledge from the old way of working to the new. In other words, it results in a situation where the new technology can be embraced by an incumbent firm with little to no friction. In contrast, Tushman and Anderson (1986) describe competence-destroying technological discontinuities as breakthroughs that demand that firms develop fundamentally new skills and technological competencies in order to compete in the market. This type of discontinuity is said to benefit entrants. In the general case, Tushman and Anderson (1986) discover that competence-enhancing shifts are predominantly initiated by incumbent firms. Furthermore, these discontinuities often benefit the incumbent firms and increase their market power since the barriers to entry are raised as a result of the incumbent firm reaping benefits of existing knowledge that entrants would need to develop from the ground up (Tushman and Anderson, 1986; Tripsas, 1997).

Tripsas (1997) looks one step further when investigating four different technology shifts in a single industry. In her study, she finds that incumbent firms' dominant positions in the market could be protected by other factors, e.g. complementary assets, when faced with a competence-destroying discontinuity. This is further supported by Sandström's (2016) investigation of additive manufacturing in the hearing aid industry, in which this partially competence-destroying technological change had a minimal effect on incumbents' market position due to the retained value of the incumbents' non-technical complementary assets. Another point of view presented by Christensen and Bower (1996) suggests that it is not a lack of technological competences that explains why large firms fail in certain types of technological changes. Instead, they observe that many large firms are very capable of obtaining new competencies when the change accommodates their existing customer base.

One example of a firm that had no problems investing in and developing new technological competences is Polaroid as investigated by Tripsas and Gavetti (2000). On the other hand, they saw that managerial beliefs that were deeply diffused in the firm influenced how these new competences were used. Any new beliefs were only developed if they were consistent with the existing business or through turnover in senior management. The first of two beliefs apparent at Polaroid was that commercial success could only come through major research projects and technological leadership. This led the firm to invest in new technologies despite the lack of a business case for them. The other belief was in the firm's business model. Development projects that were not aligned with the existing business model were discouraged. Additionally, Tripsas and Gavetti (2000) suggested two challenges for firms that face radical technological discontinuities. Firstly, that some changes require not only new technological competence but also a change in beliefs. Industrial changes might make current beliefs obsolete and leave the firm struggling. The second challenge is differences in beliefs in the different levels of hierarchy in a firm. While some levels might adapt quicker, others could hold them back. In the case of Polaroid, managers directly working with the new technology adopted new beliefs about what the firm should do but were held back by corporate executives with the traditional beliefs. This cognitive inertia was a significant source of difficulties for Polaroid (Tripsas & Gavetti, 2000).

To sum up, an incumbent firm's existing competences affect the outcome of a technology shift in terms of winners and losers. Additionally, the strategic beliefs held by the management influence might need to change, causing difficulties and hierarchical inertia. However, the performance of incumbent firms is decided by many additional factors, which will be further discussed in this chapter.

2.2.2 Types of Innovation

Henderson and Clark (1990) find that small improvements to a technology can have dramatic effects on incumbents in an industry. This observation led them to expand on the traditional categorization of innovations as being either radical or incremental. In doing so, Henderson and Clark (1990) put forth a framework that considers an innovative product both as a whole and in its parts, i.e. the individual components that make up the product. In their framework depicted in Figure 1, Henderson and Clark (1990) classify an innovation's impact along two dimensions. The first dimension, core concepts, considers whether the innovation reinforces component knowledge or makes this knowledge useless. The vertical dimension encapsulates the innovation's impact on the linkages *between* the components of the innovation, i.e. it answers whether or not the way the components are joined together changes as a result of the innovation.

		Core Concepts	
		Reinforced	*Overturned*
Linkages between Core Concepts and Components	*Unchanged*	Incremental Innovation	Modular Innovation
	Changed	Architectural Innovation	Radical Innovation

Figure 1: A framework for defining types of innovation (Henderson & Clark, 1990)

This framework provides a useful way of looking at innovations and investigating the reasons why incumbent firms find some types of innovations particularly difficult to accommodate. An *incremental innovation* building on existing architectural and component knowledge would then be the cause of what Tushman and Anderson (1986) would describe as a competence-enhancing technological discontinuity, benefitting the incumbents. *Radical innovations*, which by the same terminology are characterized by competence destruction, are often problematic for incumbent firms since they make both the architectural and component knowledge obsolete, according to the framework. An *architectural innovation* is then an innovation that changes the way the components of a product are joined together, but the components themselves remain the same as before. Put differently, an incumbent firm facing this kind of change will have their knowledge regarding how the components fit together turned obsolete, but their knowledge about the components will retain its value to the firm.

The alteration of the established product architectures can be detrimental for incumbent firms' market positions since a significant part of their competitive know-how becomes obsolete (Henderson & Clark, 1990). The framework implies that architectural innovations are both competence-destroying and competence-enhancing. This suggests that in order to successfully manage a technological change brought on by an architectural innovation, an incumbent firm needs to secure both new architectural knowledge relevant to the new product and utilize existing knowledge about the product's components. According to Henderson and Clark (1990), the former can prove cumbersome for many firms since architectural knowledge is rooted in routines and strategies that are difficult and time-consuming to adjust. Further, they explain that most of the learning in an organization occurs with regards to a stable product architecture and learning about changes to this architecture is seldom a natural occurrence, because of the way knowledge is usually managed in firms. Understanding what new knowledge needs to be acquired is therefore often a challenging task for incumbent firms according to Henderson and Clark (1990). Put together, the effect of an architectural innovation largely depends on the organizational structure of the incumbent firm.

The building of new architectural knowledge is also required for entrants looking to profit from an architectural innovation (Henderson & Clark, 1990). However, the authors point out that since new entrants do not possess any assets, they are able to develop their organizational and knowledge management structures in harmony with the new design. New entrants are not burdened by old routines and embedded architectural knowledge and should, therefore, be able to utilize the architectural innovation's potential much more efficiently compared to incumbent firms (Henderson & Clark, 1990).

2.2.3 Incentives to Invest

The benefits of adopting a new technology are generally gained throughout the life of the innovation while the costs, both financial and non-financial, are suffered at the time of adoption (Hall and Khan, 2003). These costs can be considered sunk costs, i.e. they are not recoverable. Following this logic, Hall and Khan (2003) emphasize that is it not so much a question of investing or not investing in a new technology. Rather, it is a question of investing now or postponing the decision. After adoption, the sunk costs are, by definition, irrelevant. However, ex ante, the costs are considered in relation to the expected benefits gained by the adopter. According to Hall and Khan (2003), this suggests that (1) a new technology is seldom abandoned for an old technology since all potential benefits will be lost without recovering any costs, and (2) waiting to incur the cost of adoption provides an option value when uncertainty regarding the benefits of adoption exists, which makes firms prone to waiting. This is further supported by Jensen (1982) that demonstrates that when firms are uncertain of an innovation's profitability, they tend to delay adoption in order to gather information and reduce their uncertainty until they are comfortable enough to adopt.

When Tripsas (1997) looks at the investment behavior by incumbent firms during multiple technology shifts in the typesetter industry she highlights two perspectives. The first perspective considers whether the new technology is radical or incremental. Based on her literature review Tripsas (1997) asserts that the incentives to invest in new radical technologies are greater for new entrants than for incumbents. In contrast, incremental innovations that build on existing already implemented technologies give incumbents a stronger incentive to invest compared to new entrants.

The second perspective highlighted by Tripsas (1997) draws upon Christensen and Bower (1996) who suggest that incumbent firms' investments in new technologies are mainly determined by the needs of their existing customers since these customers supply the resources the firm needs in order to continue to operate. Christensen and Bower (1996) classify technological changes as being sustaining or disruptive. According to Christensen (2011), these concepts differ significantly from the radical or incremental view of new technologies mentioned above. *Sustaining technologies* can be either radical or incremental and they enable improvements in product performance along dimensions that have historically been valued by the market. In other words, sustaining technologies satisfy the need of the firms' resource providers and incumbent firms then have clear incentives to invest in these technologies. Furthermore, Christensen (2011) finds that established firms are often successful in meeting the challenges of profiting from sustaining technologies and explains that however radical these sustaining technologies are, they seldom lead to the failure of incumbent firms.

Disruptive technologies, on the other hand, are characterized by having initially worse product performance in the traditionally valued dimensions but have other attributes that bring a different value proposition to the market (Christensen, 2011). That is, disruptive technologies do not cater to a market's mainstream customers and it is a lack of investment in these kinds of technologies that bring on incumbent firm failure and hence the success of entrants (Christensen & Bower, 1996).

The notion of *increasing returns* further influences the decision to invest. When a company, product or a technology gets an advantage in the market, this lead tends to be amplified and result in a further advantage. This is the essence of increasing returns as discussed by Brian Arthur (1989). He explains that this advantage is many times the result of random economic occurrences that lead to a certain path (e.g. a standard) and not the result of objective superiority. These occurrences are the causes of path dependence, i.e. the notion that historical events largely affect and limit future decisions (Brian Arthur, 1989). Further, this also implies that in the presence of increasing returns, there is a potential for inefficiency should the solutions that emerge not be the optimal alternative.

Brian Arthur, Ermoliev, and Kaniovski (1987) discuss that technologies often show increasing returns to adoption. As a technology is adopted, more actors learn about the technology, causing improvements to it by the new users and the suppliers, which in turn makes it even more attractive to adopt. This suggests that as the number of actors in an ecosystem increases, their individual share of control over it decreases. From the same reasoning as the positive feedback loop described above, Brian Arthur et al., (1987) assert that a path becomes more and more rigid and then gives rise to inflexibility since it becomes increasingly difficult to change the trajectory. Additionally, the actors involved in the path become less and less likely to leave it (Brian Arthur, 1989). To conclude, increasing returns implies that firms can with the best intentions commit to a path consisting of suboptimal solutions and face significant friction when trying to diverge from it.

2.2.4 Complementary Assets

The term *complementary asset* was first used by Teece (1986). In the general sense, the term describes assets that provide an advantage during the commercialization and marketing of a new technology. According to Teece (1986), examples of these crucial resources are competitive manufacturing capabilities, marketing or after-sales support. Tripsas (1997) asserts that a firm has a substantial advantage if it has proprietary access to these assets, which are necessary for commercially exploiting an innovation. She highlights the complementary asset of an established sales/service relationships that incumbents often have in place, which can be difficult for entrants to initiate. From previous research (e.g. Mitchell, 1989; Sandström, 2016; Tripsas, 1997) it is clear that a technology might change the value of a firm's complementary assets and that this change affects the investment decision. However, it is important to point out that complementary assets can both benefit and harm incumbent firms. In fact, they can act as a detrimental factor for incumbents and give entrants a distinct advantage (Tripsas, 1997).

2.2.5 Relationships in the Value Chain

Assessing a new technology without considering its effect on suppliers, customers or consumers can have disastrous effects on a firm (Afuah & Bahram, 1995). This is due to an innovation having different faces toward different actors, which Afuah and Bahram (1995) call the hypercube of innovation. When classifying an innovation into incremental, modular, architectural or radical, the results might be different for the different actors in the value chain. An innovation that is incremental for the innovator might as well be architectural, modular or radical for a supplier or customer that the innovator is dependent on. Afuah and Bahram (1995) further warn that innovations that have a high degree of radicalness for any actor in the innovator's value chain should not be pursued. However, it also provides four exceptions to that warning. Firstly, if the innovation outperforms the existing solutions so much that any competence or complementary asset destruction is outweighed. Secondly, if the industry is relatively new and lacks high value existing competences and assets. Thirdly, if complementary innovations allow actors to keep or adapt their competences. Finally, if the innovation is necessary due to institutional requirements (Afuah & Bahram, 1995).

Afuah (2000) further investigates this, finding that the performance of a firm after a technological change depends on its effect on the capabilities of its suppliers and customers. Further, the choice of supplier for the changing technology had an effect. The suppliers that were new entrants to the industry using the new technology were the key as firms that switched to these suppliers outperformed others that did not switch. The advantage of having ties with suppliers had turned into a handicap.

Additionally, the study found that firms that worked to maintain their customers' capabilities during the transition outperformed those that did not (Afuah, 2000). Additionally, Helper (1995) investigates the adoption of a new production technology and finds that a stable customer base is key. In cases where the technology would drastically increase productivity, adoption still only occurred in fewer than 50 percent of the cases in the absence of a stable customer base. According to Hall and Khan (2003), a clear customer commitment allows firms to better predict the demand and therefore the profit from the production more accurately, which makes an investment decision less uncertain.

Teece (1986) also mentioned the industry's effect on technological change. Innovations that can be protected by the innovator using patents or copyright are easier for the innovator to profit from as customers have little freedom. Innovations that can't be protected risk imitation and the innovator needs to have a tight connection with its market in order to allow the market to help design its offering (Teece, 1986).

3 RESULTS

This chapter presents a set of factors to assess by food manufacturing companies looking to understand the industrial transformation that could happen in their industry due to IIoT. The theoretical framework outlined above has been applied to the industrial and technological context, providing an answer to RQ2: *How do these factors relate to incumbents in the food industry and the technological change caused by IIoT?* A summary of the analysis is provided in Table 3, with each factor further described in this chapter. The factors constitute an answer to RQ3: *Which factors should a food manufacturer assess when implementing IIoT?*

Interviews have provided data for the analysis. The interviewees were selected due to their high level of competence in automation and production systems, as well as familiarity with food manufacturing. Experts from two different vendors of industrial automation and IIoT solutions discussed the change from a system vendor perspective. One researcher of production systems provided the perspective of industry-academia collaboration. Finally, a food manufacturing automation expert gave further context to today's situation in the industry. Additional literature about IIoT in the food industry was used to bring in international research progress.

Table 3: Factors that food manufacturers should assess when implementing IIoT

Factor to assess	Possible effect on incumbent performance	Proposed assessments
Effect on competences and strategic beliefs	Competences could be enhanced or destroyed, benefitting or harming performance Needing to change beliefs could harm performance	Available competences within IIoT systems
		Available competences within existing systems
		Flexibility of process experts
		Alignment of current strategic beliefs with the value of IIoT
Receptiveness to architectural change	Higher level of receptiveness could benefit performance	Architectural knowledge about produce-by-order products
		Rigidity of organizational structures
Willingness to invest	Higher willingness could benefit performance	Existing knowledge regarding incentives
		Usage of testing to determine incentives
		Choice of investment evaluation method
		Comparison of IIoT with currently prioritized dimensions
		Conformance to ISA 95 standard
Protection by complementary assets	Higher level of protection could benefit performance	Degree of IIoT capabilities enabled by existing systems
		Size of recent investments in systems which IIoT is not compatible with
Inertia in the value chain	More inertia toward suppliers could harm performance More inertia toward customers could benefit performance	Strength of relationship with system vendors
		Strength of relationship with retailers
		Strength of relationship with consumers

3.1 Enhancement or Destruction of Competences and Beliefs

Due to new systems, capabilities, and value provided, IIoT solutions require new competences and new ways of accessing existing competences. These are analyzed below and the proposed assessments for incumbent firms are summarized in Table 4.

Interviewees were asked which relevant competences were in place at firms currently and how these could change due to the technological change. Three types of competences were identified to be affected. For IIoT systems, new competence is needed. Generic IT replaces the proprietary solutions in place at firms. Modern programming languages replacing proprietary, machine-level code was provided as one such example. This new competence is however not industry-specific and both system vendors claimed that it does not need to be developed within the firm. Instead, it could be brought into the firm from other industries that already possess the competence or using consultants. This is in line with Christensen and Bower (1996) that find that incumbent firms are generally very capable of bringing in new competences if it is necessary. Additionally, the overall IT competence within firms needs developing according to the professor in production systems. Existing IIoT related competences is the first assessment proposed. Firms with available competences could see these enhanced during an industrial transformation while others would need to catch up, however the advantage would be minor.

The second type of affected competence is within existing production systems. During the technological change, investments in new systems would make existing systems redundant or reduce their relative importance. As such, competences within the existing systems are destroyed. This points to a challenge for incumbent firms as new entrants without the competences at risk do not need to manage this issue. However, the challenge does not seem urgent as any change would take place over a longer period of time due to the expected long lifespans of existing systems as claimed by all interviewees. Additionally, one system vendor pointed out the low-cost characteristic of the food industry and argued that the incumbent firms do not have a lot of internal competences. The second assessment proposed is to understand this internal level of existing competences. A high assessed level could result in more competence destruction and higher resistance in the firm to the technological change.

Finally, competence within food production was pointed out by one vendor to have potential for enhancement. The interviewee argued that making use of the capabilities of IIoT requires an expert understanding of how the food is produced. They added that most firms have this competence, but that today the competence is not used in that manner. IIoT systems would provide these experts with tools to use IIoT capabilities to make improvements to food production. This would require training and willingness to learn from the employees, and structural changes to empower them. Incumbent firms are not there yet, but the competence is not readily available for new entrants either. The third assessment proposed is understanding the flexibility of these process experts in case their competences could be used in a different manner. High flexibility would indicate that the competence could be enhanced during the technological change.

The way the competences at firms end up being used can be affected by strategic beliefs as suggested by Tripsas and Gavetti (2000). If the strategic beliefs held by top management at a firm need to change to accommodate an industrial transformation, the firm might struggle. Additionally, inertia due to the change in beliefs not being consistent throughout the different hierarchical levels at the firm could mean that adaption to the change is further delayed. All interviews indicate that a change in beliefs might be necessary in order to adapt to IIoT. Specifically, one vendor suggested that management in the firms in the food industry does not currently look to improve production value in the ways that IIoT enables. This indicates that the strategic beliefs in place do not align with the value that IIoT could bring. Additionally, since some existing competences might need to be used in a new way as part of the transformation, this might be cause for inertia. Top management at firms might not hold similar beliefs to the employees that are empowered during the change. During this transformation, new entrants to the industry without deeply-rooted strategic beliefs could take advantage of the changes necessary for incumbents. Some incumbents might, however, be better prepared in terms of strategic beliefs than others. The fourth suggested assessment is understanding how similar the currently held strategic beliefs at a firm are to the value that IIoT enables. Firms that already hold similar beliefs could perform better during the transition compared to firms that have differing beliefs.

Table 4: Assessments related to the effect on competences and strategic beliefs.

Factor to assess	**Proposed assessment**	**Impact on incumbent firm in case of technological change**
Effect on competences and strategic beliefs	Available competences within IIoT systems	Competences could be enhanced
	Available competences within existing systems	Competences could be destroyed
	Flexibility of process experts	Competences could be enhanced
	Alignment of current strategic beliefs with the value of IIoT	Aligned beliefs do not need to be changed

3.2 Potential for Architectural Change

An architectural change alters the way the components of a product are joined together. In the ready meals industry, this would mean the creation of new offerings without changing the components, i.e. the ingredients. In order to inquire about the likelihood of IIoT being an architectural innovation, the experts were asked if IIoT would allow the production of new meals with the same ingredients. One expert said that it would not, while two of the experts agreed that new meals could be produced if the industry moved towards individualized production. The two experts explained that IIoT could enable a high degree of communication with consumers who for example could specify the amount of nutrition, quantity of ingredients or other preferences such as allergies or how long something is to be cooked. In this case, the new offering would entail produce-by-order meals and new architectural knowledge would need to be acquired by incumbent firms. Hence, in this situation, IIoT would classify as an architectural change according to Henderson and Clark (1990). Two assessments for that situation are proposed below and summarized in Table 5.

In contrast to the incumbents, new entrants would not be encumbered by any inheritance of unnecessary architectural knowledge and should by the logic of Henderson and Clark (1990) be able to organize to accommodate the innovation better. Efficient IIoT enabled mass customization in food production is plausible (Simon, Trojanova, Zbihlej, & Sarosi, 2018) and this could pose a threat to incumbents in the Swedish food industry. In response to this threat, incumbent firms are therefore advised to assess their architectural knowledge about produce-by-order products.

Additionally, according to Henderson and Clark (1990), the effect of an architectural innovation for incumbent firms is determined by how well they manage the demanding task of acquiring new architectural knowledge, which in turn is influenced by the organizational structure and its rigidity. Similarly, the orientation framework by Grunert et al. (1997) describes how a firm could be more or less oriented towards improving processes. This change to produce-by-order meals might require firms to shift their orientation to become more process-oriented. The shift could be a challenge for all incumbent firms in the food industry. However, firms with a less rigid organizational structure would have an advantage and be more receptive to an architectural change. Therefore, assessing the rigidity of the organizational structure is proposed.

Table 5: Assessments related to receptiveness to architectural change.

Factor to assess	**Proposed assessment**	**Effect on incumbent firm in case of technological change**
Receptiveness to architectural change	Architectural knowledge about produce-by-order products	More knowledge reduces blocking
	Rigidity of organizational structures	More rigidity increases blocking

3.3 Willingness to Invest

Each interview began by discussing the definition of IIoT used in this report with the experts and talking through the value in the context of food manufacturing. When asked about these values and how well they thought incumbent firms understood them, there was a strong consensus regarding the firms' perception. According to all the interview subjects, IIoT and the associated values emphasized are seldom explicitly demanded or understood by incumbent firms. Manufacturing firms rarely reach out to the experts and inquire about for example how IIoT can help them lower their energy consumption. Instead, the incumbents' incentives to invest are more often stated in line with wanting to be a modern company and not wanting to fall behind one's competitors. This feeling of urgency appears to be further amplified by system vendors that market these solutions as prerequisites for being a leading company. There seem to be general confusion and diverging definitions about both IIoT and the benefits these technologies have the potential to enable. For incumbent firms, this manifests itself in uncertainty regarding what they can get out of IIoT, what problems the technologies can solve for them, and ultimately why they should invest. Furthermore, many of these applications are relatively new which reinforces the uncertainty further, according to all the interviewed system experts. Hence, the first assessment for incumbent firms should be to evaluate their individual knowledge of the incentives to make investments in IIoT.

This uncertainty has implications in alignment with the discussions regarding postponing investments by Hall and Khan (2003) and Jensen (1982). Since the benefits of investing in IIoT are not clear ex ante, it is hard to build a robust business case and motivate sinking the cost of adoption instead of waiting. An efficient way for manufacturers to reduce uncertainty and gather information highlighted by one of the experts is to test the solutions outside of their daily operations. The interviewee explained that it is common that firms invest soon after they have seen the value demonstrated in a test setting. This not only aids the building of a business case for committing to a new technology but also enables each individual firm to evaluate what type of innovation this technological change entails for them. If, for example, an incumbent is confident that this is an incremental change, the firm will have a greater incentive to invest (Tripsas, 1997). Following the obstacles presented above, the second assessment for incumbent firms should then be to inquire about what degree of testing is done when considering investments in new production technologies.

Adding to the uncertainty, the experts emphasized that it is more difficult to accurately calculate return on investment (ROI) for IIoT technologies than it is for other assets such as new machinery. One expert compared it to the purchase of an ERP system and explained that it is near impossible to calculate ROI on these investments. Yet firms feel that they must suffer these costs in order to be operational. Not surprisingly, an incumbent's investment decision related to IIoT could get distorted when considering the complications of calculating ROI coupled with the uncertainty and lack of understanding of the benefits. Evaluating long term investments in new technologies for industrial applications, such as generic IT or cloud computing, requires a suitable approach (Lee & Lee, 2015). For instance, using the common evaluation method net present value (NPV) to assess these kinds of investments is unsuitable according to Lee and Lee (2015) since it fails to capture the enabled flexibility. Instead, they recommend using real option valuation for strategic IT investments, as suggested by Li and Johnson (2002). The third assessment for incumbent firms should then be to determine the suitability of the evaluation methods used for investments in new technologies.

Another way of looking at the willingness to invest is to consider how the investment would impact the meals. As Christensen and Bower (1996) argue, incumbent firms tend to prioritize investments that satisfy the needs of their current customers, i.e. they prioritize investments in sustaining technologies. When asked what the main benefits of IIoT are with regards to the meals, the experts interviewed emphasized features as mass customization and enabling unprecedented levels of transparency. Yet, they all agree that there is no clear indication that the manufacturers' customers request IIoT. This implies that IIoT is not considered as sustaining, which could result in the investment not being prioritized (Christensen & Bower, 1996). In contrast, investments in accordance with the current industry standard, ISA 95, could be considered investments in sustaining technologies. Since these investments are made in order to develop the product along dimensions that the firms' customers currently value (e.g.

low price), rather than creating new markets where a set of different features determines a product's success. As Christensen and Bower (1996) would predict, these investments are readily made by incumbents and other potential dimensions enabled by IIoT (e.g. mass customization) are so far, according to the experts interviewed, mainly overlooked. This suggests that a manufacturer that can reduce their uncertainty by testing and experiencing IIoT might still prioritize investment in sustaining technologies over more disruptive ones. The fourth assessment for firms in the industry would be understanding the dimensions that they currently prioritize in comparison to what IIoT could provide. If the gap is substantial for a firm, the technological change would provide a risk of disruption. Other firms with a larger overlap of dimensions could instead find the investment sustaining and would, in that case, have little issue with investing.

The last consideration of the willingness of incumbents to invest in IIoT concerns the ISA 95 standard. According to the interviews, the industry has largely adopted ISA 95 and substantial investments are frequently being made in system integration projects. Whether or not the choice of this standard was inefficient in alignment with Brian Arthur (1989) is irrelevant for this thesis and should be for food manufacturers as well, considering that these costs are sunk. Nevertheless, firms in the food industry are involved in the ISA 95 path. As more firms joined the standard, it might have become inflexible over time. This is indicated by two of the interviews which suggest that firms do not look beyond the current standard. Any new trajectories that are not contained in this standard, like IIoT, could require a readjustment. Incumbent firms might find readjusting costly, which naturally affects the willingness to invest. New entrants that are not committed to the path in that manner would have an advantage by being less constrained. By adopting earlier, they could also have more impact on the development of IIoT and benefit from any Schumpeterian rents. Naturally, some incumbent firms are more committed than others and the degree of conformance to the standard varies. These firms could then face larger readjustment costs when changing trajectory. The proposed fifth assessment is the firm's conformance to ISA 95.

Summing up the above, the incentives are rarely known or understood sufficiently by the incumbent firms. This uncertainty makes it even more difficult to properly assess and justify the investment. Trying out the solutions in a test facility might help, but incumbent firms tend to invest in technologies that maintain the status quo, which can be inflexible and difficult to change. Put together, these factors might help explain some of the inertness observed in Swedish manufacturing. On a more severe note, it is possible that this technological change will be disruptive. Should entrants find incentives to invest while the incumbents do not, the incumbent firms would risk being displaced in the market, as observed many times before (e.g. Christensen & Bower, 1996; Tushman & Anderson, 1986). Table 6 provides an overview of the assessments proposed above.

Table 6: Assessments regarding the willingness to invest.

Factor to assess	Proposed assessment	Effect on incumbent firm in case of technological change
Willingness to invest	Existing knowledge regarding incentives	More knowledge increases willingness
	Usage of testing to determine incentives	Better testing increases willingness
	Choice of investment evaluation method	More suitable method increases willingness
	Comparison of IIoT with currently prioritized dimensions	Bigger overlap increases willingness
	Conformance to ISA 95 standard	Higher degree of conformance decreases willingness

3.4 Protection or Blocking by Existing Systems

This analysis has evaluated the existing production systems at firms in the food industry as potential complementary assets. This is due to interviews with system vendors indicating that IIoT is not a substitute for existing systems. In that case, the existing assets might be complementary for the firms and protect against new entrants. Other assets that might be complementary for firms in the food industry are not included in this analysis due to a lack of primary data. Assessments related to existing systems are developed below and summarized in Table 7.

In general, firms in the food industry are currently set up to fit the automation systems standard ISA 95. This is primarily indicated by the literature review for this thesis and confirmed by descriptions of a large firm in the industry provided by the food manufacturing automation expert. The ISA 95 standard has led to a convergence of operating and business systems and made it easier to access product and process data. Additionally, both system vendors claimed that many, if not all, IIoT capabilities are also provided by the existing systems. This indicates an alignment and so the ISA 95 standard and the existing systems are considered advantageous complementary assets for the incumbent firms.

In most cases, the existing systems are hence not blocking but rather enable a smoother transition to IIoT. Incumbent firms look to be prepared for this technological change from this perspective compared to potential new entrants that do not have any existing systems. For an incumbent firm, the existing systems instead become a factor in competing with other incumbent firms. The first relevant assessment for a firm becomes understanding to which degree its existing systems enable the capabilities of IIoT. A challenge for firms could arise if they are behind their competition in this assessment as further investments would be necessary for catching up.

Finally, all experts pointed out some ways in which IIoT generally differs from the existing systems at firms. The optional cloud computing platforms and some generic IT were identified as new system components by one system vendor. Others pointed at improved access to data and increased flexibility between subsystems. Having recently invested in systems with the intention of providing similar service, but in a manner that is not compatible with IIoT, could constitute a harmful complementary asset. This leads to the second relevant assessment: measuring recent investments in areas where IIoT is different from existing systems. Large investments could be a detriment when adapting to the technological change. Meanwhile, a lack of investments could provide an opportunity to catch up.

Table 7: Assessments to understand the level of protection by complementary assets

Factor to assess	Proposed assessment	Impact on incumbent firm in case of technological change
Protection by complementary assets	Degree of IIoT capabilities enabled by existing systems	Higher degree increases protection
	Size of recent investments in systems which IIoT is not compatible with	Larger investments reduce protection

3.5 Relationships with System Vendors, Retailers, and Consumers

How a firm's implementation of IIoT could affect its value chain was a discussion point in the conducted interviews. No major effects were identified. In terms of the innovation hypercube as coined by Afuah and Bahram (1995), there are no concrete indications of the technological change being radical for any actors in the value chain. If these would appear the article would recommend against investing. Additionally, the article provides exceptions to this recommendation. Some of the exceptions might be relevant for this technological change. If one or more of the criteria for exceptions are fulfilled, food manufacturers might still benefit from investing despite causing a radical change for another actor in the value chain. Firstly, if IIoT would outperform existing production systems drastically, which is not yet evident. Secondly, if complementary innovations such as the easy-to-use development tools mentioned by one vendor soften the transformation. Thirdly, if food industry regulations would make investments necessary. If this change proves to be radical for any actor in the value chain, further assessments of the above exceptions are needed. Other proposed assessments regarding the firm's value chain are developed below and summarized in Table 8.

Afuah (2000) found that firms performed better during a technological change if they switched to new suppliers of the new technology. This was also true even if their previous supplier adopted the new technology. It is possible that the same situation could occur with suppliers of ISA 95 production systems and new suppliers of IIoT solutions. Additionally, due to the generic and flexible nature of IIoT systems, vendors that traditionally developed more proprietary systems could be slower to adapt as they see few reasons to move into a weaker appropriability market. The previous systems were easier to profit from for these actors, while new entrants in the system vendor industry could focus on adapting to the IIoT transformation. The first assessment proposed for firms is hence understanding the strength of its relationship with vendors of their existing systems. A strong relationship might prove difficult to switch from and therefore block the incumbent firm from adapting in time. A weak or non-existent relationship enables a faster switch if necessary, which is also an advantage for new entrants.

On the other hand, Afuah (2000) found that firms that eased the transition for their customers by helping them maintain their capabilities performed better. In the case with IIoT, interviews identified the management and analysis of data towards retailers to be an opportunity for this. Helper (1995) and Hall & Khan (2003) make additional arguments for the customer relationships being key factors. They argue that having a stable customer base and strong customer commitment, respectively, helps to make investment decisions. Firms in the food industry are therefore likely to benefit from having strong relationships with retailers. Interviews indicate that this is already necessary and the case currently for most incumbents. New entrants that do not have those existing relationships are at a disadvantage compared to incumbents. However, some incumbent firms might have stronger relationships than others. The strength of the firm’s relationships with retailers is the second proposed assessment.

The same argument by Afuah (2000) regarding maintaining capabilities can also be extended to the next step in the distribution chain, food consumers. Multiple interviewees mentioned a possibility that consumers are interested in access to data about the specific individual product that they bought. This could also be an opportunity for incumbents if implemented in a way that aligns with the consumers’ current communication with the firms. The vendors interviewed claimed that increased demand for transparency from consumers would lead to a shift in the balance of power in the value chain. One interviewee claimed the shift could lead to more power for the food manufacturers since they own the data that consumers demand, while another claimed that consumers benefit from the power shift by demanding data. In either case, the situation seems in line with the findings of Cox, Mowatt, & Prevezer (2003). The study looks at power in the network of food manufacturers and retailers and concludes that the consumer behavior data empowers the retailers that collect it. A reverse situation where the consumers demand data could then indeed lead to a reverse in power balance. In such a case, the opportunity for firms to empower consumers as outlined above could rest on the strength of their relationship, which is proposed as the third assessment. A strong relationship could make it possible for firms to empower consumers and in turn shift the power balance away from retailers.

Table 8: Assessments regarding the level of inertia in the value chain

Factor to assess	Proposed assessment	Effect on incumbent firm in case of technological change
Inertia in the value chain	Strength of relationship with system vendors	Strong relationships could increase inertia
	Strength of relationship with food retailers	Strong relationships could decrease inertia
	Strength of relationship with consumers	Strong relationships could decrease inertia

3.6 Discussing the Framework

The above framework consists of five factors that could affect the performance of an incumbent firm in the food industry during a technological change due to IIoT. The framework also includes a handful of ways to assess each factor based on their nuances. Some of the factors and assessments might be more impactful for this change and this industry than others. For instance, Tripsas (1997) suggests that complementary assets might protect the firm from a competence-destroying discontinuity. However, the complementary assets that are part of this analysis are the existing production systems. Some of the competences are directly related to those systems and so that suggestion might be invalid. As such, it is necessary to apply the framework to a firm in the food industry in order to get an understanding of the factors' relative importance and interdependence.

Some of the assessments proposed above might also differ in difficulty to assess for firms. If an assessment proves impractical to conduct, other related assessments might give a similar indication for the factor in hand. The findings from applying this framework on a firm could contradict data collected during the interviews for this thesis. This could be due to different sources for the data, as a system vendor or a professor has a different perspective. Any new findings could be used to further build an overarching picture of the transformation as well as adjust the factors and assessments. One such adjustment would be including additional perspectives to the factor regarding complementary assets, as the firms in the industry likely have more than the one analyzed in this thesis. These could also vary from firm to firm.

4 CONCLUSIONS

This thesis aims to provide a new approach to understanding technological change and industrial transformation. It does so by providing an ex ante viewpoint to a technological change, building on existing literature. The set of factors provided in the literature review answers the first research question: *Which factors could determine an incumbent's readiness for technological change?*

The thesis further looks at the food industry and the change due to the Industrial Internet of Things (IIoT), using interviews with experts. This analysis answers the second research question: *How do these factors relate to incumbents in the food industry and the technological change caused by IIoT?* A framework for firms in the industry is proposed. The framework can be used to assess the different factors that affect the performance of a firm during a technological change, answering the third research question: *Which factors should a food manufacturer consider when implementing IIoT?*

There is no clear answer regarding the potential for disruption in the food industry since several factors in the framework have mixed on unclear effects. Further research could make use of the proposed framework to understand this issue further. During the interviews, two additional forces were identified. The first concerns consumer behavior and the potential for trends enabling mass customization of products and a demand for transparency about the manufacturing and materials. Understanding this area further would help clarify whether IIoT could be an architectural change for the food industry. Secondly, the effect of regulation on innovation is unclear in this situation. Raised demands on food production might constitute another incentive for the firms to invest.

The concept of technological change and industrial transformation is relevant for most industries today and other changes than the one investigated in this thesis are ongoing. Since the first research question is industry and technology agnostic, the answer to it could be applied to any technological change and industry. The analysis that led to the answers to the second and third research questions could be conducted in a similar way for a different technology and industry. The research progress from this thesis could hence be useful in various ways.

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APPENDIX A: THE SWEDISH FOOD INDUSTRY

Table 9: Swedish food industry segments with SNI-codes as classified by Statistics Sweden (SCB). Data from Bisnode and Retriever Business. 10850 Manufacture of prepared meals and dishes corresponds to the ready meals segment analyzed in this thesis. Table excludes meat production, animal feed production, berry production, and bakery segments.

Segment code and name	Total segment revenue, 2018 (billion SEK)	Market share of top 3 firms
10519 Other dairy production	29.1	73%
10511 Cheese production	23.3	79%
10850 Manufacture of prepared meals and dishes	23.1	50%
10840 Manufacture of condiments and seasonings	21.0	54%
10612 Manufacture of breakfast cereals, blended flour mixes and other prepared grain mill products	13.9	86%
10310 Processing and preserving of potatoes	10.8	79%
10830 Processing of tea and coffee	10.5	80%
10722 Manufacture of rusks, biscuits and preserved pastry goods and cakes	9.8	69%
10410 Manufacture of oils and fats	8.9	94%
10822 Manufacture of cocoa and chocolate confectionery	5.8	72%
10611 Production of flour	5.5	73%
10821 Manufacture of sugar confectionery	5.2	64%
10721 Manufacture of crispbread	3.3	89%
10320 Manufacture of fruit and vegetable juice	2.8	n.a.
10730 Manufacture of macaroni, noodles, couscous and similar farinaceous products	2.1	98%
10520 Manufacture of ice cream	1.7	66%
10860 Manufacture of homogenised food preparations and dietetic food	1.4	n.a.

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