# Determinants of Innovation Adoption in SMEs: an explorative study on dairy farmers in Four European Countries

by

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A Thesis

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# Preface

In September of 2023, I began this Master's Thesis, as the final dissertation for my Master's study Business Administration, specializing in Entrepreneurship, Innovation & Strategy. For this research I partnered with Kramp, Europe's largest distributor of agricultural parts. Through the joint interest in modern technologies used in farming and the curiosity to explore the future of farming in Europe, we came up with the following research; Determinants of Innovation Adoption in SMEs: An explorative study on dairy farmers in four European countries.

Kramp is serving the agricultural sector in Europe and has a wide distribution and sales network. With their help I visited 18 farmers across the Netherlands, Germany, France and Poland. During these visits I conducted in-depth interviews combined with a farm tour to gather information for my research. This research is for anyone interested in the innovation diffusion within the agri-sector and the development of new technologies.

This thesis could not have been completed without the guidance and help of many people. First, I would like to thank my university supervisors, R. Siebelink and E. Hofman for their guidance and support in developing the report. I would also like to thank Kramp B.V. and all my colleagues who supported me during the research and made the international travels a reality! I would also like to thank M. Di Domenico for his guidance and support during the research.

I hope the following pages help Kramp and the wider agri-sector. As new technologies help improve farming, this report can help improve the innovation diffusion process in understanding the determinants of adoption for a dairy farmer.

Philip Lutke Veldhuis

Enschede, 17-7-25

*"During the preparation of this work, the author(s) used ChatGPT in order to search for theories and improve grammar. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the work."*

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# Abstract

Technological innovation leads to greater productivity and sustainability; this is especially true in European agriculture, yet adoption of innovation in small- to medium-sized dairy farmer enterprises remains uneven. To address this gap, this study investigates which configurations of determinants motivate or hinder the adoption of Robotic Milking Systems (RMS) by dairy farmers in four EU countries (the Netherlands, Germany, France, and Poland). The RMS is used because it is a very good example of a high-technology on-farm innovation. In-depth, semi-structured interviews were conducted with 18 farmers; they were selected for maximum variance in herd size, land use, and technological state on the farm. The farmers were interviewed about their farm, technology state, and reasoning for adopting or not adopting an RMS. The responses were transcribed and scored. For the analysis, fuzzy-set Qualitative Comparative Analysis (fsQCA) was used.

The analysis reveals one dominant configurational pathway to RMS adoption: The self-driven pioneer, this farmer type has strong evidence for a personal attitude toward innovation, with an above-average farm size and an absence of network externalities (limited reliance on peers or suppliers for decision-making). They are pioneering with innovation and not being influenced by their peer farmers. They are focused on searching for new technologies without the help of others. Two alternative pathways explain the non-adoption: the risk-averse family farm with distrust of new technologies and below-average size, big enough for their own family, and that is just how they like the farm size. The other configuration is the welfare traditionalist, who has an extra focus on animal health management; he/she feels he/she is better than the new technologies and trusts in his/her own skills and experience to manage the herd and farm. This farm type is, against expectations, also a growing farm with improved operations. Build and grow on traditional foundations.

These findings extend the results of existing acceptance model research (TAM/UTAUT). It shows the causal complexity created by the fsQCA analysis and the need for future research on innovation adoption with the QCA model.

For innovation diffusion to spread in the dairy sector, the self-driven pioneer should be left alone, as he/she thrives on exploring the new technologies on his/her own. The risk-averse family should be aided by the right subsidiary to help incentivize innovation adoption. The welfare traditionalist should be reached with better health management innovations, as they are traditionally centered and do a good job this way. The technology developers can learn from these farmers how to better incorporate animal welfare technologies.

# Chapter 1, Introduction

Innovation is a critical enabler of productivity, efficiency, and sustainability across industries, including agriculture. In recent decades, the agricultural sector has undergone a significant transformation, shifting from labor-intensive methods to increasingly automated and data-driven processes (O'Grady & O'Hare, 2017). Dairy farming in particular exemplifies this evolution, transitioning from traditional hand milking to advanced technologies such as robotic milking systems (RMS), precision feeding, and herd management software. These innovations not only enhance operational efficiency and productivity but also contribute to environmental sustainability and animal welfare (Sumrin et al., 2021; Xie & Huang, 2021). For instance, Figure 1 demonstrates how larger farms, which are more likely to adopt such technologies, achieve more than twice the productivity per cow compared to smaller farms—suggesting the role of economies of scale and technological integration (*FADN*, 2024).

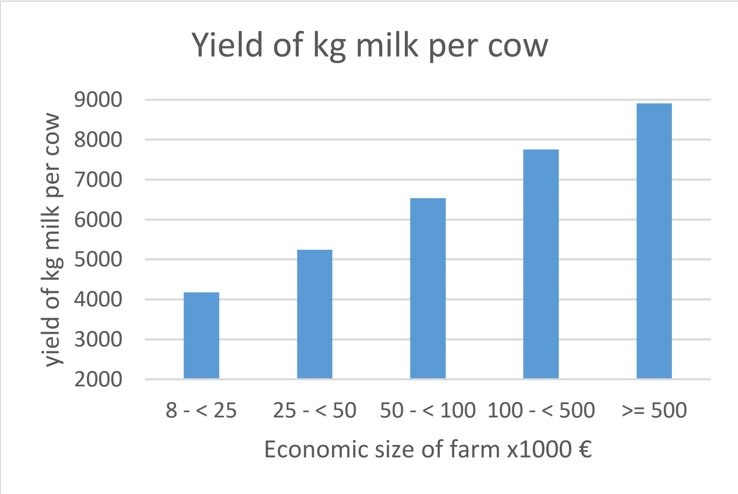


*Figure 1. Yield of kg milk per cow* (*FADN*, 2024).

Nowadays, a farmer must make important decisions about the investments made on the farm. Most investments are technological advancements for the operation of the farm. For example, RMS has been proven to increase milk output on dairy farms. Despite clear productivity and sustainability benefits, innovation adoption remains uneven (Marshall, 2009). Potentially limiting sector-wide productivity gains and closing the gap between adopters and non-adopters. Therefore, understanding the determinants influencing the adoption process is essential to create a better innovation diffusion in the agricultural sector (O'Grady & O'Hare, 2017).

Among the most important constructs related to innovation, there is the one of innovation and technology adoption. This is the process of searching, deciding, and integrating new technological or innovative developments into the existing current system (Davis, 1993). The process of adopting innovation is complex, and it is influenced by many factors, ranging from perceived usefulness to ease of use, and in a more detailed look, the size or environment in which the organization operates.

Research on technology adoption has long been dominated by theoretical models such as the widely adopted Technology Acceptance Model (TAM) (Davis, 1986) and its successors. TAM is a foundational theory in technology and innovation adoption research. Perceived usefulness and ease of use are primary predictors for technology acceptance.

These models emphasize perceived usefulness and ease of use as key predictors of adoption behavior. However, recent reviews highlight a broader array of factors that influence adoption decisions, including organizational size, environmental regulation, supplier involvement, and rational motivations (Van Oorschot et al., 2018).

It is unknown why some dairy farmers choose to adopt new technologies such as a milking robot, while other farmers don't. What are the reasons some farmers embrace innovation on their farm and see it as an important necessity for growing the business? While other farmers feel the new technologies are not of great value at all. Farmers need to take care of the animal's well-being and grow and meet governmental sustainability goals (European Union, 2020). Innovations can help with that (Frigon et al., 2020), in order to help diffuse innovation among dairy farmers (Rogers et al., 2008), understanding the determinants influencing the farmers is important. These determinants have been studied extensively in other industries, but their role specifically in SMEs within the unique setting of the agricultural sector remains underexplored. This knowledge gap is crucial for better understanding the innovation adoption process.

Farming, and in particular dairy farming, appears to be the ideal setting for exploring innovation adoption because dairy farmers represent a unique category of decision-makers who are both individuals and organizational leaders. Their adoption decisions are influenced not only by technical and economic considerations but also by environmental policy, personal attitudes, and resource constraints (O'Grady & O'Hare, 2017).

In this study, many different determinants will be under investigation. It is not known which are most influential in the innovation adoption process. It is very likely that not one but several determinants together explain the innovation adoption process of a dairy farmer (Frambach & Schillewaert, 2002).

To explore how different determinants influence innovation adoption among dairy farmers, this study applies fuzzy-set Qualitative Comparative Analysis (fsQCA). This method makes it possible to uncover multiple combinations of conditions (determinants influencing innovation adoption), called configurations, that lead to either adoption or non-adoption of technologies such as RMS. The QCA analysis is unique in its ability to identify multiple combinations of determinants, unlike traditional quantitative methods. Therefore, it is the right method for the setting of this research (Ragin, 2008).

The goal of this research is to investigate the determinants that influence the adoption of innovation by small and medium-sized enterprises (SMEs). In particular, this study aims to explore the configurations of determinants that show strong evidence in explaining the adoption of new innovations in the dairy farming industry.

This study aims to identify the key barriers and enablers of innovation adoption among dairy farmers by exploring how organizational and individual determinants influence adoption decisions. In doing so, it addresses a gap in the literature, which has predominantly focused on high-tech sectors and overlooked the unique characteristics of traditional industries like agriculture (Montes de Oca Munguia et al., 2021).

As mentioned, many determinants can influence the decision-making process of the adoption of innovation and technology. In addition to that, firms belonging to more traditional settings have been understudied, with most research focusing on more high-tech settings. I aim to fill this gap with this thesis.

Therefore, my research question is:

> *What is the combination of determinants that influence dairy farmers' decisions to adopt new technologies, and how do these determinants motivate or hinder the adoption process?*

In this project, I focus on dairy farmers as the setting of my research. In Europe, there are over 9 million dairy farmers supplying milk for milk products worldwide (*FADN*, 2024). This research will focus on four countries in Europe, namely, the Netherlands, Germany, France, and Poland. This is a suitable setting for at least three main reasons.

First, dairy farming across Europe is primarily driven by SMEs, making it a suitable lens for understanding broader innovation adoption patterns in the agricultural sector, which is resource-constrained (Rizzo et al., 2023). Second, technological advancements in dairy farming (such as automated milking systems, precision feeding technologies, and digital herd management tools) can lead to substantial gains in productivity, efficiency, and sustainability. Yet, adoption rates remain inconsistent. Third, dairy farming is situated at the intersection of multiple socio-economic and environmental concerns, including climate change, rural development, and food security. As such, it provides an interesting setting to examine how technological adoption interacts with both economic motivations and environmental policy.

This study contributes to the growing body of literature on innovation and innovation adoption in small and medium-sized enterprises (SMEs), extending it to the underexplored domain of traditional sectors, specifically, dairy farming (Montes de Oca Munguia et al., 2021). While established models such as the Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) have been widely applied in high-tech and service industries, their application in agricultural settings remains limited. This research builds on these foundational frameworks and integrates insights from reviews (Van Oorschot et al., 2018; Frambach & Schillewaert, 2002) to investigate a broader range of determinants, including economic scale, regulatory environment, supplier influence, and individual attitudes.

The academic findings contribute to the policymakers and suppliers of new technologies. By identifying specific barriers and motivators, they can better understand and steer the innovation diffusion process among dairy farmers.

In sum, this study seeks to inform innovation strategies that balance productivity, sustainability, and practical feasibility, ultimately contributing to a more resilient and future-ready agricultural sector.

In the following chapters, the thesis starts with a theoretical framework that reviews the innovation adoption literature, focusing on the most relevant models and determinants. After that, the main drivers for innovation and innovation adoption will be discussed, specifically tailored to the context of SMEs and dairy farming. The model chapter explains the development of the model for this research. The methodology explains the research design, explaining how data was analyzed using fsQCA. Then, the main findings of the analysis will be presented, showing which combinations of conditions lead to innovation adoption or non-adoption. Finally, the thesis concludes with a discussion of the results, linking them back to theory and practice.

# Chapter 2, Theoretical Framework

This chapter is structured in 5 steps. First, section 2.1 defines innovation and explains the type of innovation relevant for this study. Second, section 2.2 explains adoption and the five stages of innovation adoption. The third step, section 2.3, gives an overview of the history of innovation research and how it unfolded into several research streams. The fourth step, section 2.4, explains the innovation adoption clusters from Van Oorschot (2018), giving an overview of innovation adoption research focused specifically on the adoption differences. Finally, section 2.5 dives into the determinants that can influence the innovation adoption, concluding with the determinants selected for this study.

## 2.1 What is innovation?

Innovation is defined as "*an idea, practice, or object perceived as new by an individual or organization and expected to generate added value*" (Rogers, 2003, p. 12). In the dairy sector, where this study focuses, these innovations can range from automated robotic milking and feeding installations to herd management through data analysis. In the domain of innovation research, there are several dimensions where innovation can be classified:

**Incremental vs. radical innovation:** Incremental innovation implements small refinements that improve the performance without disrupting or changing. However, these incremental changes can add up to significant improvements. Radical innovation introduces a fundamentally new technology, making the older version obsolete. Such leaps cost more capital and time and are less often than incremental changes (Dewar & Dutton, 1986).

**Product vs. process innovation:** product innovation introduces new or improved products for the market. The core of the production process can remain the same, but the value is added at the finished product. While the process innovation changes the existing process to increase more output or quality, etc., it does not change the product itself. Benefits are therefore more focused on labor and energy savings (Utterback & Abernathy, 2018).

**Technical vs. administrative innovation**, innovation in core operating technologies versus innovation in managerial or social systems. The technical innovation is aimed at the operational side of the organization, affecting the technical systems. Technical innovations enhance the effectiveness of the organizational performance. Administrative innovation affects the social systems of an organization. An organization with a centralized structure has a lower impact on administrative innovations (Subramanian & Nilakanta, 1996).

The introduction of an RMS on a dairy farm changes the production process of collecting the milk from a dairy cow. This is a technical subsystem of the farm; it does not change the actual product. Therefore, this study focuses on a technical process type of innovation.

## 2.2 What is innovation adoption, and what are the stages of adoption?

Before a certain innovation is implemented in an existing structure, an adoption process occurs. The adoption process is a crucial part for anyone invested in an innovation. It can dictate a successful innovation adoption or an unsuccessful one. Understanding the adoption process and its determinants influencing the adoption process is crucial for understanding the adoption of an RMS on a dairy farm (Rogers et al., 2008).

The adoption process is not just a single activity; it is a behavioral process that can be segmented into different stages. There are several streams of research discussing those stages. However, the best known are the five sequential stages (Rogers, 2003):

1. **Knowledge**, become aware of the innovation's existence.
2. **Persuasion**, form an attitude about the innovation.
3. **Decision**, reject or accept the innovation.
4. **Implementation**, put the innovation into use.
5. **Confirmation**, look for confirmation and expand the innovation.

Earlier work from Holbek groups the first three stages into the initiation stage and the last two as the implementation stage (Holbek J, 1973). In the initiation stage, the individual or organization becomes aware of the innovation or technology. During this stage an attitude towards the technology is being developed. This stage is important for deciding whether to adopt the new technology or not. Evaluation, awareness, and consideration are important during this stage. The implementation stage follows when the decision to adopt the innovation is made; a successful integration and use of the innovation marks a positive end for the adoption process.

To elaborate on this even further, Frambach and Schillewaert (2002) make the distinction between organizational innovation adoption and individual innovation adoption. Recognizing different streams of research from individual acceptance and a corporate setting, focusing on the organization as a whole instead of the individual.

Understanding the phases of adoption is important for this study. As this study will focus on the determinants influencing the innovation adoption.

## 2.3 The history of innovation adoption research

In 1962 Everett Rogers (1962) published his book titled "Diffusion of Innovations," which presents a framework for understanding how a new technology or innovation is adopted within a social system. Rogers emphasizes the role of individual characteristics during the adoption process of an innovation. Five elements were proposed that have an influence on the adoption process: the innovation itself, adopters, communication channels, time, and a social system. An innovation must be widely adopted to self-sustain. The work of Rogers is the foundation for all later innovation adoption research.

An influential research stream following Rogers is the Technology Acceptance Model, TAM, by Davis (1986). It shows how users decide to accept and use a new technology. It explains that perceived usefulness and ease of use are the two primary drivers for technology acceptance of an individual. The TAM was inspired by the work of Rogers, but also by the research of Ajzen & Fishbein (1977), Theory of Reasoned Action, who analyzed the relationship between attitude and behavior. They discovered that to better predict one's behavior through their attitude, there must be a strong match between what the attitude is about and the behavior that is studied. So, when there is a high alignment between these two, the person's future actions are more predictable. However, with the later work of Davis (1986), TAM has proven to have superior empirical effectiveness compared to Ajzen's broader Theory of Reasoned Action due to its robustness, parsimony, and generalizability across different technologies and contexts (Lee et al., 2003).

With Davis reviewing his work in 2007. The two main important constructs researched for TAM used to be the perceived usefulness and ease of use of a technology. With later adaptations of TAM, researchers have identified numerous factors that influence and precede these constructs. For example, a user's prior knowledge and experience with similar technologies and user involvement in the design process have impacted the perception of perceived usefulness and ease of use. Also, interventions like training programs have a positive influence on innovation adoption (Venkatesh et al., 2007). To accommodate the additions made to TAM, researchers proposed new, more elaborate models of TAM and TAM 2. To enhance the understanding of technology's perceived usefulness and intentions to adopt even further. Instrumental processes and social influences were added. Instrumental processes are technical aspects focusing on the output of a process, such as the quality. While social influences focus on social aspects such as job relevance (Venkatesh et al., 2007).

### 2.3.1 The evolution of TAM

The core of TAM is still the causal relationship between perceived ease of use and perceived usefulness towards a new technology or innovation. However, TAM is used often in scientific research, resulting in more expansions and changes to the original model. Karahanna (2006) suggests a multivariate structural model that expands the compatibility of TAM with preferred work style, existing work practices, values, and prior experience. Making the model more rigorous and fitting for the current state of technology adoption.

After the expansions of TAM, finally resulting in TAM2, a broader and more rigorous model was developed: the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT is a culmination of extensive research in the technology adoption field of research. (Venkatesh et al., 2007; Van Oorschot et al., 2018).

UTAUT did not only originate from TAM, but the authors have also developed UTAUT based on seven other prominent information technology acceptance models, namely, the Motivational Model, the Theory of Reasoned Action, the Theory of Planned Behavior, a combined model of TAM and Planned Behavior, the Model of PC Utilization, the Innovation Diffusion Theory, and the Social Cognitive Theory. These models have in common that they all focus on predicting the innovation adoption and use. For all the models, the emphasis is on the behavioral intention as a central construct (Venkatesh et al., 2003).

UTAUT has four key constructs as determinants of user acceptance and usage behavior of technology. The first one is the performance expectancy; performance expectancy is rather like the perceived usefulness of TAM, as it is the degree to which an individual is convinced that the new technology will give him an advantage in job performance. The second one is the effort expectancy, related to the ease of use from TAM. It explains the degree to which an individual thinks the technology will be easy and without effort to use. The third one is the social influence; it is about an individual’s perception of how other important peers believe you should use the new technology. Those opinions can influence the technology use behavior. The fourth and last one is the facilitating conditions. This factor is about the belief of an individual about how the organization and infrastructure are available to serve and complement the new technology. This also includes the access to resources for the technology (Venkatesh et al., 2003).

Besides the four key constructs, the authors of UTAUT also developed four moderators between the key constructs and the behavioral intention and use behavior. Those are the gender, age, experience, and voluntariness of use of the individual responsible for the new technology (Venkatesh et al., 2003). In 2012 Venkatesh (2012) extended the UTAUT and created UTAUT2 with a focus on consumer technology context. The framework was upgraded with three new constructs: hedonic motivation, habit, and price value. Also, the moderator voluntariness was dropped.

Nowadays the original UTAUT model has over 16,000 citations on Web of Science. TAM and UTAUT have opened the doors for a lot of research on innovation adoption. Blut (2022) has made a meta-analysis synthesizing research on UTAUT. To assess the inclusion of important variables and the robustness of the model. Blut has incorporated extra constructs such as personal innovativeness and cost of technology. Also, extra moderators were added, like technology type and national culture. With the revised UTAUT model, the model has not yet reached its limitations and is still relevant for future research for even broader applications with better robustness (Blut et al., 2022).

## 2.4 A review of the innovation adoption literature

Over the past years, researchers have uncovered several types of innovation that can be adopted for different reasons. Each innovation has its own type of adoption process and effect on an organization. This section will be about the different existing adoption processes. Van Oorschot, Hofman and Halman (2018) conducted an extensive literature review about all these different innovation adoptions and constructed five clusters bibliographically coupled to each other. These clusters show the current state of literature on innovation adoption and will be discussed in this section. Among other things, the first cluster uses TAM theory, and the fifth cluster studies the agricultural innovations.

### 2.4.1 Cluster one, drivers and impediments of information innovation adoption

Cluster one, drivers and impediments of information technology (IT) adoption, focuses predominantly on information technology adoption, IT. For example, supply chain management and e-commerce. IT is an important driver for innovation, with effects on the whole organization. Two streams can be recognized in the IT adoption: one stream explores individual intentions for IT innovation acceptance, while the second delves into organizational-level acceptance (Van Oorschot et al., 2018).

Most articles in the first cluster consider the impediments and drivers of adoption that are associated with the distinct stages of adoption. One of them is the effect of the size of an organization influencing the subsequent stages of IT innovation adoption (Van Oorschot et al., 2018). Patterson (2003) highlighted in his research the effects of size and environment on IT adoption. TAM is also present in the articles from cluster one, together with the Theory of Planned Behavior and Theory of Reasoned Action. TAM was used to research the adoption of IT in organizations and for individuals.

### 2.4.2 Cluster two, the adoption of technological standards

Cluster two is about the adoption of new technological standards for products and processes. These standards must be integrated into the organization's process and can have a positive, but also negative, influence on those processes. To increase the likelihood of a more successful implementation of new technological standards, an organization can adjust its strategy and make complementary organizational changes (Colombo et al., 2013).

### 2.4.3 Cluster three, organizational rationales associated with innovation adoption

Cluster three is called 'organizational rationales associated with innovation adoption.' This cluster examines how organizations adopt management systems like lean management with IT innovations (Van Oorschot et al., 2018). Management innovations can be intangible and difficult to realize. Measuring the gained results is also complex due to the intangible nature of management innovations. Lin (2016) has researched this and developed a framework containing four dynamic capabilities that measure the innovations at different stages of the process. However, when management innovations are implemented successfully, firm performance and productivity growth will increase (Mol & Birkinshaw, 2009).

### 2.4.4 Cluster four, modelling the diffusion process

Cluster four is called modeling the diffusion process. It is about using models to predict and understand how innovations spread among people and organizations. A common model to analyze this is the Bass model (Kim & Hong, 2015). The Bass model is a mathematical model used to understand the diffusion of new innovations and products. The model is simplistic and effective in analyzing the diffusion dynamics. A diffusion process is influenced by two factors: the internal and external factors. The internal factors come from communication with (potential) adopters. While the external factors arise from commercials and pricing policies (Kim & Hong, 2015).

### 2.4.5 Cluster five, adoption of agricultural innovations

Cluster five analyzes the environmental considerations and economic impact of adopting agricultural innovations. This is researched with a focus on environmentally friendly innovations in agriculture, but also the impact biotechnology has on the environment and economic performance of the farm. Factors such as price and personal perceptions are discussed (Van Oorschot et al., 2018).

This section has outlined the state of the art on innovation adoption and is structured around five bibliographically coupled clusters (Van Oorschot et al., 2018). These clusters capture the multifaceted character of innovation adoption.

## 2.5 Possible determinants influencing innovation adoption

After talking about the innovation itself, the adoption process, and types of innovation adoption. The following section will dive into more determinants that have an influence on the innovation adoption process. To start, the types of determinants will be explained. After that, the framework by Frambach and Schilleweart (2002) will be explained; this framework gives an extensive overview of all determinants that can have an influence on the innovation adoption. In the third section, a list of determinants relevant for this study will be given. Due to resource and time constraints, this study does not allow every determinant from Frambach to be used in the model. The third section will therefore also explain how the determinants relevant for this study are selected.

### 2.5.1 Three categories of innovation adoption determinants

In his book, Damanpour (1998) classified three broad categories for the innovation adoption determinants. Namely, the individual, organizational, and environmental factors. However, the individual determinants were found to be most significant for predicting innovation adoption. It shows the important role the individual has in adopting innovations. Even in a pro-innovation climate organization, the individual has the critical role. The dairy farmer studied in this research is mostly an individual owner and worker on his own farm.

### 2.5.2 Framework by Frambach and Schilleweart

Currently, there are many more determinants under research that could affect the innovation adoption of an organization or individual. So, in the following section, the framework from Frambach and Schilleweart (2002) will be presented. This framework gives an overview of all possible determinants influencing innovation adoption. Frambach and Schillewaert (2002) constructed two frameworks that integrate various determinants for innovation adoption. One framework is developed for the organizational level of adoption, while the other framework focuses on the individual level of adoption. The authors tried their best to make both frameworks as comprehensive as possible. Therefore, the frameworks incorporate both indirect and direct effects of factors influencing the innovation adoption. Determinants of organizational-level adoption are, but are not limited to, supplier marketing efforts, social networks, environmental influences, and perceived innovation characteristics; see Figure 2 for a more detailed look at the organizational-level framework.

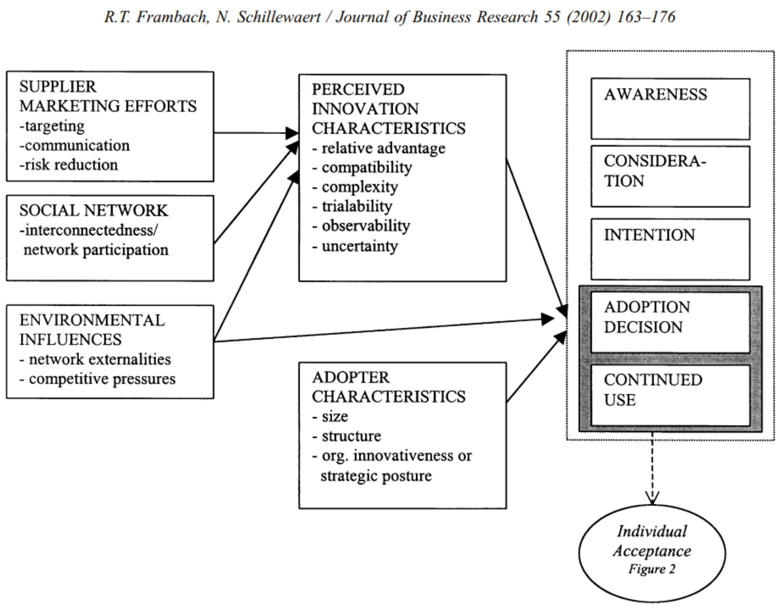


*Figure 2, organizational level framework of innovation adoption (Frambach & Schillewaert, 2002).*

The framework continues into the individual level of innovation acceptance within an organization. The authors made the distinction between organizational facilitators like training and support as determinants and personal characteristics like demographics and experience. Network externalities have a direct effect on the individual's acceptance (Frambach & Schillewaert, 2002), see figure 3 for a more detailed look.

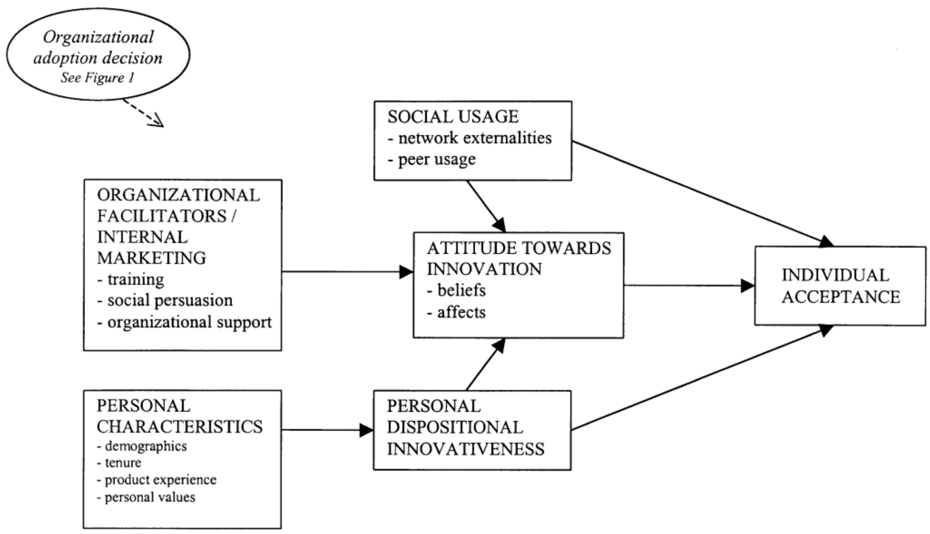


*Figure 3, individual-level framework of innovation adoption (Frambach & Schillewaert, 2002).*

## 2.6 Determinants used for this study

Due to time and resource constraints, not all determinants can be tested for their influence on the dairy farmers innovation adoption. Besides, based on previous research on innovation adoption in the agri-sector, not all determinants will be equally influential in the decision-making process of the farmer (Beza et al., 2018; Xie & Huang, 2021). As the research stream for determinants has grown significantly, only the most influential determinants will be discussed. These are selected based on previous research and the reporter's own knowledge about the agri-sector/dairy farmers. The following determinants are selected:

- **Rational**, individual determinants
- **Economic**, organizational determinants
- **Size**, organizational determinants
- **Supplier**, environmental determinants
- **Environmental**, environmental determinants
- **Regulations**, environmental determinants
- **Sustainability**, environmental determinants
- More yet unknown determinants?

These determinants will be explained in the following subsections. It is, however, likely that there could be more determinants influencing the innovation adoption of a dairy farmer. So, for this exploratory research, there will be room for more possible determinants that can originate from the data gathering.

### 2.6.1 Rational determinants

Daniel (2012) analyzed that not only economic factors like cost and revenue influence the decision-making process for innovation adoption, but also individual and organizational rationales. This refers to the underlying motivations or reasons to choose an innovation. The rationales discussed by Daniel are psychodynamic, political, and cultural. The psychodynamic view refers to a person adopting innovations out of anxiety, wanting a sense of control out of it. Emotional decisions serve the personal need instead of the organizational need. Political rationales also serve the individual need, but with a purpose to gain more power or achieve career advancements. With both psychodynamic and political reasoning, the innovation stops when the person responsible for the innovation leaves.

Patterson (2003) also researched the effect of uncertainty on innovation adoption. Firms that face more uncertainty in their environment have an increased likelihood of adopting new information technologies. The need to adapt to a changing environment with the right innovations is more important for these firms.

Besides the organizational rationales, the training level of an individual is a strong predictor for innovation adoption. When an individual had a high training level, by following courses about the innovation and having access to professional guidance, the likelihood of adopting an innovation increased. The education level follows the training level as the second strongest predictor for innovation adoption (Talukder & Quazi, 2011).

### 2.6.2 Economic determinants

For a technology or innovation to be considered and eventually accepted by an individual or organization, the perceived benefits and economic revenue gained from the technology must at least exceed that of alternatives, perhaps lower novelty options (Frambach & Schillewaert, 2002). The perceived benefits and economic revenue of a technology play an important role in the decision-making process to adopt. Western Europe and Japan have, on average, a lower return on investment requirement for new technologies in comparison to the United States. Therefore, diffusion of innovation is faster in Japan and Western Europe (Mansfield, 1993).

### 2.6.3 Size determinants

Size is shown to be positively correlated with innovation adoption, meaning that larger organizations are more likely to adopt new technologies (Patterson et al., 2003). Smaller organizations face difficulties due to a lack of resources or technical knowledge. The larger organizations can allocate relatively more resources to a successful IT innovation adoption. However, research suggests that smaller organizations are indeed better able to adopt new technologies, as they are more agile and are able to adjust the organizational structure faster towards the new organization (Holbek J, 1973).

Damanpour (1992) suggests that there is a positive correlation between size and innovation adoption. Larger organizations have skilled workers and more diverse resources to invest and contribute to innovation capabilities. This is in line with the work of Patterson (2003). Although this effect is bigger in manufacturing and profit-making organizations, in contrast to non-profit and service organizations. Besides the type of organization, there are two more moderators at work, according to Damanpour. The measurement method of the size and the implementation vs. initiation of the innovation. The effect of size is more strongly related to the implementation. In his later work he acknowledged the complexity of innovation, it is not predictable by just one or a few variables. It includes a broader model including, but not limited to, the type of industrial sector and environmental uncertainty a firm faces (Damanpour, 1998).

Wagner and Hansen (2005) researched the innovation adoption differences in small vs. large firms in the wood products industry. This industry faces the same environmental challenges and innovation needs as the farming industry. The study found no significant differences between large and small firms about the innovation adoption. Although large firms lead in process innovation and small firms in product and business system innovation.

Innovation adoption research measures size in number of employees, capacity, financial volume, or volume. None of them consider the unique setting of a dairy farmer, where the number of employees is mostly just one and the volume is measured in number of cows or output per cow. It can be measured in financial volume, but a dairy farm depends on the constantly shifting milk price and possible side activities, so a financial volume measurement can be difficult. The study by Wagner and Hansen (2005) acknowledges environmental challenges and innovations needed in the wood products industry, similar to the farming industry.

### 2.6.4 Supplier determinants

The supplier of the new technology or innovation plays an important role in the adoption process of the individual or organization. With the right tools and communication, a supplier can achieve a better adoption rate. The communication, targeting of the innovation, and activities the supplier can undertake to reduce the perceived risks for the potential customer are all important factors for adoption (Hultink et al., 1997).

As for targeting, a supplier can specify its marketing and communications to potential customers who are heavy users of the alternative technology. They can be more receptive to adopting the new technology compared to others. Targeting efforts are important to consider for an organization (Gauvin & Sinha, 1993).

### 2.6.5 Environmental determinants

Organizations must always deal with their environment. How the environment interacts with the organization influences how an organization deals with its innovation adoption process. Environmental factors are outside influences that the organization cannot control. They can be political, social, economic, or cultural in nature. Depending on the location of the organization, these external factors can have a positive or negative influence on the innovation adoption process (Damanpour & Schneider, 2006).

Four factors were identified as influential towards the innovation adoption. Urbanization, community wealth, population growth, and unemployment rate. When an organization is in an urban area, it faces more diverse and complex environments, and combined with the availability of resources and the density of information linkages, this has a positive influence on innovation adoption. Higher community wealth and population growth also stimulate innovation. However, when there is a high unemployment rate, the innovation adoption will be negatively affected. It shows that a good economy in the right location can really stimulate innovation adoption (Damanpour & Schneider, 2006).

Competitors are an important part of the organization’s environment. In the SME market, competitive pressure forces organizations to continuously change and innovate to maintain a competitive advantage. In a highly competitive market, this is even more evident. In both the initiation and implementation phases, the innovation is adopted faster, thus enhancing the competitiveness (Hsiu Fen Lin, 2014).

### 2.6.6 Regulatory Determinants

Regulatory constraints are those that are implemented by governments and to which firms must adhere. Environmental regulation involves rules and requirements for individuals, organizations, or farms to rehabilitate damaged ecosystems or prevent or mitigate environmental harm completely (Han & Chen, 2021).

Governments in Europe want to downsize farming as it has a negative impact on the environment. Too much farming can cause erosion and loss of organic matter in the soil, as well as an increase in nitrogen in the soil and air (Xie & Huang, 2021). The use of pesticides also needs to be downsized in order to save and maintain biodiversity (Skevas et al., 2014).

The European Commission (EC) aims to enhance sustainable farming practices through the Farm-to-Fork Strategy and the Green Deal. The main goal is to achieve an environmental and climate impact reduction. The use of pesticides as well as antimicrobials must be reduced by 50% before 2030. The EC also aims to increase organic farming to 25% of the total farming in the EU before 2030 (European Union, 2020). In this light, the importance for a dairy farmer to invest in new environmentally friendly technologies to achieve sustainable growth is evident.

For a farmer to adopt pro-environmental behavior refers to actions that protect the ecological environment (Xie & Huang, 2021). Farmers adoption of pro-environmental investments is influenced by the regulations imposed by the government, but also by (mostly financial) incentives from the government.

Successful implementations are further enriched with having the right policy instruments in place. Governmental policymakers can design instruments that stimulate investments in environmentally friendly innovations. Jaffe (2005) has shown in his research the positive effect that those instruments have on innovation. adoption, environmentally friendly innovations are not always economically the best investments, but by financially incentivizing the investments, organizations are more willing to invest. Besides incentives, a tax reduction on the environmentally friendly investment can also be a stimulus from the government to increase sustainable business growth (Requate, 2005).

### 2.6.7 Sustainability determinants

Eco-innovations are different compared to conventional innovations as they rely more on external factors and influences. Besides the regular drivers to adopt innovations, eco-innovations are also driven by the urge of individuals to help the environment and by governmental regulations stimulating the organization to adopt eco-innovations (Frigon et al., 2020).

The research by Han (2021) focused specifically on eco-innovation adoption for SMEs, innovations that have a positive impact on the environment while helping the organization. In line with Demanpour and Lin, the competitiveness and location of the organization have a positive influence on the eco-innovation adoption.

What is novel about this research is the effect of managerial environmental concerns, that is, the degree of concern the management has towards the environment and the environmental innovation strategy (Han & Chen, 2021). These concerns show how fast a firm is willing to take action against environmental challenges. When managers have a heightened sense of environmental concerns, the chance of adopting eco-innovation is also higher. When the management supports eco-innovation, the overall adoption process will improve (Sumrin et al., 2021).

A study from 2006 was conducted about the determinants to adopt no-till farming, an eco-innovation about soil-conserving techniques. These techniques have a positive impact on the farm and environment. As mentioned by the TAM model, farmers adoption of no-till increased when they were advised and voluntarily acquired more information about the technique, showing the commitment the farmer has for adopting eco-innovation (D'Emden et al., 2006). When advised personally about eco-innovation and with a voluntary adoption, the chances of actually adopting eco-innovation increase (Marshall, 2009). However, no research was conducted about the size of the farm or the potential governmental regulations about soil farming and the use of pesticides.

### 2.6.8 Conclusion on determinants

Table 1 gives an overview of the determinant selected for this study. However, this study uses an exploratory approach to find additional, context-specific determinants other than the selected ones. The unique setting of dairy farmers may involve decision-making influences not captured by existing models, arising from sector-specific characteristics or emergent themes in practice. Thus, the literature-based model serves as a foundation, but it is anticipated that empirical fieldwork will extend it by integrating novel insights from dairy farming practice, ultimately resulting in a more comprehensive understanding of innovation adoption determinants among dairy farmers.

| **Category** | **Determinants** | **Category** |
|---|---|---|
| Rational | Organizational rationales | Individual |
| Economic | Perceived benefits and economic revenue | Organizational |
| Size | Correlates with innovation adoption | Organizational |
| Supplier | Communication and targeting by suppliers | Environmental |
| Environmental | Urbanization and community wealth | Environmental |
| Regulations | Regulatory constraints and requirements | Environmental |
| Sustainability | Environmental concerns | Environmental |
| More yet unknown? | | |

*Table 1, determinants used in this research.*

# Chapter 3, Model development

The methodology chapter is split into chapter 3 and chapter 4. Chapter 3 explains the model development for this research. Chapter 4 explains the fsQCA analysis in detail. Chapter 3, model development, includes the data calibration and condition reduction as well. These are the first steps for fsQCA analysis and are already presented in this chapter, as these steps lead to the final model used for fsQCA analysis.

## 3.1 Research Design and Approach

This methodology section explains the research approach used to explore determinants influencing innovation adoption among dairy farmers, specifically focusing on RMS. RMS is an example of an advanced innovation in dairy farming because of its high technological impact on farm operations. The central research question for this study is, "What is the combination of determinants that influence dairy farmers' decisions to adopt new technologies, and how do these determinants motivate or hinder the adoption process?"

This research follows an exploratory qualitative design. This is chosen because of its ability to identify and understand the complex process of determinants influencing the innovation adoption. Multiple determinants all can have different influences on the outcome of an adoption process. This qualitative exploratory approach can give deep insights into the participants reasoning for innovation adoption. This type of research also gives the ability to explore beyond the existing determinants and possibly discover new innovation adoption determinants unique to this setting (Creswell & Poth, 2016).

For data collection, semi-structured interviews were selected to gain a broad view of the farmer and gather as much information as possible regarding their innovation adoption behaviors and motivations. Interviews provided flexibility for follow-up questions and allowed for a deep dive of participants' views on innovation adoption, fitting the exploratory objectives of this research (Creswell & Poth, 2016). The interviews, organized and financed by Kramp B.V., involved a sample of 18 dairy farmers from diverse geographical contexts (Netherlands, France, Poland, and Germany) to ensure broad representation of the farmers. The interview was about farm history, current technological status, attitudes toward innovations, and decision-making criteria for innovation adoption (see Appendix A for the full interview guide).

Interview data was systematically analyzed through qualitative coding (Williams & Moser, 2019). To start, the predefined determinants from the literature were used for the analysis, followed by inductive coding to look for the possibility of more, yet unknown, determinants.

## 3.2 Sample and data collection

Sampling for this study was conducted using a non-probability, purposive sampling method with an emphasis on diverse case selection to maximize variation, particularly across farm size, technological state, and geographic contexts (Seawright & Gerring, 2008). Eighteen dairy farmers were selected from four European dairy-producing countries: the Netherlands, Germany, Poland, and France. These countries were deliberately chosen due to their importance in the European dairy industry, varied innovation adoption levels, size, and the availability of dairy farms within Kramp B.V.'s professional network, facilitating practical accessibility for field research.

While the use of Kramp B.V.'s existing network introduced practical limitations regarding biases in the sample selection, as every farmer is somewhat affiliated with Kramp B.V., By explicitly seeking out farms with considerable variation in size, technological state, and location, the risk of bias introduced through network limitations was minimized. Although it cannot be minimized to zero, the researchers own network was also used for selecting dairy farms to further help the sampling process.

The sample ranged from a small farm in Poland with 75 dairy cows to an exceptionally large Polish operation with over 1,800 cows and approximately 7,000 hectares of land, ensuring broad operational representation. In Table 2 an overview of all interviewed dairy farms is given; included in the table are also the characteristics per farm.

| | | Name | Orgin | Date | Size | | | | | | Milk installation | | | | Feeding and Manure | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ownership | Employees | Dairy cows | Other | Total ha | Owned ha | Type | Size | Brand | Year | Feeding | Manure handling |
| France | 1 | Jean Luc | Poitiers region | 20-3-2024 | 4 co-owners | 3 | 160 | 1000 | 350 | 290 | Carousel and robot | Ca. 66, robots 3 | Ca. GEA, robot Lely | 2018 | Self driving | Chain |
| | 2 | Tom | Poitiers region | 20-3-2024 | 3 co-owners | 0 | 0 | 230 | 220 | 40 | side by side | 2x20 | Westfalia | 2020 | tractor telehandler | non |
| | 3 | Luvic | Poitiers region | 19-3-2024 | family farm | 0 | 0 | 140 | 35 | 35 | sidy by side | 2x15 | Westfalia | 1984 | tractor telehandler | non |
| | 4 | Mark | Poitiers region | 20-3-2024 | family farm | 1 | 120 | | 220 | 160 | Robot | 2 (3 next year) | Lely | 2016 | tractor telehandler | 2 Lely collectors |
| | 5 | Adrian | Poitiers region | 19-3-2024 | familiy farm | 0 | 90 | | 197 | 120 | Robot | 1 | Lely | 2012 | tractor telehandler | chain |
| | 6 | Benjamin | Poitiers region | 19-3-2024 | 4 co-owners | 0 | 90 | | 450 | 225 | Robot | 1 | Lely | 2023 | tractor telehandler | chain |
| Germany | 7 | Micheal | Haldern region | 14-3-2024 | Family farm | 1 | 200 | | 140 | 35 | Robot | 3 | Lely | 2021 | Self driving | Lely robot |
| | 8 | Carsten | Haldern region | 14-3-2024 | Family farm | 1 | 120 | 100 | 150 | 25 | Side by side | 2x7 | Marus, now Delaval | 1994 | Tractor telehandler | Roosters |
| | 9 | Matias | Haldern region | 11-3-2024 | Family farm | 3 | 240 | | 150 | 45 | Robot | 5 | Lely | 2010 | Tractor telehandler | Robot |
| | 10 | Markus | Haldern region | 11-3-2024 | Family farm | 1 | 300 | | 150 | 10 | Robot | 4 | Delaval | 2009 | Tractor telehandler | Robot Lely |
| | 11 | Andreas | Haldern region | 11-3-2024 | 3 co-owners | 0 | 240 | | 140 | 40 | Side by side | 2x8 | GEA | 1999 | Tractor telehandler | |
| Poland | 12 | Top Farms | Glubscyce-Sady | 5-3-2024 | Chinese owners | 200 | 1800 | | 7000 | ??? | Side by side, future robots | 2x20 and 2x16 | Delaval | | Selfdriving RMH | Drying installation |
| | 13 | Szum | Szum region | 5-3-2024 | Family farm | 1 | 260 | 400 | 180 | 80 | Side by side, future 6 robots | 2x20 | Westfalia (GEA) | 2000 | Tractor telehandler | Robot |
| | 14 | Mateosz | Patrzykow region | 6-3-2024 | Family farm | 0 | 75 | | 120 | 45 | Robot | 1 | Lely | 2024 | T. telehandler, lely pusher | Roosters |
| | 15 | Mizerny | Czarków region | 6-3-2024 | Family farm | 4 | 325 | | 275 | 225 | Sidy by side | 2x14 | Delaval | 2017 | Self driving | Robot |
| The Netherlands | 16 | Maurits | Barneveld | 29-2-2024 | Family farm | 0 | 175 | | 75 | 35 | Sidy by Side, Swing over | 2x11 | Dairymaster | 2008 | Sourced out to self driver | Robot |
| | 17 | Jakko | Den Bosch region | 29-2-2024 | Family farm | 1 | 250 | | 160 | 120 | Robot | 5 | Lely | 2010 | Self driver | Seperation plant |
| | 18 | Emma | Saasveld | 24-2-2024 | Family farm | 0 | 120 | | 60 | 60 | Sidy by side, Swing over | | Boumatic | | Tractor telehandler | robot |

*Table 2, Sampling Overview.*

In France, selected farms near the Poitiers region varied significantly in size and technological implementation, from manual milking installations to advanced RMS. German farms, located near the Dutch border, provided additional insights, particularly given their generally larger scale and sophisticated technological setups. The inclusion of prominent individuals, such as a former CEO of Arla in Germany and pioneering technology adopters in the Netherlands, further enriched the dataset. These varied perspectives were critical in providing balanced and robust insights, ensuring that the results reflect a broad spectrum of operational contexts despite any constraints created by reliance on an existing professional network.

The data for this study was collected by visiting every farmer in person. During each visit, a semi-structured interview was conducted; the interviews took about 40 minutes each. This interview approach was selected because it offers the flexibility to explore individual experiences in depth while still allowing for comparison across different cases (Creswell & Poth, 2016). The interview questions were developed with existing literature on innovation and innovation adoption, providing a solid theoretical basis and contributing to the validity of the research (Agarwal & Prasad, 1998; Aubert et al., 2012).

Throughout the research process, ethical considerations were carefully taken into account. Participation was voluntary, confidentiality was ensured, and all interviews were recorded with the explicit consent of the participants. Each interview was transcribed verbatim for accurate analysis. Following the interviews, a guided tour of the farm was conducted. This allowed for validation of the statements made during the interviews and provided a direct view of the technological status of the farm in practice.

## 3.3 Measures and Operationalization

To come up with a final model for fsQCA analysis, the data calibration and condition reduction have to be done. This will bring the conditions down to a workable amount and prepare the data for the fsQCA analysis, which will be explained in chapter 4.

Data calibration is an important step in fsQCA, transforming qualitative interview data into fuzzy sets that explain the membership scores of the interviewees (Schneider C. Q. & Wagemann C., 2012). In this study, fuzzy-set calibration was chosen to represent the varied responses on the topic of innovation adoption among dairy farmers. Each determinant's qualitative responses were calibrated onto a scale ranging from 0 to 0.05 (non-membership), through 0.45 to 0.555 (crossover point), to 0.95 to 1 (full membership) (Ragin, 2008).

To start, all interviews were analyzed through thematic analysis after anonymization (Thomas & Harden, 2008). Initial qualitative coding was applied only to determinants derived from the literature to structure the analysis around known determinants, staying close to the scope of this research (Gioia et al., 2013). This process identified broad ideas and patterns, which were subsequently grouped by similarity. Then, per construct, a score was given of how and how often it was mentioned by the farmer. So, a farmer talking enthusiastically about visiting fairs and exploring new ideas for their farm scored higher on innovation attitude than someone who talked about not trusting an RMS to do his/her work for him. This meant determinants were coded based on how frequently and passionately each farmer mentioned specific factors during the interviews. In more detail, the final score for each determinant was based on frequency and intensity. With frequency weighing heavier. For example, a farmer talking about testing a new feeding robot and giving three examples of how this feeding robot could help the farm or how it operates scores a 0.95 on innovation attitude, as it is both enthusiastic and mentionedmultiple times. If a farmer said he likes the traditional way of farming without saying he distrusts machines to do his job for him, he scores lower on innovation attitude, 0.3, but not the lowest, as there are no repeated negative examples given. After the summarizing and scoring were complete, the results were shared with one farmer close to the researchers home. Here it was checked for completeness and correctness.

The size of the farm was measured in number of cows and hectares of land. This was the only quantitative dataset; it was compared to its country-specific population average and scored comparatively. This was to ensure a clear dataset; the sample was too small to do a within-sample analysis, and the differences in agricultural land prices are too high for a true comparison.

The age of the RMS was also measured by asking the interviewee in what year the RMS was installed or if it was already the second or third RMS used on the farm. Farmers with the oldest RMS scored highest, as they were earlier adopters compared to relatively young installations being installed for the first time on the farm.

The analysis was based on the determinants given by literature, providing an initial theoretical foundation for analysis. However, as for the explorative nature of this research, more possible determinants could have an influence on the innovation adoption of an RMS. An inductive analysis of the interview data and the researchers own experiences during the farm visits resulted in the emergence of two new context-specific determinants. Namely, “electronic health management” and "animal welfare.” These emerged repeatedly as influential factors, consistently mentioned by multiple farmers. Electronic health management is the monitoring and improving of the animal’s health with innovative new systems, the same as humans wear electronic sport watches with heartbeat and activity sensors. A cow can wear a collar with sensors, monitoring their health and behavior 24/7. Or diagnostic sensors measuring milk specifications, reflecting these results back to the cows health (*Lely | Innovatieve Oplossingen Voor de Landbouw*, n.d.). Animal welfare is about a more general focus on welfare. Animal welfare is an important part of the farm’s operations. Some farmers talked a lot about their cows and how they try to treat them as best they could. While other farmers barely mention animal welfare. This is reflected in the state of the stables and cows; when treated well, the cows look better. This could be seen by the researchers own knowledge about the animals and could be checked during the farm tour.

Given its significance, these newly identified determinants were systematically included and scored alongside established determinants. All determinants recognized and measured from interview responses are summarized in Table 3.

| Farmer | Abbreviation | Scoring | Definition |
|---|---|---|---|
| **1** | Attitude towards innovation | 1 = positive 0 = negative | This determinant gives a score of the overall attitude towards innovation the interviewee gave. This could be anything from following certain online news websites about technological advancements in the Agri-sector or visiting fairs to see the latest stages on innovation. The highest scoring interviewees specifically mention going to fairs and visiting other farmers specifically to inspect newer technologies on their farm, with the purpose of staying up to date and possibly seeing changes for their own farm. The lowest scoring interviewees tended to express a distrust in technology and 'computers' doing the work for them. |
| **2** | Network externalities | 1 = a lot 0 = a little | Scoring is given on this determinant whether or not the interviewee talked a lot about other farmers or neighbouring farmers. Some farmers specifically talked about other farmers and their experiences with certain technologies or RMS, saying they loved or hated it specifically because they heard another farmer talk about it. |
| **3** | Electronic health management | 1 = a lot 0 = a little | Farmers talking about using electronic health systems on their farm, like braces to read biometric information from the cow or feed management systems. This determinant gained the attention because a lot of farmers talked about it. |
| **4** | Animal welfare | 1 = a lot 0 = a little | Whether or not a farmer finds the animal welfare an important part of their farming operations. Farmers have different opinions whether or not the RMS and other technologies are benefiting the animal welfare or not. |
| **5** | Economic | 1 = robot is financially beneficial 0 = not | The interviewee talking about seeing economic benefits or drawbacks about a RMS. Farmers talking a lot about the RMS being expensive scored lower. |
| **6** | Supplier | 1 = being convinced by supplier 0 = does not mention it | If the farmer mentions being convinced by the supplier or not when investing in a RMS. Farmers saying they got visits that helped them in their decision making scored highest |
| **7** | Rational | 1 = robot being a must for farm 0 = does not mention it | Whether or not the farmer sees the RMS as a must for continuing the farming operations or not. For example, in a situation of continuing stagnation in labour where new technologies are the only way for a farm to survive. |
| **9** | Size cows | Fuzzy compared to country population | How many cows the farm has. |
| **10** | Size land | Fuzzy compared to country population | How many hectares of land the farm uses for its operations, both owned and rented. |
| **11** | Side act | 1 = has activities, 0 = no significant side activities | Whether or not the farm has significant other revenue streams, like an on-farm dairy processing plant or large crop-growing activities. |
| **12** | Age adopt | 0 = no robot, 0,5 = first robot, 1 = second or more robot | At what year the RMS was implemented if there is one on the farm and whether it is the first one or a replacement. |
| **13** | Regulations | 1= heavily influenced 0 = not influenced | If the farmer experiences governmental policies influencing its decision making on innovation adoption. Farmers who talk a lot about the government restricting them, and how this influences the farms operations and growing score highest. |
| **14** | Sustainability | 1 = invests for environment 0 = does not invest | If the farmer talks about investing in a RMS out of environmental factors. Saying he has a lot of concerns about the enivronment and wants to actively contribute to a better environment. |
| **15** | RMS | 1= yes, 0=no | Whether or not the farmer has a RMS. |

*Table 3, determinants resulting from interview analysis.*

## 3.4 Condition reduction

The scoring matrix from table 3 had to undergo a condition reduction process, as it is not possible to do an fsQCA analysis with 15 conditions in a sample of 18 (Ragin, 2008). The optimal number of conditions has to result from a structured condition reduction process. To ensure theoretical robustness, analytical traceability, and empirical validity (Schneider C. Q. & Wagemann C., 2012).

First, determinants that lacked sufficient empirical grounding were excluded. For instance, the determinant "rational" was explicitly mentioned by only two farmers and thus lacked the empirical relevance required for inclusion. Similarly, "side activities" was removed due to partial redundancy with "size of the land," as its explanatory effect was already reflected in that construct. Most farmers with side activities had extra land cultivating (outside own farm needs) as a side activity; this fell in line with the size of the land. This step aligns with the recommendation to avoid redundancy and ensure condition distinctiveness in QCA research (Schneider C. Q. & Wagemann C., 2012) .

The determinant 'size from population' was constructed by combining two dimensions of farm scale: the number of dairy cows and the total hectares of land. Each farm's size was normalized against the national average by calculating the standard deviation from the average farm size per country. This allowed for a relative, rather than absolute, measurement of size, accounting for structural differences in land prices and typical farm structures across countries such as the Netherlands, France, Poland, and Germany. A Dutch farmer has on average 14.3 hectares, while a French farmer has on average 58 hectares of land. However, a hectare of land in the Netherlands is more than 10 times the price of that in France. This also means that the land size in the Netherlands could be a limited factor for growing the farm; in contrast, in absolute euros, the farms lie closer to each other.

Determinants with overlap and similar results were also removed. "Economic" was excluded as it was dependent on the structure and size of the farm. Farms scoring high on economics also scored high on size. Both land and herd size contributed equally to the final fuzzy-set score. This method ensured that size reflected the broader economic and operational capacity of the farm staying true to the country of origin of the farm.

The determinant "regional policies" was removed based on its limited perceived influence across cases and the policies differing per country, also to preserve parsimony in the model, following best practices to focus only on conditions with substantial theoretical and empirical support (Ragin, 2008).

To further improve conceptual clarity and remove redundancy, related determinants were merged. The variables "electronic health management" and "animal welfare" were combined into a single determinant labelled "health management," reflecting their interconnected role in farm-level innovation and welfare practices. Likewise, the constructs "supplier" and "network externalities" were combined under "network externalities" due to their shared emphasis on the influence of external actors and peer experiences in shaping adoption behavior, consistent with Rogers' (2008) diffusion of innovation theory.

Additionally, the sample size consists of data from four different countries. However, due to the limited number of cases per country, performing a robust cross-country comparative analysis is not feasible. Consequently, the country-specific context is acknowledged, but the analysis focuses primarily on identifying common determinants influencing innovation adoption among dairy farmers rather than cross-national variations.

This structured reduction process resulted in a final selection of four core determinants: innovation attitude, network externalities, health management, and size of population. These constructs represent a theoretically grounded and empirically informed foundation for the subsequent fsQCA. See table 4 for the final scoring matrix. These attributes were measured by combining the scoring results from different determinants, as explained in the condition reduction subsection.

| ***Farmer*** | ***robot*** | ***At. to inno*** | ***net ext / supplier*** | ***health / welfare*** | ***size cow/land pop.*** |
|---|---|---|---|---|---|
| **1** | 1 | 0 | 0,75 | 1 | 1 |
| **2** | 0 | 0,25 | 1 | 0 | 0,5 |
| **3** | 0 | 0,1 | 1 | 1 | 0,4005 |
| **4** | 0,85 | 0,75 | 0,501 | 0,75 | 1 |
| **5** | 0,9 | 1 | 0,501 | 0,501 | 0,95 |
| **6** | 1 | 0,1 | 0,1 | 0 | 0,95 |
| **7** | 0,8 | 0,75 | 0,501 | 0,501 | 0,745 |
| **8** | 0 | 0,4 | 1 | 1 | 0,7 |
| **9** | 1 | 1 | 0,501 | 0,75 | 0,8 |
| **10** | 1 | 1 | 0 | 0,75 | 0,6 |
| **11** | 0 | 0,501 | 0,75 | 0,75 | 0,795 |
| **12** | 0,2 | 0 | 0 | 0 | 1 |
| **13** | 0,2 | 0,25 | 0,501 | 0,501 | 1 |
| **14** | 0,8 | 0,501 | 0,501 | 0,501 | 0,9 |
| **15** | 0 | 0,501 | 0,75 | 0,75 | 1 |
| **16** | 0 | 0,25 | 0,25 | 0,9 | 0,95 |
| **17** | 1 | 0,501 | 0 | 0 | 1 |
| **18** | 0 | 0 | 0,501 | 0,75 | 0,95 |

*Table 4, scoring matrix for fsQCA.*

## 3.5 The model

In this study, the outcome of interest is the adoption of an RMS. This dependent variable is calibrated as a fuzzy set, ranging from 0 (indicating non-adoption) to 1 (indicating full adoption); the range in between indicates the age of adoption. Several conditions were included as independent variables, namely, the farmer's attitude towards innovation (innovation attitude), supplier influence and network externalities (network externalities), if the farmer was passionate about electronic health management and animal welfare (health management), and the size of the farm measured in number of cows and hectares of land compared to the country average (size from population); see figure 4 for the model.

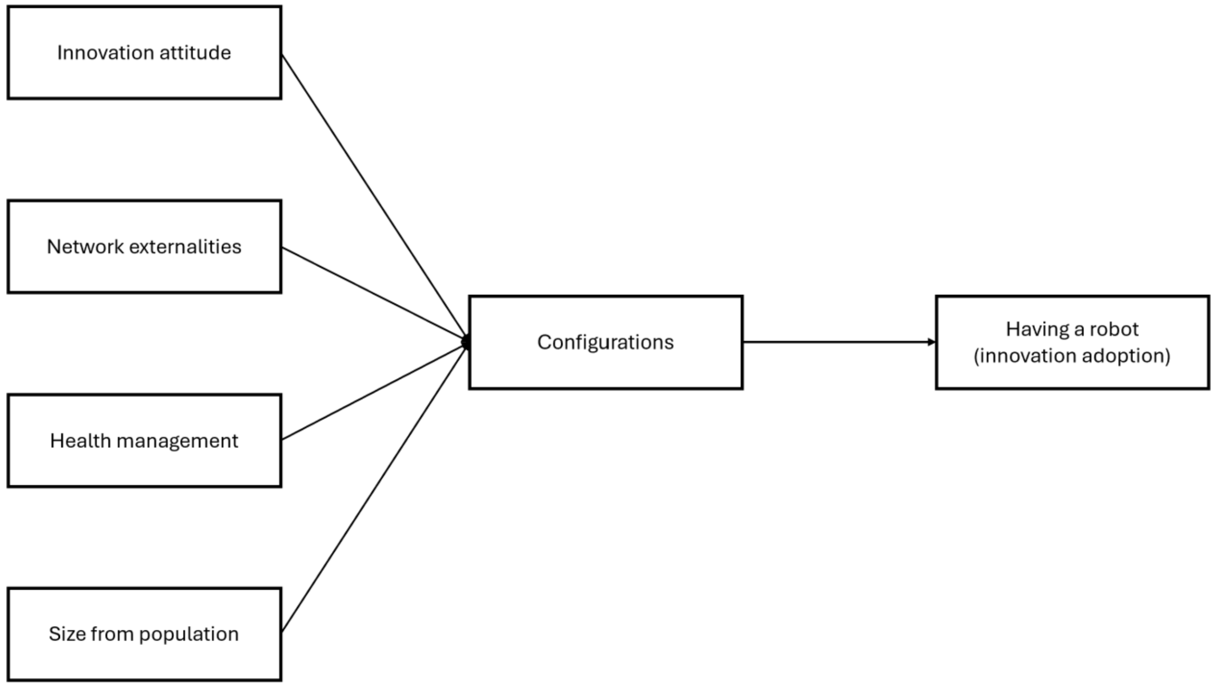


*Figure 4, fsQCA model.*

# Chapter 4, Methodology

To explain the complex relations of all possible determinants (including possible new determinants) and how they influence the innovation adoption process, fuzzy-set Qualitative Comparative Analysis (fsQCA) was employed (Ragin, 2008; Ragin Charles C., 2000). FsQCA is particularly helpful for this research as it accounts for multiple causal pathways and interactions among determinants, allowing for configurational analysis that traditional statistical methods can overlook. This method enables the identification of multiple pathways through which farmers may arrive at the same outcome. It also allows for asymmetrical relationships, where the conditions leading to adoption may differ from those leading to non-adoption. This makes fsQCA suitable for the setting of this research (Creswell & Poth, 2016).

The fsQCA procedure involved calibrating interview-derived determinants into fuzzy sets, constructing a truth table, and identifying consistent configurations associated with innovation adoption outcomes. Conducted using specialized software, this analysis generated clear sets of configurations. These results help with understanding the research of innovation adoption among dairy farmers, contributing substantially to strategic frameworks guiding agricultural innovation decisions.

The analysis using fuzzy-set Qualitative Comparative Analysis (fsQCA) followed a structured, multi-step procedure. For the analysis, the fsQCA software from Compass.org was used (*COMPASSS*, 2025). First, the calibrated data was entered into the fsQCA software tool. Based on this input, a truth table was constructed, showing all possible combinations of conditions and their associated outcomes. In the following subsection, the procedures are explained.

## 4.1 Truth table construction and analysis

To analyze the determinants of RMS adoption, a truth table was constructed using fsQCA software, applying the Quine-McCluskey algorithm. This algorithm enables a systematic exploration of all possible combinations of conditions that could lead to the adoption of innovation. By setting a consistency threshold at 0.80, the analysis focuses on those configurations that reliably explain the outcome (Schneider C. Q. & Wagemann C., 2012).

The analysis was done with a frequency threshold set at 1. This means that all configurations observed at least once were retained for consideration. Because of the relatively small sample size, every case member is included (Schneider, C. Q., & Wagemann, C., 2012). Cases 10 and 17 had a high membership score and were therefore also important to include in the analysis and to strengthen the practical relevance.

## 4.2 Logical minimization

Following this step, logical minimization was performed, generating three types of solutions: complex, intermediate, and parsimonious. The complex solution has no logical remainders produced from the truth table analysis. So, every causal term remains visible, giving a rich but lengthy result. The parsimonious solution strips away non-essential terms, and the output is the shortest and most abstract. The intermediate solution is there to combine the best of two. Being more concise than the complex solution and more empirically grounded than the parsimonious one. Comparing these three solutions on their coverage and consistency identifies the core versus peripheral conditions. Logical minimization distinguished between core conditions, which are essential to the outcome, and peripheral conditions, which play a supporting role (Ragin, 2008).

## 4.3 Core and Peripheral Conditions

In fsQCA, conditions are identified through the process of logical minimization. There are two types of conditions, core or peripheral. Core conditions are essential across multiple configurations; they have a consistently strong and robust relationship with the outcome in this case, innovation adoption. Peripheral conditions have a complementary but less central role; the evidence, or explanatory power, is less strong for a peripheral condition. Making a clear distinction between core and peripheral conditions is important; it shows the different characteristics a determinant has on the case. Core conditions are shown as large circles and are present in both the intermediate and parsimonious solutions, showing their importance, while peripheral conditions appear only in the intermediate solution, shown as smaller circles. A condition can also play an absent role, meaning there is no strong evidence or effect in the configuration. This is marked by an empty space (Ragin, 2008).

## 4.4 Necessity analysis

The analysis also included an evaluation of necessity. Necessary conditions refer to those that must be present for the outcome to occur; it is a 'gateway.' If the condition is missing, the desired results become impossible, no matter what other factors are combined. It is important to analyze and find necessary conditions, as they play a key role in explaining the innovation adoption (Greckhamer et al., 2018). The outcome of the necessity analysis is shown in the tables in chapter 5, findings.

## 4.5 Supplemental and robustness analysis

Supplemental analysis is just like a normal regression analysis necessary to check and validate the results from the fsQCA analysis. There are several analyses and robustness checks available for rigorous results testing. In this research, a robustness check by changing the threshold value and subgroup analysis is undertaken to validate the results. Also, an analysis of the reversed desired outcome is made by not having an RMS as an outcome. In fsQCA, the configurations that produce a certain outcome rarely mirror those that prevent it. So the 'negative' of a configuration does not lead to the same 'negative' outcome. To check this, an analysis of reversed desired outcome is done (Greckhamer et al., 2018).

Threshold robustness tests were conducted by changing the consistency threshold in the fsQCA analysis, testing the stability and sensitivity of the identified configurations. The threshold is set at 0.80, but in the robustness check it is changed to 0.70 and 0.90. This process strengthens the reliability and validity of the results, as configurations that stay the same across multiple thresholds have a better explanatory power (Greckhamer et al., 2018; Carsten Q. Schneider & Claudius Wagemann, 2012).

In addition, subgroup analysis was carried out by applying fsQCA separately to a distinct subset of the data. In this research it was done by taking all the cases from France; it has the most cases from one country and is homogeneous in case characteristics. This step allowed for a closer examination of the stability of the results within a single-country context. This step is used for testing if identified configurations are generalizable versus context-specific (Greckhamer et al., 2018; Carsten Q. Schneider & Claudius Wagemann, 2012).

## 4.6 Descriptive statistics

Descriptive statistics for the model are presented in Table 5, including mean values, standard deviations, and the range of scores. These statistics show variation in the sample. For example, size had the highest average score (mean = 0.85), while attitude towards innovation showed the lowest average (mean = 0.44). The standard deviations across variables reflect a high degree of heterogeneity among the respondents, indicating differing perceptions and priorities among dairy farmers.

This diversity shows that the use of fsQCA is suitable, as the method is specifically designed to deal with such variation by identifying different configurations of conditions that explain either the presence or absence of innovation adoption.

| Variable | Mean | Std. Dev. | Minimum | Maximum | N Cases | Missing |
|---|---|---|---|---|---|---|
| **robot** | 0,4861111 | 0,4496312 | 0 | 1 | 18 | 0 |
| **innovation attitude** | 0,4363333 | 0,339079 | 0 | 1 | 18 | 0 |
| **network externalities** | 0,5059444 | 0,3256934 | 0 | 1 | 18 | 0 |
| **health management** | 0,578 | 0,3476502 | 0 | 1 | 18 | 0 |
| **size from population** | 0,8466944 | 0,1830913 | 0,4005 | 1 | 18 | 0 |

*Table 5, descriptive statistics for fsQCA analysis.*

# Chapter 5, Findings

This chapter outlines the main findings from the fsQCA analysis, focusing on the configurations explaining dairy farmers' decisions to adopt or not adopt RMS, meaning innovation adoption. The results are organized into detailed configurational pathways that account for both adoption and non-adoption outcomes, backed up by interview quotes and linkages to the actual farms from the interviewees. Before that, the analysis of the necessary conditions is given, and supplemental analysis results are explained, ending with the chapter's conclusion.

## 5.1 Analysis of Necessary Conditions

The analysis of necessary conditions identified one determinant that exceeded the consistency threshold of 0.90; see Table 6 for all necessary analysis results. This shows the important role of this particular condition in the innovation adoption process. The size of the population appears to play a crucial role in adopting an RMS. It, however, also plays an important role (although not above 0.90) in the non-adoption of an RMS. This only shows even more how the size of the land can help or hinder the process, both ways. The size of the population is a necessary condition when the RMS is adopted, so it is set as present in the fsQCA analysis software.

| Outcome | Condition | Consistency | Coverage |
|---|---|---|---|
| **robot** | innovation attitude | 0,651557 | 0,725999 |
| **robot** | network externalities | 0,406286 | 0,390359 |
| **robot** | health management | 0,566057 | 0,476067 |
| **robot** | size from population | **0,919429** | 0,52787 |
| **~robot** | innovation attitude | 0,31373 | 0,369493 |
| **~robot** | network externalities | 0,692108 | 0,702976 |
| **~robot** | health management | 0,681189 | 0,605632 |
| **~robot** | size from population | 0,81573 | 0,495095 |
| **robot** | ~innovation attitude | 0,434057 | 0,374335 |
| **robot** | ~network externalities | 0,690857 | 0,679748 |
| **robot** | ~health management | 0,531086 | 0,611769 |
| **robot** | ~size from population | 0,120571 | 0,382316 |
| **~robot** | ~innovation attitude | 0,767351 | 0,699586 |
| **~robot** | ~network externalities | 0,399784 | 0,415833 |
| **~robot** | ~health management | 0,417003 | 0,500132 |
| **~robot** | ~size from population | 0,222108 | 0,744519 |

*Table 6, analysis of necessary conditions.*

## 5.2 Sufficiency analysis

In this section the main findings of this research are presented, and configurations are explained and shown in the table. First, the “self-driven pioneers” are explained; this is the configuration with farmers who adopted an RMS. Second, the “risk-averse family” and “welfare traditionalist” configurations are explained; these configurations show evidence for non-adoption of an RMS. These configurations differ a lot from each other; this shows high causal complexity. Stating the need for an fsQCA analysis in this research.

### 5.2.1 The Self-driven pioneers

The fsQCA analysis revealed a single configuration that is sufficient to explain the adoption of RMS among dairy farmers; see table 7 for a detailed overview of the fsQCA results.

| | **Having a robot** |
|---|---|
| | **Self-driven pioneers** |
| innovation attitude | ⬤ |
| network externalities | ⨂ |
| health management | |
| size from population | ● |
| Consistency | 0,83 |
| Raw coverage | 0,45 |
| Unique coverage | 0,45 |
| Number of cases | 2 |
| Overall solution consistency | 0,83 |
| Overall solution coverage | 0,45 |

*Note: large black circles (⬤) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⨂) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a ‘don’t care’ condition.*

*Table 7, configurations sufficient for having an RMS.*

In this configuration, the strongest evidence is visible with innovation attitude. The condition could include anything from farmers visiting agritechnology fairs, searching the internet, or actively visiting other farmers with new technologies on their farms. That this condition is a core condition means that it has the strongest evidence in the total configuration for adopting an RMS.

Supporting this main driver is the size of the farm, although not as a main driver but as a peripheral driver. While this factor is not independently promoting innovation adoption, it is facilitating the ideal recipe for innovation adoption. Interestingly, network externalities, such as supplier relationships and the network from other farmers, are a core absent condition in this configuration. This absence suggests that for this group of adopters, internal motivations and attitudes towards innovation take precedence over external influences. This particular configuration has good consistency (0.83) and moderate coverage (0.45), effectively capturing a significant share of cases, though not accounting for all possible scenarios.

But what does it mean when looking at the individual farmers, their farms, and the complete configuration? It appears that this configuration shows strong evidence for farmers who are pioneering in the field of farming; they have a large farm and are completely self-driven. They have a big farm, with the possibility of growing even further when pioneering in innovation. They are focused only on their own farm as a solo pioneer. The focus on innovation suggests they have the ambition to grow bigger and faster with the right technology. Looking at some of the quotes from interviews, this confirms the self-driven pioneering mindset of those farmers.

Farmer 4 said he is going his own way when searching for innovative technologies. Without the need for suppliers or a network.

Farmer 4:
***"I am looking at YouTube and Instagram for the latest innovation. When I am searching on the internet, I get inspired. This is how I get my information. I am making my own decisions; I'm not really influenced by what my neighbors are doing."***

Farmer 16 calls himself innovative; he has a manure-handling robot and is investing in an RMS when the farm is visited. It shows these farmers are actively and enthusiastically searching for new innovations. While focusing on growing the farm bigger. Seeing that the RMS gives them more time to focus on other parts of the farm.

Farmer 16:
***"I am an innovative farmer. I dare to do it. I also have a manure vacuum robot. I am someone who wants to have it under control. I often compare. I look a lot before I do something."***

Although this configuration consists of only 2 cases, more farmers gave similar quotes about innovation adoption; see, for example, farmer 13: *"I don't really look at what others do. I do my own thing. If something works for me, I do it."* And farmer 7: *"No, I always like to swim against the current."*

These farmers all have an RMS right now. This suggests that they have a pioneering mindset of only looking at what's best for their own business, without letting them be influenced by other farmers or suppliers. They are truly pioneering on their own to make their farm better and bigger for the future. They do their own research and let them not be influenced by fellow farmers or suppliers.

### 5.2.2 Risk-averse family

In contrast to the configuration about adopting, this analysis identified two distinct pathways associated with the non-adoption of RMS. see table 8 for an overview of the two configurations.

| | Not having a robot | |
|---|---|---|
| | Risk averse family | Welfare traditionalist |
| innovation attitude | ⊗ | ⊗ |
| network externalities | ● | ⊗ |
| health management | ● | ⬤ |
| size from population | ⊗ | ● |
| Consistency | 0,95 | 0,80 |
| Raw coverage | 0,22 | 0,30 |
| Unique coverage | 0,15 | 0,24 |
| Number of cases | 1 | 1 |
| Overall solution consistency | 0,85 | |
| Overall solution coverage | 0,45 | |

*Note: large black circles (⬤) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table 8, configurations sufficient for the absence of an RMS.*

The first configuration, risk-averse family, is characterized by the absence of both innovation attitude and size of the farm. Farmers operating on a smaller scale, combined with not enthusiastically talking about innovation and new technologies, show strong evidence of not adopting an RMS. The risk-averse family is further characterized by two peripheral conditions for the absence of an RMS. The network externalities and electronic health management should be present for a farmer to be likely to not adopt an RMS. This risk-averse family has a high consistency (0.95) but lower coverage (0.22), indicating that while it explains non-adoption very precisely, it applies to a more limited subset of cases.

The evidence for this configuration means that the risk-averse family is a small-scale family farm. These smaller farms are usually operated solely by the family living on the farm. They have their focus on the well-being of the animals on the farm. The cows are central to the operations. New technologies are passed on as they do not fit with the mindset of cow-central farming and the size of the farm. They have their own family, and that's it. There is low explanatory power for the influence of peer farmers or suppliers. These farmers are smaller; the reason for this could be that they do not have the ambition to grow and use new technologies, on the other hand. They could be too small to invest in expensive innovations and stay small.

Farmer 18 says she cannot afford an RMS. The technology is too expensive for the size of the farm they have. They have no workers and just enough work for the father and daughter; they want to keep it that way.

Farmer 18:

**“A robot is a serious investment; I don’t think we could do it on our farm. We try to keep costs low. Also, we can easily manage the farm on our own; we don’t need the time savings. I think we have it good, just the way we are right now.”**

Farmer 18 gives a good example of the risk-averse family; they “have it good, just the way we are right now.”

### 5.2.3 Welfare traditionalist

The second configuration is the welfare traditionalist; it shows the combined absence of both innovation attitude and network externalities. Here, farmers who lack incentives from both internal and external sources consistently resist adopting an RMS. These non-adopters place a strong emphasis on electronic health management and animal welfare, suggesting a preference for traditional practices that they perceive as more beneficial for animal care. In this configuration, even larger farms are reluctant to adopt if innovation motivation is missing, despite their scale. This pattern has a fairly good consistency (0.80) and low coverage (0.30).

The welfare traditionalist has a strong focus on the animal welfare of their animals. They want to take care of their animals and do not need new technologies to do that for them. They could even go one step further and say it is part of being a farmer to milk your own cows. Staying in a very traditional sphere. They go their own way, not being influenced by the neighboring farms. Even with no affinity with innovation, they still manage to have a larger farm.

Farmer 8 says he totally relies on his own personal expertise to manage his herd.

Farmer 8:
***"For me, traditional methods are proven and reliable. New technology can often create more problems than it solves. I'm not convinced by robots. You lose the personal contact with your cows, and you can't fully trust a machine to notice when something is wrong."***

Although the configuration consists of only 1 case, the quotes from farmers 1 and 3 suggest that they might even have a slight bias towards the RMS, but that they are definitely more focused on inspecting the cows while milking, saying this is more important than the new innovations. Really wanting to stay in the traditional way of farming. Farmer 1: *"I think it's important to be present when the cows are milked. I want to see my cows every day. I trust my eyes more than any machine."* Farmer 3: *"Personally checking cows during milking is critical. You immediately notice if something is wrong; you see it in their behavior, their stance, something a robot can't replace."*

Innovation is said to be the best way forward (Rogers, 2003). However, the welfare traditionalist has larger farms as well. Like the self-driven pioneers. Perhaps the traditional way of milking gives benefits for growing as well. As it is cheaper, the craftsmanship of a good herd manager can really come into play when he milks his own cattle every day.

## 5.3 Supplemental analysis

The supplemental analysis is necessary for the reliability and validity of the results. In the following section, a subgroup analysis and robustness check are given.

### 5.3.1 Subgroup analysis

The configurations identified in the French subgroup differ from the overall analysis; see table 9 for the results. In the first configuration, innovation attitude is less important, and size has become more important. Health management went from insignificant to a core absent condition. This suggests that in France there is a different mindset about having an RMS and not being interested in health management. Network externalities still remain a core absent condition. Suggest its importance in the overall solution outcome. It is still the self-driven pioneer, with more emphasis on farm size. The second configuration only has present conditions, suggesting that all conditions have a positive effect on the RMS adoption, with innovation attitude having the strongest evidence.

The overall solution consistency and coverage are slightly higher in the sample analysis. However, the sample is too small to do cross-country analysis. It could even be argued that this sample is too small for subgroup analysis (Schneider C. Q. & Wagemann C., 2012). A subgroup analysis of not having an RMS is being made and is shown in appendix B.

| | Having a robot | |
|---|---|---|
| | **1** | **2** |
| innovation attitude | ● | ⬤ |
| network externalities | ⊗ | ● |
| health management | ⊗ | ● |
| size from population | ⬤ | ● |
| Consistency | 1,00 | 0,91 |
| Raw coverage | 0,31 | 0,27 |
| Unique coverage | 0,24 | 0,20 |
| Number of cases | 1 | 1 |
| Overall solution consistency | 0,95 | |
| Overall solution coverage | 0,51 | |

*Note: large black circles (⬤) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table 9, subgroup analysis of France: RMS is present, threshold level 0.8*

### 5.3.2 Robustness checks

To ensure the validity and reliability of the fsQCA findings, a series of robustness checks were undertaken; see appendix B for all robustness check results. The consistency threshold was changed to test the findings (Schneider C. Q. & Wagemann C., 2012), the levels were changed to 0.7 and 0.9, so lower and higher than the set 0.80 threshold setting used in this research. At the lower threshold of 0.7, see Table 10, the analysis gave exactly the same results as the threshold level of 0.80. This indicates that the identified configuration is very stable. By lowering the threshold level, no more cases were added or removed. The results are not sensitive to minor threshold adjustments and are therefore robust and theoretically valid. When the threshold level was set at 0.90, there were no solutions, suggesting that there are no cases with a threshold level of 0.90 or higher. Meaning the sample did not contain cases with a meaningful contribution higher than 0.90.

| | Having a robot |
|---|---|
| | 1 |
| innovation attitude | ⬤ |
| network externalities | ⨂ |
| health management | |
| size from population | ● |
| Consistency | 0,83 |
| Raw coverage | 0,45 |
| Unique coverage | 0,45 |
| Number of cases | 2 |
| Overall solution consistency | 0,83 |
| Overall solution coverage | 0,45 |

*Note: large black circles (⬤) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⨂) are core absent conditions, small circles with a cross (⨂) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table 10, consistency benchmark variations, RMS is present, threshold level 0.7*

## 5.4 conclusion

These findings show causal complexity. The three configurations explain the adoption or non-adoption of an RMS, or in other words, innovation adoption. Three distinct groups were discovered from the analysis. The self-driven pioneer, with a large-scale, innovation-minded farm. He is led by his own curiosity rather than his peers. He/she grows bigger because of the technology adopted on his farm. Embracing the technology gives him/her more chances to grow. The risk-averse family, however, is rather small and likes to keep it this way. Innovation is not on the agenda; good animal well-being, however, is. The stability and family work ethic are core to the family farm. The third configuration is that of the welfare traditionalist, a medium-scale farm that views its own skills as leading for the herd management. They do not trust or see the benefit in any technology; they believe the farm will grow by their own skills in monitoring the animals well-being.

# Chapter 6, Discussion

The aim of this study was to identify configurations of determinants that can explain their influence on the innovation adoption of a dairy farmer. With the use of fsQCA analysis on 18 in-depth interviews in four EU countries, one pathway for adoption of an RMS and two alternative pathways for non-adoption were discovered.

## 6.1 Theoretical contributions

This study has multiple contributions to the literature on technology adoption and innovation diffusion. It integrated classical adoption theories with the use of fsQCA, a configurational analysis. The configurational nature of this study brought new insights. The findings confirm the model reasoning from TAM and UTAUT. The self-driven pioneering farmer has an enthusiastic innovation attitude with an above-country-average farm size and is not bothered by network externalities for the adoption of an RMS. This aligns with TAM's emphasis on a positive attitude towards technology (Davis, 1986). The self-driven pioneer does his own research and does not get influenced by someone else. He or she sees the benefits innovation has on the farm and sees it as an essential part for improving and growing the operations. It confirms that favorable beliefs in a technology result in adoption (Davis, 1986).

The UTAUT model extended the framework with performance expectancy and social influence (Venkatesh et al., 2003). This study shows that performance expectancy alone does not lead to innovation adoption. It is part of the self-driven pioneer, where the farmer needs to be of a certain size and open to innovation as well. Also, the social influence should not be present in this configuration; contrary to the UTAUT model, where it is a positive influencer (Venkatesh et al., 2003), the pioneering farmer is better off not being influenced.

Two pathways for non-adoption were discovered. The welfare traditionalist is also working on his own but does not value new technologies at all and has, on the contrary, a strong emphasis on animal welfare. Interestingly, this farmer also has a large farm size. This might suggest that there is a stream of farmers that can grow their operations with a traditional mindset, inspecting their own cattle by skill instead of technology. That these farmers grow shows that innovation is not always the key to better operations (Rogers, 2003). However, it confirms that the individual traits are key in innovation adoption, even with a bigger farm size (Venkatesh et al., 2003). A traditionalist mindset can block innovation, although this does not mean that his/her farm is 'worse off' than the self-driven pioneer. It is interesting to see the traditional farm with a focus on animal welfare also improving and growing his farm operations (Montes de Oca Munguia et al., 2021). It is yet unknown how this is possible, as innovation usually leads to better prosperity (Rogers, 2003). It could be that the family farm is driven by incremental innovation while the pioneering farmer is driven by radical innovation (Dewar & Dutton, 1986). The nature of a dairy farm is centered around the animal. You could argue that new technologies improve the farm but also let the farmer move away from the animal. While the traditionalist stays true to its operations and animal-centered farming and gets his/her improvements and growth from better caretaking.

This is not the case for the risk-averse family; this configuration has a small farm with a mistrust in innovation. They would rather stay small to keep the work within the family; they do not trust the technology to do the work for them. This is the only configuration that shows evidence for network externalities as well. This means that the social influence has a negative effect on innovation diffusion in the dairy farming sector. This confirms that all three types of determinants have an influence on the innovation adoption: the individual, the organization, and the environment (Damanpour, 1996). One could also argue that the risk-averse family farm has too small of a farm to be able to invest in new technologies, therefore not being able to grow.

These results show the complexity and multi-factor nature of innovation adoption (Frambach & Schillewaert, 2002). Innovation adoption models should account for a combination of individual, organizational, and environmental factors instead of just researching them on their own (Van Oorschot et al., 2018).

The use of fsQCA in this research demonstrates that a configurational approach offers a better and deeper understanding of innovation adoption determinants compared to traditional regression models (Ragin, 2008; Schneider C. Q. & Wagemann C., 2012). The multiple pathways show equifinality to the innovation adoption. A combination of multiple determinants can lead to the same outcome. This confirms the need for a more rigorous research approach on innovation adoption (Van Oorschot et al., 2018). Three farm types were developed in this study; this shows that the innovation adoption determinants cannot be captured by a single factor/determinant. It must be seen in a configuration with multiple determinants. This also confirms that innovation diffusion is a non-linear process (Rogers, 2003).

## 6.2 Practical contributions

These findings have important implications for the suppliers of new technologies in the agri-sector and the governmental policymakers. The farmers are segmented into three groups: the self-driven pioneers, risk-averse families, and welfare traditionalists. Each has their own unique motivations and barriers. There is no one way to stimulate innovation diffusion in the dairy sector (Rogers, 2003).

The mindset of the farmer is important in how he/she feels about new innovations. This study shows that the self-driven pioneer reacts differently to supplier outreach or new innovation compared to the risk-averse family farmer. Segmentation in these categories with tailored messaging could benefit suppliers trying to sell their new technologies.

Also, respect the pioneers autonomy on their farm. Persuasion from peers or suppliers could react negatively on those farmers, as the network externalities should be absent. These farmers could benefit from doing their own homework about an innovation provided by the supplier, such as an online return on investment calculator or on-farm demos.

For the non-adopters, it could be useful to find ways to incorporate more and better health management/monitoring on the RMS or other new technologies. Showing that those tools are not only for labor savings, etc., but also as an improved health management tool on their farm. The welfare traditionalist shows that an animal-centric farm also can grow the business.

Perhaps technology developers can learn from these farms and have an animal-centric focus on technology development. Capturing the best of both worlds, the benefits from the pioneer and the traditionalist.

Research shows that RMS and other on-farm innovations have a positive impact on the environment (D'Emden et al., 2006; Van Oorschot et al., 2018). For policymakers, it is important to understand that the farmers attitude has stronger evidence than the size of the farm, meaning their mindset is more influential than their financial capabilities. To increase innovation diffusion in the agri-sector.

The size of the farm is, however, still an important aspect of the adoption process. By making specific subsidies only for below-country-average or average farm sizes. These farmers could get just the last bit of financial motivation to invest in new technologies. While not giving out subsidies to farmers who are big enough to do it on their own.

RMS and the broader innovation Adoption is not about external convincing or large subsidies. It is about a farmer's own mindset towards innovation, enabled by its size. Understanding the importance of the individual entrepreneur's mindset and the segmentation is valuable for policymakers and suppliers. Tailored strategies and context-specific subsidies help reach innovation and sustainability goals.

However, policymakers can also learn from the welfare traditional farmer, who has a good operating farm without the need for new technologies. What is he doing better? And how can this stream of farmers help achieve sustainability goals? It is not only about the environment; the cows well-being is, and will be even more, an important aspect of farming.

## 6.3 Limitations and future research

The limitations for this research can be split up into two parts: the first focuses on the methodological setup of this research, while the second is about the result-specific limitations and future research.

The self-driven pioneering farmer adopts innovation and has a growing operation. This is in line with literature (O'Grady & O'Hare, 2017; Rogers, 2003). However, the welfare traditionalist achieves the same operational improvements and growth, but without the adoption of new technologies or an RMS. It is very interesting to get a deeper understanding of why these farmers became or still are innovation-averse, and even more interestingly, how are these farms performing just as well? This seems to be the case when judged by the researchers own expertise during the farm visits. What are they doing to have this farm with no need for innovation? Deeper research could even be made on the benefits of innovation adoption on dairy farms, as it is a sector-specific branch. Deepening the work from O'Grady and O'Hare (2017).

This study was made for the dairy sector. The agri-sector in general is very big and wide in operations. Future research should widen the scope in the agri-sector. What happens with plant-based farming? They have the same land prices as dairy farmers, but do they have the same segmentation of farmers as well?

The differences in country are also interesting to deepen the research in; the sample from this research was too small to do country-specific analysis (Schneider C. Q. & Wagemann C., 2012). There are, however, still country differences yet unknown. Within the agri-sector, this is even more evident in other sectors. Greenhouse horticulture, for example, is leading in the Netherlands with the most advanced greenhouses. Why is this not in Germany, for example?

This exploratory research made use of the network from Kramp B.V., although action has been taken to reduce bias because almost all cases came from the same network. It can not be ruled out that bias is present in the sample selection (Ragin, 2008).

This study focused on the RMS for dairy farmers. The RMS was, in this study, the focus for innovation adoption. It is, however, not the only new technology a dairy farmer can have. The technologies spread far beyond just the RMS. For example, special lighting, feeding, and stable construction. So saying that RMS represents innovation adoption is a limitation for this research.

The sample is also relatively small, with 18 cases. Future research should test the configurations given by this study in a larger sample, rightly representing the population. Possibly with a widespread survey.

This thesis set out to answer which combination of determinants influences the adoption process of new technologies and how these determinants motivate or hinder the adoption process. 18 in-depth interviews in four European countries were conducted and analyzed via fsQCA analysis. The configurational pathways revealed that the adoption process is not influenced by a single determinant but rather via multiple configurational pathways with causal complexity and equifinality. This study offers a new perspective on innovation adoption for the agricultural sector and helps accelerate innovation in Europe's dairy sector. As well as discover that we can learn from innovation-averse farmers as well.

# Bibliography


Agarwal, R., & Prasad, J. (1998). A Conceptual and Operational Definition of Personal Innovativeness in the Domain of Information Technology. *Information Systems Research*, *9*(2), 204–215. https://doi.org/10.1287/ISRE.9.2.204

Ajzen, I., & Fishbein, M. (1977). Attitude-Behavior Relations: A Theoretical Analysis and Review of Empirical Research. *Psychological Bulletin*, *84*(5), 888–918.

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, *54*(1), 510–520. https://doi.org/10.1016/J.DSS.2012.07.002

Beza, E., Reidsma, P., Poortvliet, P. M., Belay, M. M., Bijen, B. S., & Kooistra, L. (2018). Exploring farmers' intentions to adopt mobile Short Message Service (SMS) for citizen science in agriculture. *Computers and Electronics in Agriculture*, *151*, 295–310. https://doi.org/10.1016/J.COMPAG.2018.06.015

Blut, M., Yee, A., Chong, L., Tsiga, Z., & Venkatesh, V. (2022). Meta-analysis of the unified theory of acceptance and use of technology (UTAUT): challenging its validity and charting A research agenda in the red ocean. *Papers.Ssrn.ComM Blut, A Chong, Z Tsiga, V VenkateshJournal of the Association for Information Systems, Forthcoming, 2021•papers.Ssrn.Com*, *23*(1), 13–95. https://doi.org/DOI10.17705/1jais.00719

Colombo, M. G., Croce, A., & Grilli, L. (2013). ICT services and small businesses' productivity gains: An analysis of the adoption of broadband Internet technology. *Information Economics and Policy*, *25*(3), 171–189. https://doi.org/10.1016/J.INFOECOPOL.2012.11.001

*COMPASSS*. (2025). https://compasss.org/

Creswell, J. W., & Poth, C. N. (2016). Defining Features of Phenomenology. In Qualitative inquiry and research design: Choosing among five approaches. In *Sage Publications*. Washington DC, United States of America: Sage publications. https://books.google.com/books/about/Qualitative_Inquiry_and_Research_Design.html?hl=nl&id=DLbBDQAAQBAJ

D'Emden, F. H., Llewellyn, R., & Burton, M. P. (2006). Adoption of conservation tillage in Australian cropping regions: An application of duration analysis. *Technological Forecasting and Social Change*, *73*(6), 630–647. https://doi.org/10.1016/J.TECHFORE.2005.07.003

Damanpour, F. (1992). Organizational Size and Innovation. *Http://Dx.Doi.Org/10.1177/017084069201300304*, *13*(3), 375–402. https://doi.org/10.1177/017084069201300304

Damanpour, F. (1996). Organizational Complexity and Innovation: Developing and Testing Multiple Contingency Models. *Https://Doi.Org/10.1287/Mnsc.42.5.693*, *42*(5), 693–716. https://doi.org/10.1287/MNSC.42.5.693

Damanpour, F. (1998). *Organizational Innovation: A Meta-Analysis of Effects of Determinants and M oderators* (1 (Ed.)). Taylor and Francis. https://doi.org/10.4324/9780429449482-8/ORGANIZATIONAL-INNOVATION-META-ANALYSIS-EFFECTS-DETERMINANTS-MODERATORS-FARIBORZ-DAMANPOUR

Damanpour, F., & Schneider, M. (2006). Phases of the Adoption of Innovation in Organizations: Effects of Environment, Organization and Top Managers1. *British Journal of Management*, *17*(3), 215–236. https://doi.org/10.1111/J.1467-8551.2006.00498.X

Daniel, E., Myers, A., & Dixon, K. (2012). Adoption rationales of new management practices. *Journal of Business Research*, *65*(3), 371–380. https://doi.org/10.1016/J.JBUSRES.2011.06.033

Davis, F. D. (1986). A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results. In *Sloan School of Management, Massachusetts Institute of Technology.* (pp. 1–33). https://doi.org/10.1002/9781119678816.iehc0776

Davis, F. D. (1993). User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. *International Journal of Man-Machine Studies*, *38*(3), 475–487. https://doi.org/10.1006/IMMS.1993.1022

Dewar, R. D., & Dutton, J. E. (1986). The Adoption of Radical and Incremental Innovations: An Empirical Analysis. *Https://Doi.Org/10.1287/Mnsc.32.11.1422*, *32*(11), 1422–1433. https://doi.org/10.1287/MNSC.32.11.1422

European Union. (2020). Farm to Fork Strategy. *DG SANTE/Unit 'Food Information and Composition, Food Waste'',' DG SANTE/Unit 'Food Inf. Compos. food waste'','* 23. https://ec.europa.eu/food/sites/food/files/safety/docs/f2f_action-plan_2020_strategy-info_en.pdf

*FADN*. (2024). Eurostat. https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html

Frambach, R. T., & Schillewaert, N. (2002). Organizational innovation adoption: a multi-level framework of determinants and opportunities for future research. *Journal of Business Research*, *55*(2), 163–176. https://doi.org/10.1016/S0148-2963(00)00152-1

Frigon, A., Doloreux, D., & Shearmur, R. (2020). Drivers of eco-innovation and conventional innovation in the Canadian wine industry. *Journal of Cleaner Production*, *275*, 124115. https://doi.org/10.1016/J.JCLEPRO.2020.124115

Gauvin, S., & Sinha, R. K. (1993). Innovativeness in industrial organizations: A two-stage model of adoption. *International Journal of Research in Marketing*, *10*(2), 165–183. https://doi.org/10.1016/0167-8116(93)90003-H

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking Qualitative Rigor in Inductive Research. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151'

Greckhamer, T., Furnari, S., Fiss, P. C., & Aguilera, R. V. (2018). Studying configurations with qualitative comparative analysis: Best practices in strategy and organization research. *Strategic Organization*, *16*(4), 482–495. https://doi.org/10.1177/1476127018786487

Han, M. S., & Chen, W. (2021). Determinants of eco-innovation adoption of small and medium enterprises: An empirical analysis in Myanmar. *Technological Forecasting and Social Change*, *173*, 121146. https://doi.org/10.1016/J.TECHFORE.2021.121146

Holbek J, Z. G. D. R. (1973). *Innovations and Organizations*. Wiley; 99th edition. https://cir.nii.ac.jp/crid/1130282271603827200?lang=en

Hultink, E. J., Griffin, A., Hart, S., & Robben, H. S. J. (1997). Industrial new product launch strategies and product development performance. *Journal of Product Innovation Management*, *14*(4), 243–257. https://doi.org/10.1016/S0737-6782(97)00009-X

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2005). A tale of two market failures: Technology and environmental policy. *Ecological Economics*, *54*(2–3), 164–174. https://doi.org/10.1016/J.ECOLECON.2004.12.027

Karahanna, E., Agarwal, R., & Angst, C. M. (2006). Reconceptualizing compatibility beliefs in technology acceptance research. *MIS Quarterly: Management Information Systems*, *30*(4), 781–804. https://doi.org/10.2307/25148754

Kim, T., & Hong, J. (2015). Bass model with integration constant and its applications on initial demand and left-truncated data. *Technological Forecasting and Social Change*, *95*, 120–134. https://doi.org/10.1016/J.TECHFORE.2015.02.009

Lee, Y., Kozar, K. A., & Larsen, K. R. T. (2003). The Technology Acceptance Model: Past, Present, and Future. *Communications of the Association for Information Systems*, *12*, 752–780. https://doi.org/10.17705/1CAIS.01250

*Lely | Innovatieve oplossingen voor de landbouw*. (n.d.). Retrieved July 4, 2025, from https://www.lely.com/nl/

Lin, Hai Fen, Su, J. Q., & Higgins, A. (2016). How dynamic capabilities affect adoption of management innovations. *Journal of Business Research*, *69*(2), 862–876. https://doi.org/10.1016/J.JBUSRES.2015.07.004

Lin, Hsiu Fen. (2014). Contextual factors affecting knowledge management diffusion in SMEs. *Industrial Management and Data Systems*, *114*(9), 1415–1437. https://doi.org/10.1108/IMDS-08-2014-0232/FULL/XML

Mansfield, E. (1993). The Diffusion of Flexible Manufacturing Systems in Japan, Europe and the United States. *Https://Doi.Org/10.1287/Mnsc.39.2.149*, *39*(2), 149–159. https://doi.org/10.1287/MNSC.39.2.149

Marshall, G. R. (2009). Polycentricity, reciprocity, and farmer adoption of conservation practices under community-based governance. *Ecological Economics*, *68*(5), 1507–1520. https://doi.org/10.1016/J.ECOLECON.2008.10.008

Mol, M. J., & Birkinshaw, J. (2009). The sources of management innovation: When firms introduce new management practices. *Journal of Business Research*, *62*(12), 1269–1280. https://doi.org/10.1016/J.JBUSRES.2009.01.001

Montes de Oca Munguia, O., Pannell, D. J., & Llewellyn, R. (2021). Understanding the Adoption of Innovations in Agriculture: A Review of Selected Conceptual Models. *Agronomy 2021, Vol. 11, Page 139*, *11*(1), 139. https://doi.org/10.3390/AGRONOMY11010139

O'Grady, M. J., & O'Hare, G. M. P. (2017). Modelling the smart farm. *Information Processing in Agriculture*, *4*(3), 179–187. https://doi.org/10.1016/J.INPA.2017.05.001

Patterson, K. A., Grimm, C. M., & Corsi, T. M. (2003). Adopting new technologies for supply chain management. *Transportation Research Part E: Logistics and Transportation Review*, *39*(2), 95–121. https://doi.org/10.1016/S1366-5545(02)00041-8

Ragin, C. C. (2008). *Redesigning Social Inquiry: Fuzzy Sets and Beyond*. University of Chicago Press. https://books.google.nl/books?hl=nl&lr=&id=WUj9yT5zAiIC&oi=fnd&pg=PR5&dq=Ragin,+C.+C.+(2008).+Redesigning+Social+Inquiry:+Fuzzy+Sets+and+Beyond.+Chicago,+IL:+The+University+of+Chicago+Press.+&ots=WvJFLMNkQX&sig=ZUnp5p-PMXAjtO-6pi7g35utSaw&redir_esc=y#v=onepage&q&f=false

Ragin Charles C. (2000). *Fuzzy-Set Social Science*. The University of Chicago Press. https://books.google.nl/books?hl=nl&lr=&id=nZC2dLUH-OAC&oi=fnd&pg=PA1&dq=Ragin,+C.+C.+(2000).+Fuzzy-Set+Social+Science.+Chicago,+IL:+The+University+of+Chicago+Press.&ots=9QnLZSuD1A&sig=kHimdxecNPLH3jQQRLqNHh-T6jI&redir_esc=y#v=onepage&q&f=false

Requate, T. (2005). Dynamic incentives by environmental policy instruments—a survey. *Ecological Economics*, *54*(2–3), 175–195. https://doi.org/10.1016/J.ECOLECON.2004.12.028

Rizzo, G., Migliore, G., Schifani, G., & Vecchio, R. (2023). Key factors influencing farmers' adoption of sustainable innovations: a systematic literature review and research agenda. *Organic Agriculture 2023 14:1*, *14*(1), 57–84. https://doi.org/10.1007/S13165-023-00440-7

Rogers, E. M. (1962). *Diffusion of Innovations* (1st ed.). The Free Press of Glencoe, NY. NY, 1962.

Rogers, E. M. (2003). Diffusion of Innovations. In *Free Press* (5th ed.). https://www.managementboek.nl/boek/9780743222099/diffusion-of-innovations-everett-rogers

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2008). Diffusion of Innovations. In *An Integrated Approach to Communication Theory and Research* (2nd ed., pp. 432–448). Routledge. https://doi.org/10.4324/9780203887011-36

Schneider C. Q., & Wagemann C. (2012). *Set-Theoretic Methods for the Social Sciences: A Guide to Qualitative Comparative Analysis*. Cambridge University Press. https://doi.org/10.1017/CBO9781139004244

Seawnght, J., & Gerring, J. (2008). Case Selection Techniques in Case Study Research. *Http://Dx.Doi.Org/10.1177/1065912907313077*, *61*(2), 294–308. https://doi.org/10.1177/1065912907313077

Skevas, T., Stefanou, S. E., & Oude Lansink, A. (2014). Pesticide use, environmental spillovers and efficiency: A DEA risk-adjusted efficiency approach applied to Dutch arable farming. *European Journal of Operational Research*, *237*(2), 658–664. https://doi.org/10.1016/J.EJOR.2014.01.046

Subramanian, A., & Nilakanta, S. (1996). Organizational innovativeness: Exploring the relationship between organizational determinants of innovation, types of innovations, and measures of organizational performance. *Omega*, *24*(6), 631–647. https://doi.org/10.1016/S0305-0483(96)00031-X

Sumrin, S., Gupta, S., Asaad, Y., Wang, Y., Bhattacharya, S., & Foroudi, P. (2021). Eco-innovation for environment and waste prevention. *Journal of Business Research*, *122*, 627–639. https://doi.org/10.1016/J.JBUSRES.2020.08.001

Talukder, M., & Quazi, A. (2011). Demographic Determinants of Adoption of Technological Innovation. *Journal of Computer Information Systems*, *52*(1), 34–42. https://doi.org/10.1080/10919392.2011.564483

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology*, *8*(1), 1–10. https://doi.org/10.1186/1471-2288-8-45/FIGURES/2

Utterback, J. M., & Abernathy, W. J. (2018). A Dynamic Model of Process and Product Innovation. *Organizational Innovation*, 193–210. https://doi.org/10.4324/9780429449482-10/DYNAMIC-MODEL-PROCESS-PRODUCT-INNOVATION-JAMES-UTTERBACK-WILLIAM-ABERNATHY

Van Oorschot, J. A. W. H., Hofman, E., & Halman, J. I. M. (2018). A bibliometric review of the innovation adoption literature. *Technological Forecasting & Social Change*, *134*, 1–21. https://doi.org/10.1016/j.techfore.2018.04.032

Venkatesh, V., Davis, F. D., & Morris, M. G. (2007). Dead or Alive? The Development, Trajectory and Future of Technology Adoption Research. *Journal of the AIS*, *8*(4), 267–286. https://doi.org/10.17705/1jais.00120

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly: Management Information Systems*, *27*(3), 425–478. https://doi.org/10.2307/30036540

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Quarterly: Management Information Systems*, *36*(1), 157–178. https://doi.org/10.2307/41410412

Wagner, E. R., & Hansen, E. N. (2005). Innovation in large versus small companies: Insights from the US wood products industry. *Management Decision*, *43*(6), 837–850. https://doi.org/10.1108/00251740510603592/FULL/PDF

Williams, M., & Moser, T. (2019). The art of coding and thematic exploration in qualitative research. *International Management Review*, *15*(1). http://www.americanscholarspress.us/journals/IMR/pdf/IMR-1-2019/IMR-v15n1art4.pdf

Xie, H., & Huang, Y. (2021). Influencing factors of farmers' adoption of pro-environmental agricultural technologies in China: Meta-analysis. *Land Use Policy*, *109*, 105622. https://doi.org/10.1016/J.LANDUSEPOL.2021.105622

## Appendix A, Interview script

Philip Lutke Veldhuis, Master Business Administration Thesis

1 hour

Given the nature of the study, this is a semi-structured interview. The interviewer asks a set of pre-determined macro questions (MQ) with the possibility to explore particular themes or responses further. While listening to the answers, the interviewer makes sure that all the items of interest are touched. If not, the interviewer asks potential additional questions to target such items.

**Intro*:***

***Give a welcome and thank you to the interviewee for participating in this interview and taking the time for me.***
***Explain the goal of the interview: technology adoption among dairy farmers.***
***Tell the interviewee that his/her information is confidential and will only be used for research purposes.***
***Tell the interviewee there is always room for questions on his/her side.***

***Ask the interviewee for consent to record the interview and use his/her transcript in an anonymized way for research purposes.***

***The researcher introduces himself and briefly presents the goal of the research.***

**MQ1: General introduction of the farmer and its firm.**

> ***Can you tell me something about you and your farm? I am particularly curious about your personal history—such as how you became a dairy farmer—as well as the history of your farm.***

Potential additional questions:

1. What motivates you to be a farmer?
2. Can you tell me about the history of your farm?
3. What type of farm (family farm, funded by the farmer, …) do you have?
4. Is your farm self-sufficient in land use? if any?
5. What is the size of your farm? Including the number of full-grown dairy cows and the number of workers.
6. What are your ambitions for the future?

**MQ2***:* **Firm view towards technology and innovation.**

> ***Now, I am curious about your role of technology on the farm. For example, can you tell me about your milking installation and other important machinery on the farm?***

Potential additional questions:

1. What type of milking installation does your farm use? What is its size?
2. What type of feeding installation does your farm use? What is its size?
3. What type of manure installation does your farm use? What is its size?

**MQ3. Determinants of adoption or non-adoption.**

<u>In the case of a robot milking installation on the farm (= technologically advanced)</u>

> ***What are the most important reasons for you to choose this installation?***

<u>In the case of a traditional milking installation on the farm (= not technologically advanced)</u>

> ***Why have you refrained so far from investing in a robot installation?***
>
> ***Under which circumstances would you start to invest in a robot installation?***

Potential additional questions:

1. What are the reasons why you chose/did not choose the installation?
2. What are the most important factors that you consider when investing?
3. What are other factors that influenced the decision-making?
4. Do other farmers, your family, or others have a role in the decision-making process? With whom do you discuss your choices?
5. What would you tell others to think about when investing?

**MQ4. Personal attitude towards technology and innovation***.*

> ***Can you tell me something about your personal view on technology? For example, do you keep yourself updated on new technologies being developed for farming?***

Potential additional questions:

1. Do you search on the internet for the latest trends regarding your job? Why/why not?
2. Do you go to fairs to check out the latest models of machinery? Why/why not?
3. Do you see benefits in having the latest technologies available?
4. Are you interested in trying the latest farming equipment on your farm?

**MQ5. Purchasing behaviour KRAMP**

Part 1: Milking installations

***Let's talk about your milking installation and its maintenance.***

Potential additional questions:

1. Is your milking installation serviced through maintenance contracts? Is this fully serviced by your dealer, or do you also do it (partially) yourself
2. Do you have the flexibility to decide how it is maintained? If not, what are the consequences?
3. Do you buy more often original or aftermarket parts? Why?
4. Are you allowed to use non-original parts for repairs or maintenance? How about for cleaning or other consumables (nipple lining)?
5. Where do you buy parts and consumables? Could you list all the channels you buy through? Including parts through a dealer (or not).
6. How often are you looking online for parts and consumables?
7. How much do you spend on maintenance every year, more or less?

Part 2: Animal husbandry

***Let's talk about animal husbandry equipment. Can you talk to me about the maintenance of this? How is this arranged?***

***Beyond milking installations, we are aware that there are a lot of products that you commonly buy to manage your barn and cattle. Both in the barn (such as animal husbandry, feeding, and cleaning) and outside the farm (such as fencing).***

***At Kramp, we want to make sure we can provide a relevant offer to the market. Therefore, we would like to ask you about these categories too.***

Potential additional questions:

1. What are the 5 products that you buy most commonly?
2. What are the 5 products that you spend the most money on? Can you estimate how much you spend on those every year?
3. For these products, what are your preferred channels to buy from and why?
4. Do you buy through other channels, such as online retail or directly from suppliers? For which kind of products?
5. Do you buy original or aftermarket parts for your animal husbandry, and why?
6. Can you estimate how much you spend in total on animal husbandry parts on a yearly basis?

**MQ6. Local situation and influence of regulation**

***Can you tell me how it is being a dairy farmer in your country?***

Potential additional questions:

1. Is your outlook for your business positive or negative for the coming years, and why?
2. What challenges are you facing?

   How are regulations and policies impacting you? What are you doing to adjust to this changing business environment?

**Conclusion:** ***Beyond what we already talked about, is there anything you feel we missed today? What would you want to be able to buy through your dealer or elsewhere that is not possible today?***

***After the interviews I will transcribe and anonymize the data. The data will be aggregated into themes and used in my research to discover determinants for technology adoption. Could I make contact with you again at a later stage for questions or remarks if I discover uncertainties or problems in my data?***

## Appendix B, robustness checks

The first four tables show the crossover point adjustments with thresholds varying from 0.7 to 0.9. Circles marked in red differ from threshold level 0.8. At 0.9, there was no solution when having an RMS.

The last two tables show a subgroup analysis of France. France had the biggest sample size and overall the most consistent sample; therefore, France was chosen for the subgroup analysis.

| | Having a robot |
|---|---|
| | 1 |
| innovation attitude | ● |
| network externalities | ⊗ |
| health management | |
| size from population | • |
| Consistency | 0,83 |
| Raw coverage | 0,45 |
| Unique coverage | 0,45 |
| Number of cases | 2 |
| Overall solution consistency | 0,83 |
| Overall solution coverage | 0,45 |

*Note: large black circles (●) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table B1, consistency benchmark variations, RMS is present, threshold level 0.7*

| | Not having a robot | |
|---|---|---|
| | 1 | 2 |
| innovation attitude | ⊗ | ⊗ |
| network externalities | • | |
| health management | ● | ● |
| size from population | ⊗ | • |
| Consistency | 0,78 | 0,76 |
| Raw coverage | 0,46 | 0,49 |
| Unique coverage | 0,05 | 0,08 |
| Number of cases | 1 | 1 |
| Overall solution consistency | 0,78 | |
| Overall solution coverage | 0,55 | |

*Note: large black circles (●) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table B2, consistency benchmark variations, RMS is absent, threshold level 0.7*

| | Having a robot |
|---|---|
| innovation attitude | |
| network externalities | |
| health management | |
| size from population | |
| Consistency | |
| Raw coverage | |
| Unique coverage | |
| Number of cases | |
| Overall solution consistency | |
| Overall solution coverage | |

*Note: large black circles (●) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table B3, consistency benchmark variations, RMS is present, threshold level 0.9—no solution*

| | Not having a robot |
|---|---|
| | 1 |
| innovation attitude | ⊗ |
| network externalities | ● |
| health management | ● |
| size from population | ⊗ |
| Consistency | 0,97 |
| Raw coverage | 0,16 |
| Unique coverage | 0,16 |
| Number of cases | 1 |
| Overall solution consistency | 0,97 |
| Overall solution coverage | 0,16 |

*Note: large black circles (●) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table B4, consistency benchmark variations, RMS is absent, threshold level 0.9*

*Vvv*

| | Having a robot | |
|---|---|---|
| | **1** | **2** |
| innovation attitude | ● | ⬤ |
| network externalities | ⊗ | ● |
| health management | ⊗ | ● |
| size from population | ⬤ | ● |
| Consistency | 1,00 | 0,91 |
| Raw coverage | 0,31 | 0,27 |
| Unique coverage | 0,24 | 0,20 |
| Number of cases | 1 | 1 |
| Overall solution consistency | 0,95 | |
| Overall solution coverage | 0,51 | |

*Note: large black circles (⬤) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table B5, subgroup analysis of France, RMS is present, threshold level 0.8*

| | Not having a robot |
|---|---|
| | **1** |
| innovation attitude | ⊗ |
| network externalities | ● |
| health management | ● |
| size from population | ⊗ |
| Consistency | 1,00 |
| Raw coverage | 0,27 |
| Unique coverage | 0,27 |
| Number of cases | 1 |
| Overall solution consistency | 1,00 |
| Overall solution coverage | 0,27 |

*Note: large black circles (●) are core present conditions, small black circles (●) are peripheral present conditions, large circles with a cross (⊗) are core absent conditions, small circles with a cross (⊗) are peripheral absent conditions; blank spaces indicate a 'don't care' condition.*

*Table B6, subgroup analysis of France, RMS is absent, threshold level 0.8*