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GROWERS' ADOPTION INTENTION OF INNOVATIONS IS CRUCIAL TO ESTABLISH A SUSTAINABLE GREENHOUSE HORTICULTURAL INDUSTRY.

An empirical study in Flanders and the Netherlands

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Abstract

In a project funded by the European Union, six high-tech innovations were developed to improve the energy-efficiency and sustainability of the greenhouse horticultural industry in the border region Flanders (Belgium) and the Netherlands, in a collaborative effort with various stakeholders. Although there is reason to be optimistic about the feasibility of these innovations, past experiences and research bear witness to the lack of adoption of climate-friendly technologies in the greenhouse horticultural industry. The current study reports the results of a mixed-method research project that explores the motivational drivers and barriers of the adoption of sustainable technological innovations by growers. The conceptual model is an extension of the Theory of Planned Behavior and is empirically tested by means of qualitative interviews with 28 growers and an online survey with 152 growers. The results show that attitude and subjective norm, but also company reputation, past experience with innovations, and sustainable orientation give insights into the adoption intention towards sustainable innovations. Managerial implications are offered as well.

Keywords: sustainable innovation, horticultural industry, adoption process, mixed method research

1. Introduction

Due to global population growth, the tension between the demand for food and the unwanted environmental impact of producing it is rising (Tilman et al., 2011). Agriculture is responsible for ten to twelve percent of the total greenhouse gas emissions, and at the same time, it is in itself a sector that is extremely vulnerable to climate change (Smith et al., 2007). Greenhouses play an increasing role in the food supply (Marcelis and Heuvelink, 2019). They provide a controlled microclimate that is adaptable to the needs of crops and aims at achieving higher yields, improving quality, and aiding in the lengthening of market availability of fruits and vegetables (Lichtenberg et al., 2015). The promising impact of greenhouses to deal with food shortage is tempered by its environmental impact. Worldwide, greenhouses use extensive land area exceeding 470,000 ha (of which 40,000 ha glass-covered) with yields up to approximately ten times higher per unit area compared to field production (Wageningen University & Research, 2021). In Europe, more than 200,000 ha of greenhouses emerged the last decades. Thirty percent of these greenhouses have a permanent structure and are equipped with techniques using fossil fuels for maintaining optimal microclimate conditions (Heuvelink et al., 2020).

Four conditions are at play that contribute to crop growth: temperature, light, water and humidity, and carbon dioxide (Yano and Cossu, 2019). In colder areas, the extension of the cultivation period to colder seasons is managed by heating assistance, often driven by fuel burning, leading to an increased amount of energy consumption (Mariani et al., 2016). For instance, according to Qian et al. (2011), the energy consumption of the Dutch greenhouse industry contributed about 10% to the total national energy use. To avoid unwanted high temperatures which affect crops negatively, additional methods such as forced ventilation must be used during summer times (Thongbai et al., 2010). Photon energy of sunlight is the natural energy source needed for plant growth. The internal irradiance in a greenhouse is usually less than the exterior irradiance. Therefore, the roof structure of the greenhouse needs to be adapted to deliver as much sunlight as possible to the plants. Moreover, supplemental lighting is used in regions with a limited amount of sunlight (Bambara and Athienitis, 2019). Additional lighting during nighttime is also applied, in accordance with market demand. In a greenhouse, the natural water that plants would receive from the rain is blocked. Although it may be beneficial for many reasons, replacing the natural system with irrigation systems and supplying plants with necessary nutrition, affects plant transpiration and infections through the interior humidity system. Crop photosynthesis is limited under lower CO_2 concentration conditions even if sufficient sunlight is available, and vice versa. Ventilation control plays a crucial role in managing the CO_2 concentration, temperature, and humidity of the greenhouse interior air. In conclusion, to design an optimal greenhouse interior climate, one must take into account both the microclimate and the plants' physiological conditions, given that these factors interact in a complex manner every day and night throughout the different seasons.

As mentioned before, energy and especially electricity are used extensively to control greenhouse conditions. The whole microclimate conditioning could reach an energy demand of 400 W/m^2 (heating, lighting, cooling). For its future potential, the industry must be aware of climate-sensitive natural resources (Ignaciuk, 2015). In line with 2050 CO_2 commitments, increased attention should be paid to the environmental sustainability of greenhouse production: "*meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*" (WCED, 1987).

The purpose of the current study is to report and discuss the results of part of a research project called GLITCH, funded by the European Union. This project aims at developing innovative, energy-efficient and climate-neutral greenhouse cultivation systems and techniques. Although there is reason to be optimistic about the feasibility of technological innovations to meet sustainability goals, past experiences and research bear witness to the lack of adoption of climate-friendly technologies by growers in the greenhouse industry (Wreford et al., 2017), which is a crucial prerequisite for the successful implementation of innovations. Two important factors are explored in the current paper, (1) growers' perceived benefits of and barriers to the adoption of the innovations, and (2) the identification and characteristics of growers that can be considered to engage with the innovation at an early stage in the innovation diffusion process. The study was conducted in the Netherlands and Flanders (Belgium), and is based on a mixed-method approach, combining in-depth interviews and a quantitative survey, and uses an extension of the Theory of Planned Behavior (Ajzen, 1991) as the conceptual framework. The study tries to answer three research questions:

RQ1: What are the drivers and barriers to the adoption of sustainable innovative solutions developed throughout the GLITCH-project?

RQ2: What are the characteristics of early adopters of sustainable innovative solutions developed throughout the GLITCH-project?

RQ3: Are the drivers and barriers for adoption of sustainable innovative solutions developed throughout the GLITCH-project different between early and late adopters?

The contribution of this study is that it adds to our understanding of the adoption process of sustainable technological innovations in the greenhouse industry, which is an activity of great importance for the food supply chain that at the same time struggles with sustainability issues. Furthermore, the study's scope is relevant in that it investigates the drivers of and barriers to adopt these innovations from the perspective of growers, who are crucial stakeholders for innovation adoption. The study has practical relevance for governments, industry organizations and growers. Governments and industry organizations that want to promote sustainable technological innovations can use the results of the study to identify early adopter segments and to develop campaigns based on the insights we provide. Growers could benefit from our insights to take up their role in organizing their production methods such that it is not only efficient and profitable, but that they also take their societal role as responsible actors in fighting resource depletion and negative effects of their activities on the climate. As such they can become active partners in promoting sustainable production methods. In the current business environment, companies have a greater awareness of the impact of their activities on the environment and are increasingly motivated by environmental concerns in their pursuit of innovations. Investment, exploitation, and the use of green technologies and innovations should get special interest from growers that aim to evolve towards the efficient use of resources while improving ecological activities and productivity (Läpple and Van Rensburg, 2011).

1.1 The GLITCH-project

The combination of the complex conditions that greenhouse designs need to satisfy, and the need for a reduced environmental impact led to the launch of a co-creative project aimed at the development of innovative, energy-efficient and climate-neutral greenhouse cultivation systems and techniques. The project is called GLITCH (translated abbreviation stands for: Greenhouse horticulture innovates through co-creation with low-carbon high tech) and was set up as a Europe-funded project (EFRO-INTERREG) in the border region of Flanders (Belgium) and the Netherlands, which is a leading region in the international greenhouse horticulture industry. The total area of greenhouses in this region is estimated at around 14,000 ha and is one of the nine so-called 'top sectors' in this region (Wageningen University & Research, 2021). During the last decades, a flow of innovative technological approaches has been developed by collaborations between firms, research institutes, and governments.

The GLITCH project entails six innovative trajectories in line with challenges to keep the industry competitive with sustainability goals concerning energy saving and climate control (European Commission, 2020a, 2020b). More information on the six innovations that are ready to implement in the greenhouse horticultural industry can be found in Moons et al. (2021):

- Reducing energy use by implementing optimal LED lighting in the cultivation of tomato, lettuce and cucumber;
- Reducing land and energy use by implementing a four-layer cultivation system in the cultivation of strawberry;
- Reducing energy by installing low-grade heating systems;
- Isolating and optimizing the climate conditions by using energy balancing day screens in the cultivation of bell pepper and tomato;
- Isolating and optimizing the climate conditions by using energy balancing night screens in the cultivation of bell pepper and tomato;
- Optimizing the humidity by implementing a climate-neutral vapor heat pump.

In collaboration with horticultural research centers, greenhouse construction firms, universities, research centers, and with other experts, crop experiments were carried out in each of these six trajectories. The six co-created innovations have proven to be promising regarding greenhouse microclimate conditions (e.g., better temperature/humidity balance) and crop conditions (e.g., higher yields), as well as regarding positive impacts on the environment (e.g., up to 30 percent of energy reduction by implementing LED lighting and up to 65 percent energy savings using the energy-balancing screens in combination with the vapor heat pump). The high-tech innovations affect the sustainability of advanced crop production, since they radically change the growing process by reducing land use, energy consumption, and carbon emissions.

1.2 Conceptual framework

Research into the adoption intention of behavior in general, and innovations in particular, often uses the Theory of Planned Behavior (TPB) as a conceptual framework. In the TPB there are three antecedents of behavioral intention: the attitude towards the behavior, social influence (subjective norm) on the behavior, and the perceived behavioral control in conducting the behavior (Ajzen, 1991). *Attitudes* are evaluative responses to the behavior, i.e., to what extent the behavior is perceived as positive or negative. The *subjective norm* stands for perceived social pressure by significant others or relevant reference groups to perform or not to perform a certain behavior. Hereby information through reference groups serve as important comparison anchors. . *Perceived behavioral control* is a person's perception about whether the behavior is perceived as easy or difficult. It is related to the perceived ability and the external source constraints, as well as the facilitators of the behavior (Taylor and Todd, 1995). These factors can be, for instance, financial constraints, regulatory issues, lack of skills or organizational rigidities.

The TPB can be extended with components of models of innovation adoption, namely the Innovation Diffusion Theory (IDT) and the Technology Acceptance Model (TAM). Following the IDT, the attitude towards and the adoption or continuous use (intention) of an innovation is influenced by five factors: the *perceived relative advantage* of the innovative solution, the *perceived simplicity* (lack of complexity), the *perceived compatibility* or the fit with the potential adopter's existing values, previous experiences, and current needs; the *observability*, and the *trialability* of the innovation (Rogers, 2010). According to the TAM, two factors determine the attitude towards and the acceptance of innovative technology (Davis, 1989). *Perceived ease of use* is the degree to which a person believes that the innovative technology will not be difficult to understand, learn or operate and its use will be effortless. *Perceived usefulness* is the degree to which a person believes that using the innovation will provide benefits that supersede those of existing technologies in terms of enhancing economic benefits, convenience, satisfaction and/or job performance. The former is very similar to the lack of complexity in the IDT, and the latter reflects the perceived relative advantage factor in the IDT (Taylor and Todd, 1995). Finally, previous research supports the idea that risk perception or risk tolerance can also influence the adoption intention of innovations (Bocquého et al., 2014). In the current study we integrate these factors into an Extended Theory of Planned Behavior, as shown in the Figure in Appendix A.

Technology diffusion theory includes both research on the patterns of diffusion and research on the structure and process of firm- and consumer-level adoption (Montalvo, 2008). Along the same lines, Kemp and Volpi (2008) report a review of previous literature with suggestions for future innovation diffusion analysis. Previous research into the adoption of innovations in agriculture has tested several models, investigating the drivers and barriers of innovation adoption. For instance, Adnan et al. (2019) focus on how to facilitate sustainable agriculture through green fertilizer technology adoption, focusing on farmers' behavior. Montes de Oca Munguia (2021) provides an overview of conceptual models of the adoption of innovations in agriculture. Many of these models are (partly) based on or extend the TPB, IDT and TAM. For instance, in the context of the greenhouse horticultural industry, Verstegen et al. (2003) compared the barriers and drivers of 95 greenhouse entrepreneurs with those mentioned in the TPB. They divided the growers into five clusters according to their energy saving profile which was based on behavior, perception and attitude in relation to energy saving. They concluded that innovations should be implemented gradually and that economic benefits are more important than rules and guidelines imposed by the government. A combination of benefits for the environment and attaining better production and quality goals leads to sympathy from the farmers. Moreover, farmers are strongly influenced by their colleagues to take up environmental friendly innovations. Both farmers and horticultural growers were surveyed in a follow-up study that again started from the TPB framework, but also took some strategic choices and entrepreneurial characteristics into consideration (Verhees et al., 2012), and conclude that entrepreneurial as well as market orientation play a role in strategic choices such as, amongst others, cost reduction, collaboration, and increasing sustainability.

Forbes and De Silva (2015) used elements of the TPB to study the adoption of sustainable technology in the New Zealand horticultural sector amongst a sample of 51 growers. They found a significantly positive relationship between the level of implemented sustainable practices and the achievement of expected benefits, particularly in the area of environmental sustainability. Environmental sustainability appears to be embedded in normal business practice for a number of growers, and there is an increasing emphasis being placed on social sustainability. Hansson et al. (2012) studied the importance of the opinion of peers (subjective norm) on the decisions made by farmers, such as the networking of growers with their neighbors, friends and colleagues. Moreover, expert opinion is very important to bring improvements and changes in a greenhouse's effectiveness and development. The opinions or suggestions of crop consultants, horticultural scientists, bioengineers, advisory service providers, universities, and research centers, are considered expert opinions (Greenhalgh et al., 2004).

The role of different information channels as part of the subjective norm should not be underestimated for the diffusion of an innovation into a targeted market. Information channels are often classified as either formal (structure, channels and rules are important) or informal (works within social affiliations) (Mehra et al., 2001). McBride and Deberkow (2003) investigated the role of different interpersonal information sources (the extension service, crop consultants, input suppliers, special events/project demonstrations, other growers/grower associations, and the news media) on the adoption intention of sustainable precision technology measurements and concluded that information from these sources is associated with adoption intention directly and indirectly through attitude formation and perceived behavioral control. Personal-formal contacts showed a positive association with perceived behavioral control, whereas impersonal information sources had a negative association with attitudes. Crop consultants and input from suppliers had the greatest impact on the adoption process. The importance of personal formal information sources was also confirmed in a study by Caffaro et al. (2020) with 314 Italian farmers. The results show that personal-formal sources of information are positively associated with perceived behavioral control. Also in a study on the adoption of organic farming practices, the importance of this information source was confirmed in relation to adoption intention of agricultural environmental measures (Unay Gailhard et al., 2015).

Perceived behavioral control factors have also been studied in the context of innovations in agriculture. In the context of precession technology adoption, studies report the predictive power of profitability, resource availability, and economic benefits (Batte and Arnholt, 2003). Other factors such as demand constraints, regulatory issues, lack of skills and organizational rigidities are reported to act as inhibitors to the innovative activity of firms. Sustainability-related benefits or concerns may play a role as well, such as the perceived impact of the innovation on the labor circumstances and the perceived impact on environmental goals (Elkington, 1994).

Aubert et al. (2012) state that agricultural technology adoption is more complex and multi-faceted than many studies assume and suggest integrating concepts from the TAM and the IDT, as well as the role of incentives in early adoption phases, and the role of image building, voluntariness and normative norms. In their research on the adoption of precision technology they conclude that compatibility and quality of support influence the perception of the perceived ease of use of innovative technologies. Next, they found that compatibility, relative advantage, information use and ease of use impact the perceived usefulness of innovative farming technologies. Finally, they conclude that also observability and trialability impact the adoption decision of these technologies.

Six case studies conducted in the US show that profit (relative advantage) was the most significant factor in technology adoption by farmers (Batte and Arnholt, 2003). A survey of 30 farmers in Germany also found that economic reasons (relative advantage) were the most important driving force behind the adoption of precision technology (Kutter et al., 2011). In their qualitative study of farmers in Indiana (U.S.), Reimer et al. (2012) report that perceived relative advantage, observability, and compatibility are the most important factors in understanding the adoption of agricultural best management practices (such as the use of cover crops). Lamm et al. (2017) applied Rogers' (2010) characteristics of innovations to find complexity and compatibility to be the major factors influencing U.S. growers' adoption of water treatment technologies (such as chlorination). In a wider agricultural context, Pierpaoli et al. (2013) identified three main adoption drivers by reviewing 20 studies: competitive and contingent factors, socio-demographic factors, and financial resources. Hereby trialability/observability, size, facilitating factors, and perceived ease of use were classified into competitive and contingent factors; social factors, age, previous experience, and confidence were categorized into socio-demographic factors; and cost, perceived benefit, and perceived usefulness were labelled financial resources. This review concludes that innovations should be based on benefits to the growers/farmers, either through an improvement or by doing something easier and/or cheaper than before to achieve innovation diffusion.

Finally, several authors emphasize the importance of risk. At a conceptual level, risk is often defined as '*risk perception*' and can be seen as a barrier towards adoption behavior (Batte and Arnholt, 2003). In that sense, some authors consider 'risk' as belonging to the construct of PBC as it is decribed as the grower's interpretation of the riskiness of the investment linked to possible rewards and failures (Bocqueho et al., 2014). However previous research also consider risk as '*risk tolerance*' which is defined as the growers' general predisposition towards assuming risk (Hoffmann et al., 2013). Pennings and Wansink (2004) pose that risk perception ranges from perceiving no risk at all to perceiving high risk, while risk tolerance ranges from extremely risk averse (refusing any risk under any condition) to extremely risk seeking. In previous research risk tolerance was found to be related to the signing of crop insurance contracts and the adoption of crop diversification, marketing strategies, and crop innovations (Hellerstein et al., 2013). Pennings and Wansink (2004) show a moderating effect of risk perception on the relation between motivational drivers and adoption intention. In a study conducted in the hog industry, Trujillo-Berrera et al (2016) report a moderating effect of risk tolerance but not of risk perception on the relation between expected rewards and adoption of sustainable practices. In the current study, we explore both 'risk perception' and 'risk tolerance'.

Besides identifying the main drivers and potential barriers to the adoption of promising climate-friendly technologies by growers, it is important to identify interesting target segments and how they differ in terms of the adoption process. First of all, not all potential users change their behavior towards using promising technologies and practices, even when these have proven superior characteristics (Diederen et al., 2003). Indeed, diffusion of innovations typically takes time and rarely covers the whole potential adopter population immediately. It is particularly important to identify innovators and early adopters and explore how they adopt technological innovations. In previous research, market share and firm size have been identified as determining factors (Karshenas and Stoneman, 1995). However, Tey and Brindal (2012) also refer to a large set of other firm-related factors to classify growers into adoption categories, such as operator age, years of farming experience and formal education, farm size, and farm sales. Besides these variables, two variables are often reported as relevant for early adopters and innovators: *opinion leadership* and *innovativeness* (Moons et al., 2012). Opinion leadership refers to the inclination of lead users being at the forefront and drive an innovation forward. They are often the first ones to use the product or technique, having information and willing to buy the product. They acknowledge the link between their need and the solution of the technology. Opinion leaders are often innovative and, equally importantly, influence their peers in adopting innovative solutions (Arts et al., 2011).

2. Methods

The conceptual framework in Appendix A was empirically explored using a mixed-method research design. In line with the study of Warner et. al. (2020) the qualitative part tries to identify the drivers and barriers towards the adoption of the GLITCH innovations. Data from the qualitative study were triangulated with information from a quantitative study that additionally explored adopter segments within the grower population. Participants in both parts of our study got the following information. '*In the context of the GLITCH project, an interregional research project between Flanders and the Netherlands that investigates innovations in the greenhouse horticulture sector, we appreciate your opinion about sustainable innovative techniques. We want to find out which aspects are important to you when you would intend to implement these innovations in your company. The innovations are technological cultivation systems and cultivation techniques that contribute to a sustainable greenhouse horticultural industry. Examples include LED lighting, multi-layer cultivation, energy balancing screen, and low-grade heat systems.*'

2.1 Qualitative research

From May 2020 until October 2020, 28 semi-structured in-depth interviews were conducted (n=13 Belgian growers, n=15 Dutch growers). Growers from small, medium-sized, and large greenhouse cultivation companies were included (ranging from 1.2 ha to 31 ha). The sample included growers with different crop cultivation: tomato, bell pepper, cucumber, strawberry, lettuce, or a combination of these crops. The Belgian growers were interviewed by two academic researchers. For the interviews with the Dutch growers, a collaboration with a Dutch market research firm was set up. Due to the COVID-19 pandemic, the interviews were conducted online. The interviews lasted between 24 and 77 minutes, with an average of 47 minutes. The (with permission) recorded interviews were anonymized in the transcription process. The literature review was used to construct a topic list for the interviews.

First the growers presented their company in terms of the size of their greenhouses, the innovations they adopted in the past, the company owner's future succession, how they look at the future of their company, and the crops they cultivate. Subsequently the interviewers presented the GLITCH innovations. Spontaneous reactions were registered, and the interviewees were probed to express their intentions and attitudes towards these innovations. The influence of the five IDT elements on this opinion was further investigated. Next, an in-depth discussion of barriers and motivators towards the adoption of the innovations was held, starting with subjective norm related elements such as the influence of stakeholders and information channels they consult. Then, perceived behavioral control barriers and drivers were discussed, such as financial, environmental, and crop-related factors, and factors related to working conditions. Finally, risk perception and risk tolerance were explored.

2.2 Quantitative research

The quantitative research was conducted from December 2020 until January 2021 in collaboration with a Dutch market research agency. Starting from a growers file they selected horticultural firms that grow relevant greenhouse cultivated crops (in line with the ones we investigate for the GLITCH project). Out of this dataset (n=1250), they randomly selected the respondents. A total of 152 growers completed the survey. Different kinds of crops were represented: tomato, lettuce, cucumber, strawberry, bell pepper and a combination of crops. The sizes of the companies they represent vary from less than 1 ha to more than 15 ha of glass covered cultivation. See Appendix B for sample description and a comparison with the actual crop distribution in the greenhouse industry.

To increase participation, we opted for phone calls with a limited questionnaire (less than five minutes). At the beginning of the questionnaire, the respondents were given the above-mentioned description of the GLITCH innovations. Next, the respondents were asked about the kind of crops they grow, and the techniques they use in the greenhouse. Subsequently, all constructs in the conceptual model in Appendix A were measured. The measures and their items are shown in Appendix C. For all items of these measures, 5-point Likert scales were used, ranging from 'totally disagree' (1) to 'totally agree' (5). First, *attitude (AT)* was measured using one item, followed by *adoption intention (AI)* (two items). *Subjective norm (SN)* was measured with four items. Then, the five antecedent factors of the attitude towards innovation from the *IDT* were measured with one item for each factor. As for *perceived behavioral control (PBC)* four items were used, namely financial reasons (FR), environmental reasons (ER), working conditions (WR) and crop condition (CR). *Risk tolerance (RT)* was measured by means of one item. Next, the *green identity (GI)* of the growers was measured using four items. Finally, two variables were measured to be used in the segmentation analysis. *Innovativeness (IN)* consists of four items and *opinion leadership (OL)* was measured with one item.

2.3. Data analysis

For the qualitative part of the study, the transcripts of the interviews were analyzed using the qualitative text analysis software NVivo. The data was analyzed by following an a priori coding scheme that was adjusted throughout the coding process, based on observations emerging from the data. The final coding scheme revealed the following main- and subcodes: adoption intention, attitude, the IDT factors, subjective norm, growers ability factors, perceived behavior control, risk perception, finance-related factors, environment-related factors, work condition related factors, crop-related factors, subjective norm, reputation of the company, risk tolerance, experience with past innovations and innovator profile. The coding schema is presented in Appendix D.

For the quantitative part of the study, we used IBM SPSS Statistics 27. AI was measured with two items that are sufficiently correlated (appendix C). We used the mean of these variables in the analyses. For the multi-item measures, SN (Subjective Norm), IN (Innovativeness), GI (Green Identity) and the IDT factors, first a principal components analysis was carried out. The results of these analyses can be found in Appendix E. For SN, IN and GI, this analysis resulted in one-component solutions. Next, we carried out Cronbach's Alpha analyses to test scale reliability. Two of the Alpha values are lower than the commonly used,.70 cut-off, namely SN and GI. Removing scale items does not improve these Alphas (see also Appendix E). However, the traditional .70 cut-off is rather arbitrary (see, for instance, Taber, 2018 and Van Griethuijsen et al., 2015) and also depends on the number of scale items: smaller scales typically result in smaller Alphas. Therefore, for instance Hair et al. (2019) qualify an Alpha >.60 as 'moderate' or 'acceptable'. For each of these three constructs we used the mean of their items for further analysis. The five IDT factor items were also entered in a principal component analysis with oblique rotation, resulting in two components (see appendices C and E for details). These components are: compatibility and lack of complexity (perceived ease of use) (CompSimp) and trialability and observability (TriObs). Since the two items of the first component and the two items of the second component were sufficiently correlated, we used the means of the two items loading on each of these factors in further analysis. The remaining item, Relative advantage (perceived usefulness) (RelAdv), was also used in subsequent analyses.

Clusters of growers were derived on the basis of a K-means cluster analysis based on two cluster variables, i.e., innovativeness and opinion leadership, leading to three clusters, based on the significance of the difference between clusters for the two cluster variables, and the interpretability of the cluster characteristics (Appendix F). Differences in cluster member characteristics were tested by means of chi^2 analysis and t-tests (Appendix G).

The conceptual model was tested by means of multiple linear regression analysis, both for the full sample and for two clusters separately. These results can be found in Appendices H and I. In what follows, we first describe the results of the qualitative study and then of the quantitative study.

3. Results

3.1 Drivers of and barriers to the adoption of sustainable innovative solutions

3.1.1 Attitude and adoption intention

All interviewees indicate that their attitude as well as their intention to use the proposed sustainable innovations are influenced by four out of the five elements of the IDT. Only complexity seems no issue in this technological context. Observability is mentioned by 22 out of the 28 interviewees. Furthermore, trialability appears to be an important aspect, as it is mentioned by 19 interviewees. Many horticulturists seem to carry out experiments regularly, sometimes through research centers and sometimes within their own company. (*"I'm still an old-fashioned grower, I want to walk around in the greenhouse and feel the innovation. I want to feel whether it's good or not.").* Half of the interviewees mention compatibility with cultivation techniques and crop growing conditions, company values, and infrastructure. Nineteen growers mention that the innovation should have a clear advantage over the technique that they currently use, including allocation of the workforce, year-round production, cost savings, healthier crops, higher-quality products, simplification of tasks and higher efficiency.

3.1.2 Subjective norm

Subjective norm recurs in all interviews and is mentioned most frequently out of all factors. Growers appear to rely on different sources to gain information and seek opinions. Growers often visit *peers* (n=26) to observe technologies, innovations, and cultivation techniques. (*"Of course we often talk to colleagues! We regularly visit each other's companies.")*

Most growers talk about environmental regulations imposed by the *government*. Some growers believe the government's rules are justified and beneficial for the environment (*"In the end, we can all complain about the regulations, but I think laws and regulation in the Netherlands have brought us to a very high level.")*, while others seem to find the regulations unjustified and not helpful. (*"It's always going to get more difficult. You should try starting a new company, you aren't able to obtain the necessary licenses." / "Often I think: government, mind your own business.")*

The influence of *retailers* is mentioned by 23 interviewees and can be considered a relevant factor in growers' decision-making processes as they impose a lot of conditions, often related to sustainability (*"We are Planetproof certified, also because supermarkets ask for that. They impose it on us as a condition, but then the retailers and the market are not willing to pay a higher price for it.")*

Consumer demand (as mentioned by all interviewees) seems to have an important impact on growers' production processes and product assortments (*"Perhaps we would like to grow strawberries during winter, but if none of our consumers or customers ask for it, then it doesn't make a lot of sense.").* The consensus among the growers seems to be that consumers are not willing to pay a higher price for sustainable products. (*"The Dutch consumers say they want sustainable products but when they're in the store they choose the cheapest products possible."*)

Horticulturists perceive the *employees and coworkers'* support as an essential factor for the success of an innovation, and state that they would not adopt the innovation without their team believing in it. (*"Usually I also consult with my co-company directors, because when investing in an* *innovation, my entire team needs to agree and understand what I'm doing, ... If my team complains and says that they really don't want to do it, I won't.")*

According to the interviewees, the following *information channels* seem to be most relevant as these are all mentioned at least twenty times: suppliers and representatives, research centers, trade magazines, advisers, and the internet.

3.1.3 Perceived behavioral control

Amongst others, technical cultivation aspects (nineteen mentions), year-round production (seventeen mentions), market demand (fifteen mentions), and personal ability (fourteen mentions) are important barriers and motivations to adopt the innovations. A remarkable result is the frequent spontaneous reference to labor circumstances (fifteen mentions) as an important consideration when adopting innovative technologies.

When an innovation helps the agriculturists to produce more *high-quality products*, to have healthier plants and to achieve this in a simplified way, they appear to be more inclined to adopt it. (*"How can you measure the happiness of a person? That's how he or she produces. When you're happy, you'll be able to do a lot more. A happy plant also produces more.")*

When an innovation makes the *work conditions* within their company more pleasant or efficient, growers seem more inclined to adopt the innovation. Some growers aim for year-round production based on customer demand, while others see it as a way to ensure labor continuity. *("Our customers asked us to start producing year-round.")*

The three *financial subfactors* that were raised most frequently are the following: return-on-investment (ROI), (*"The most important factor is of course the ROI."),* payback period (*"Smaller investments definitely need to be paid back in a period of three to five years. For larger investments, you need to take into account a period of ten years. But if the payback period is twenty years, then...)*, and investment cost. In addition, the low sales price of crops is also mentioned multiple times (*"The largest barrier for me is market prices that are too low, which is not the case for just one year but for a longer period").*

Additionally, *personal ability* is brought up by several interviewees as a barrier to innovation. ("*I'm 50 years old, it's not the time and place to invest in big innovations anymore."/ "Our company is too small for such a project." / "I don't have any successors so what would I be doing it for*?").

3.1.4 Risk

In the interviews a distinction between risk perception and risk tolerance was observed. Risk perception is mentioned less frequently than expected. Some growers (n=5) indicate that they have not undertaken certain investments because they perceived the risk as being too high. Other growers (n=9) seem to like to expose themselves to high risks and seem to be risk tolerant or even risk seeking. *(Eventually we decided it was too risky to carry out such big innovations in our own company." / "I get an adrenaline rush from organizing my cultivation process this way.")*

3.1.5 Additional factors

Several additional factors emerged from the qualitative study. Growers' negative *experiences with past innovations* is a topic that recurs frequently as important learning moments that prevent them from making similar mistakes in the future. One of the often-mentioned reasons for past failure is "being too early" and wished to have waited for more results (from research centers, peers, etc.) before carrying out the innovation.

About one-fourth of the interviewees appear to see their *company's reputation* as an important factor when deciding on an innovation. Some growers indicate that being innovative and sustainable helps in the brand-building process and can be used in marketing efforts towards customers *("We have transformed an exchangeable bulk product into a brand that people ask for. They ask for our tomatoes, and in the end that's what every company wants.")*. Other growers mention that they care about their company's reputation and image. *("It's nice to show our company and say 'Look, we are concerned with our environment, ...'")*

The majority of the growers seems to be aware of their *impact on the environment* and have undertaken several initiatives. The increasing environmental awareness stems from various sources like the grower's own beliefs, market demand, regulations etc. The feeling that "sustainable" is being used as a buzzword nowadays is recurring in many interviews. (*"I think the word 'sustainable' is being described in a wrong way. What is sustainable? A tomato grown with artificial lighting or a tomato imported from Morocco?")*

The majority realizes that paying attention to the environment has become inevitable. A group of growers undertake sustainable initiatives driven by *intrinsic motivation*, with a clear consensus that people and organizations owe it to the planet. This subgroup seems to be aware that they have a bigger influence on the environment than individual consumers (*"I believe that, as a company, you can actually have a bigger influence on the environment than as an individual. Especially with a company sized like ours, you can take bigger steps with regards to the environment.")*. The other group is driven by *extrinsic motivations* and undertake sustainable actions due to external pressure.

3.1.6. A quantitative test of the conceptual model

To corroborate the findings from the qualitative in-depth interviews discussed above, we carried out a quantitative analysis by empirically testing the model in Appendix A. First, a multiple linear regression analysis was conducted to predict adoption intention (AI). The independent variables was attitude (AT), subjective norm (SN), four separate PCBs (financial reasons (FR), working conditions (WC), environmental reasons (ER), cultivation reasons (CR), and risk tolerance (RT). The model is significant and the results are shown in Appendix H. Attitude has the strongest significant influence on adoption intention. Also, the perceived amelioration of working conditions as well as the subjective norm (the latter marginally significant) exert a significant influence on the intention to adopt sustainable innovative solutions. A second regression analysis (Appendix I) that was carried out to predict the attitude towards the sustainable innovations by means of the IDT variables was not significant. These findings only partly corroborate the findings from the qualitative study.

3.2 Characteristics of early adopters of sustainable innovative solutions

To answer the second research question concerning the identification of early adopter segments, we carried out a K-means cluster analysis based on two variables, i.e., innovativeness and opinion leadership, leading to three clusters (Appendix F). Both innovativeness and opinion leadership scores are significantly different across the three clusters. The smallest cluster (n=13) 'Wait and see' is the least inclined to adopt the innovations. Cluster 2 (n=78) 'Innovators' is the most innovative one, and cluster 3 (n=61) 'Open-minded growers' is somewhat in between. Bonferroni pairwise t-tests (all p<.05) reveal that adoption intention scores are significantly different between each pair of clusters. Innovators are more innovative than open-minded growers which, in turn, are more innovative than 'wait and see' growers. Bonferroni pairwise t-tests (all p<.05) show that the innovativeness scores are significantly different between each pair of clusters. Innovators and 'Wait and see' growers score significantly higher on opinion leadership than Open-minded growers (Bonferoni pairwise t-test significant between cluster 3 and 1 and between cluster 3 and 2 (p<0.05).

Half of the growers can thus be qualified as innovators (they are both highly innovative and opinion-leading), and another 40% scores relatively high on innovativeness, although they are not very opinion-leading. Only a relatively small minority (8,5%) are not open nor innovative concerning new sustainable technological solutions. Adoption intention differs significantly between the clusters (p<0.001), ranging from 2.88 for the 'wait and see' cluster, 3.39 for the open minded growers and 3.80 for the innovators on a five point Likert scale. This is consistent with the results from the qualitative interviews. When considering the innovation attitude and behavior of the growers, thirteen of them could be categorized as innovators (*"I like to be ahead of other growers and try out new things, that's what makes cultivating more fun.");* ten of them are open-minded (*"I think it's fun not to be the first one, but to be part of the first ones."*) and five of them wait and see (*"We don't innovate too quickly or hasty. We really need to be convinced of the relative advantage and it needs to feel right.").*

3.3 Differences between innovators and open-minded growers

Since we are especially interested in the early adopter groups of the sustainable innovation, and since only a limited number of growers are classified as 'Wait and see', we only tested the differences between the Innovators and the Open-minded growers. The Innovators are more likely to adopt the leading innovation and at the same time to exert influence on other growers. The open-minded growers are 'following' this group as they are less opinion-leading themselves. Appendix

G shows that both segments appear to be very similar. However, the innovators on average have larger greenhouse areas, innovated their infrastructure more recently, identify more with ecological friendly business management, are more frequently represented in cucumber cultivation, and are marginally less concerned with the triability and observability of innovations.

Next, we test the model in Figure A (drivers of and barriers for innovation adoption) separately for the two groups using multiple regression analysis (Appendices H and I). In line with the regression model applied to the overall sample, for innovators, attitude is the most important predictor for adoption intention. The opinion of relevant others (SN) as well as the beneficial effect the innovation might have on working conditions also have a positive influence. Environmental as well as financial factors exert a negative effect on adoption intention. For the Open-minded growers, only the attitude towards sustainable innovation has a significant positive effect. As the regression analysis in Appendix I shows, the models predicting attitude by means of the three IDT factors are not significant for either group.

4. Discussion

The current paper proposes a conceptual model of the drivers and barriers towards the adoption intention by horticultural greenhouse growers of sustainable innovative solutions. As observed in both the qualitative and the quantitative study, and as often reported in TPB-related research, attitude is the main predictor of the intention to adopt sustainable innovations. Although not corroborated in the quantitative study, based on the interviews, attitude seems to be mainly driven by the relative advantages of the sustainable innovative solutions, which is in line with earlier research (Batte and Arnholt, 2003). However, growers consider trialability and observability important as well. This underpins the importance of the experimental centers for horticulture that were set up in the last decades. Growers are open to be involved in test settings with innovative solutions and are willing to share their experiences. We expected that compatibility of an innovation with existing infrastructure could be an issue, but it appears to be of less importance, since most innovative growers consider thorough innovations once they want to invest in their greenhouse of the future. Nevertheless, compatibility with business strategy and with a company's sustainable orientation drive a positive attitude. The importance of trialability, observability and compatibility is in line with previous findings. For instance, Reimer et al. (2012), report that perceived relative advantage, observability, and compatibility are the most important factors in understanding the adoption of the use of cover crops. Lamm et al. (2017) found complexity and compatibility to be the major factors influencing U.S. growers' adoption of water treatment technologies. However, some of our findings contradict their results as the lack of complexity (perceived ease of use) does not drive the attitude towards innovation. A possible explanation for the reluctance towards 'easy and simple' solutions is the context of our research. Growers may naturally expect that more technology-driven solutions are generally more complex because they are confronted with complex challenges.

The interviewed growers are influenced by the social pressure (SN) exerted by experimental centers, peer growers, retailers, consumers, governments, and information channels. These findings are in line with earlier studies. For instance, Hansson et al., (2012) found that peers (subjective norm) such as the network of growers with their neighbors, friends and colleagues, have a substantial impact on farmers' decisions. Greenhalgh et al. (2004) report that expert opinion (crop consultants, horticultural scientists, bioengineers, advisory service providers, universities, and research centers) is very important to improve and change greenhouses' effectiveness and development. As growers seem to be very much involved in their business and as they are aware of the ever-changing context they are operating in, they are eager to get informed by many sources (Verstegen et al., 2003).

With respect to perceived behavioral control, the qualitative study reveals that some growers feel less able to get involved in new sustainable innovations due to their age or due to their personal or financial situation. Indeed, from a personal perspective, the changes in the horticultural industry in the studied region may be a concern. Increasingly more horticultural greenhouse companies started to scale up to increase profits. As a result, during the last decades, the number of growers has halved (from 15,700 in 2006 to 8,300 in 2016) and the surface area per company has drastically increased (from 0,555 ha in 1980 to 2.15 ha in 2014). There are increasingly more large companies (e.g., in 1990 two growers of 100 ha or more and in 2007 69 growers of 100 ha or more) (Beelen, 2018). Consequently, growers with fewer acres and with less financial power may consider this as a serious barrier to innovation. The fact that especially financial considerations (and related yield size and quality) are mentioned, is in line with the findings of Batte and Arnholt (2003). In his review of 20 studies also Pierpaoli et al. (2013) report that financial resources are amongst the three main adoption drivers.

In line with Forbes and De Silva (2015), we find that environmental drivers are gaining importance for today's growers. An important motivational distinction is the one between intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation, which refers to doing something because it leads to a separable outcome The drivers of the growers appear to be mainly intrinsic because they want to take their responsibility for the deteriorating planet, which is in line with Steg (2016). Acting pro-environmentally can make growers feel good about themselves and give them pleasure from benefiting the environment. Hereby, intrinsic motivation is likely to be obligation-based rather than enjoyment-based as growers may feel obliged to follow their principles, norms, and values to engage in pro-environmental actions, and doing so elicits pleasant feelings. The results from our interviews are in line with research as from Mzoughi (2011) on integrated crops and organic farming that shows that, although economic concerns play a strong role, a significant number of respondents give high importance to moral and social concerns, such as working conditions and impact on the environment. Consistent with Verstegen et al (2003), laws, rules and external incentives or punishments, which are considered external drivers, are rather classified as a barriers by the interviewees. They mainly perceive the changing imposed environmental rules as irritating and perceive the laws as not transparent. The importance of financial barriers and environmental motives are not confirmed in the quantitative study. However, the fact that growers are concerned about the working conditions for themselves and their employees was found in both the qualitative and the quantitative study. This was also confirmed in other studies in the GLITCH project.

Growers' concern with their company's reputation explains why they take care of the environment as well as of employees. This is in line with previous research that posits that the long-term viability of a firm depends on its fit with the values of society, and the benefits that it achieves for all stakeholders (Brønn and Vidaver-Cohen, 2009). Indeed, companies are devoting more attention to ethical and sustainable aspects and take up social responsibility (Nguyen et al., 2021). Moreover, building an innovative brand personality seems an opportunity for most growers. Several growers seem eager to take risks and have a high risk tolerance. This is in contrast to what we expected based on earlier findings by, for instance, Trujillo-Barrera et al. (2016). Also Pennings and Wansink (2004) found a moderating effect of risk perception on the relation between motivational drivers and adoption intention. However, negative past experiences seem to trigger risk perception and refrain other growers from trying out new opportunities.

This study also identified three grower segments in terms of their level of innovativeness and opinion leadership, and explored differences between them, with special focus on the large groups of innovators (more than 50%) and open-minded growers (almost 40%). The results from this quantitative study are in line with the qualitative insights: most growers are very open to innovations. In the pursuit of a vital, sustainable, and climate-neutral greenhouse horticulture by 2050, the industry is investing a lot in innovation (Galen and Ge, 2009). Policy support seems to affect growers' attitudes and business perspectives. The innovator group is different from the open-minded group in that the former are, on average, larger (more greenhouses surface) and more recently innovated their greenhouses thoroughly. This is partly in line with research that reports on the role of firm-related characteristics. For instance, Karshenas and Stoneman (1995) report that market share and firm size are important determinants of innovation. Also Tey and Brindal (2012) found that, apart from other firm-related factors such as operator age, years of farming experience and formal education, farm size and farm sales are important drivers of innovation. Moreover, innovators are more oriented towards the environment than other segments. For both groups, the attitude towards sustainable innovation initiatives is the most important driver of adoption intention, and working conditions also play a significant role. Specifically, for innovators, environmental motivators, and financial considerations also drive adoption intention.

The conceptual contribution of the current research is that it develops and explores a model in which the insights of the Theory of Planned Behavior, the Technology Acceptance Model and the Innovation Diffusion Theory are integrated and extended, more specifically by adding the risk tolerance factor. Additionally, two seemingly important extra factors were identified that could enrich future research on the adoption intention of sustainable innovative innovations, namely company reputation and previous experiences with innovations.

5. Managerial and public policy implications

Industry leaders and public agents can use the insights of our study to support and promote sustainable innovations more efficiently. One way to improve growers' attitudes is by emphasizing that these innovations are a way to enhance their corporate as well as their brand reputation. As social pressure is important, investing in networks can be stimulated, especially by involving the growers in the 'innovator' segment. Companies that develop innovative technologies should also focus on the impact of these innovations on working conditions and efficient deployment of their innovations in practice. Good working conditions in an innovative company may be used as a proposition that can attract good-quality and motivated employees. Awareness campaigns should emphasize successful best-practice cases with positive (financial) results and a positive impact on the company's reputation. As the impact of sustainability measures is still a bit confusing for the growers, good impact indices and communication about the impact on the environment should be made clearer. Negative past experiences seem to trigger risk perception and refrain other growers from trying out new opportunities. Therefore communication to reassure growers and counter the perception of potential risk should be given attention when introducing innovative techniques. Testimonials from others growers as well as demonstrations by experience centers can play a crucial role. Risk reduction can also be incorporated in the business model by offering sufficient services and/or by changing the idea of 'ownership' of the innovative technique.

As literature on the interplay between internal and external motivation stress the importance to support internal motivational processes by rewards (external motivations) and moreover, as studies on risk perception and risk tolerance reveal the importance of perceived rewards on the willingness to adopt sustainable technologies by farmers, policymakers should implement supportive implementation strategies based on incentives.

6. Limitations and further research

Although we conducted a rather extensive qualitative and – compared to many other similar previous studies – also quantitative study, the quantitative part of our study was still limited, both in terms of sample size and variables included in the model. Moreover we opted for a limited interview time to obtain a high response rate and therefore used single item scales for some of the variables, which limited our ability to conduct more sophisticated analyses. Some multi-item scales we used had relatively low Cronbach Alphas, more particularly 'green identity' and 'subjective norm'. Deleting items did not improve the Alphas. Adding more items to the scale could increase these Alphas. For subjective norm, following Ajzen (1991) we suggest to determine with a pilot study which groups are influencing decision-making as normative beliefs and motivation to comply should be assessed for each relevant reference group and for each specific topic. This may lead to additional subjective norm items (reference groups that influence decisions and/or information channels). Further, in future research, authors can consider measuring organizational green identity by using or adding (some of the) six scale items developed by Chen (2011) and used by Song and Yu (2018): 'The company's top managers, middle managers, and employees… (1) have a sense of pride in the company's environmental goals and missions; (2) have a strong sense of the company's history about environmental management and protection; (3) feel that the company has carved out a significant position with respect to environmental management and protection; (4) feel that the company have formulated a well-defined set of environmental goals and missions; (5) are knowledgeable about the company's environmental traditions and cultures; (6) identify strongly with the company's actions with respect to environmental management and protection.'

The explanatory power of our regression models is rather low. This means that the chosen variables could only explain a limited part of the variation in attitude and adoption intention. Therefore, we suggest future research to develop a more complete conceptual framework that includes additional variables. Potentially interesting factors that emerged from the qualitative study are reputation and previous experiences. Additionally, other variables could be considered, such as cultural and environmental values. Also personality traits which may determine growers' business development strategies might be considered, such as ambiguity aversion, fear of negative evaluation, and locus of control. Finally, many growers seem to be concerned about both working conditions and the environment. Also these factors may be included in future research. The distinction between internal and external underlying motivations for sustainable innovation behavior, for instance descriptive or injunctive norms (Park and Smith, 2007), a factor that is to date understudied in a business context, could be further explored. The role of risk is not fully understood either. Having to take risks is a consideration for innovators, but the pride of being the first one to adopt a high-tech innovation is also important. Related to this, the interplay between brand building, reputation management and adopting sustainable high-tech innovations is relevant. What is the relative importance of sustainability and high-tech motivations to increase brand equity? Besides predominantly rational variables that we included in the adoption intention model, more feeling-related drivers may play a role, and should be investigated in more depth. In a larger sample, structural equation modeling could be used to investigate such a more comprehensive model that would also allow to formally test mediation and moderation mechanisms.

7. Conclusions

The current study proposes and tests an integrated model of the drivers and barriers towards the adoption intention by horticultural greenhouse growers of sustainable innovative solutions. The attitude towards the innovation is the main predictor of this adoption intention This attitude seems to be mainly driven by the relative advantages of the sustainable innovative solutions. However, growers consider trialability and observability important as well. Growers are open to be involved in test settings with innovative solutions and are willing to share their experiences. Compatibility with business strategy and with a company's sustainable orientation also drive a positive attitude. Additionally, growers are profoundly influenced by experimental centers, peer growers, retailers, consumers, governments, and other informationchannels. Some growers feel less able to get involved in new sustainable innovations due to their personal or financial situation.

Environmental drivers are gaining importance for today's growers. They want to take their responsibility, and follow their principles, norms, and values to engage in pro-environmental actions. Additionally, growers give high importance to social concerns, such as working conditions. These factors are also fueled by growers' concern with their company's reputation Moreover, building an innovative brand personality seems an opportunity for most growers, and several growers have a high risk tolerance, although negative past experiences seem to trigger risk perception and refrain other growers from trying out new opportunities. Most growers perceive themselves as true innovators, or at least open-minded towards innovation. Policy support seems to partly drive these attitudes and business perspectives. True innovators are often larger and more oriented towards the environment than other grower segments.

Industry leaders and public agents can use the insights of our study to support and promote sustainable innovations more efficiently. One way to improve growers' attitudes is by emphasizing that these innovations are a way to enhance their corporate reputation. Investing in networks can be stimulated, especially by involving the growers in the 'innovator' segment. Good working conditions in an innovative company may be used as a proposition that can attract good-quality and motivated employees. Awareness campaigns should emphasize successful best-practice cases with positive (financial) results and a positive impact on the company's reputation. Testimonials from others growers as well as demonstrations by experience centers can play a crucial role.

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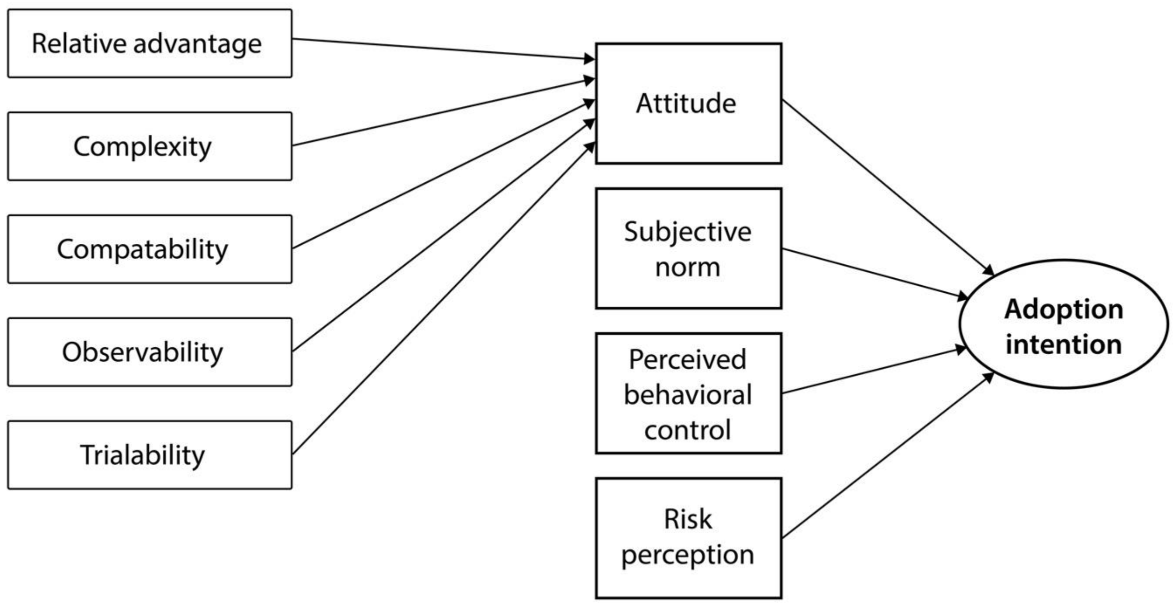
Appendix A: Conceptual model



Appendix B: Sample characteristics

		Frequency in sample	Percentage in sample	% of actual greenhouses growing these crops(*)
What kind of crops do you grow? (More than one option possible)	Lettuce	12	6.1	5.4
	Cucumber	50	25.4	16.8
	Tomato	35	17.8	19.8
	Bell Pepper	22	11.1	15.9
	Strawberry	30	15.2	19.2
	Other	48	24.4	22.9
	Total	197	100	100
How long have you been active in the industry?	<3 years	7	4.6	
	3-5 years	6	4.0	
	6-10 years	11	7.2	
	11-20 years	27	17.8	
	>20 years	101	66.4	
	Total	152	100	
When were the greenhouses in your company thoroughly renovated the last time?	<3 years	20	13.2	

	3-5 years	19	12.5	
	6-10 years	15	9.9	
	11-20 years	62	40.7	
	>20 years	36	23.7	
	Total	152	100	
Are you the… generation from your family in this company?	First generation	49	32.2	
	Second generation	44	28.9	
	Third generation or more	57	37.5	
	Total	150	98.6	
	Does not apply	2	1.4	
With regard to succession, do you plan to hand over the business within five years?	Yes	37	24.3	
	No	115	75.7	
	Total	152	100	

Which of the following applies to you? Whenever I want to stop.	Follow-up is assured	26	17.1	
	I will sell the company to another (cultivation) company	22	14.5	
	The company stops	14	9.2	
	I don't know at the moment	90	59.2	
	Total	152	100	
How large is the company in terms of greenhouse area?	Up to 1 ha	21	13.8	
	1 to 5 ha	78	51.3	
	6 to 15 ha	34	22.4	
	More than 15 ha	19	12.5	
	Total	152	100	
Age	45 years or less	45	29.6	
	46-54	64	42.1	
	55 or older	43	28.3	

	Total	152	100	
Gender	Male	138	90.8	
	Female	14	9.2	
	Total	152	100	

(*) Based on: https://www.cbs.nl/nl-nl/nieuws/2017/32/vooral-tomaten-in-de-kas

Appendix C: Measures

Measure	Items	Reference	Mean	S.D.	Cronbach Alfa or Pearson correlation
AT	To what extent are you positive about these innovations aimed at climate-neutral greenhouse horticulture?	Cauberghe and De Pelsmacker (2008)	3.70	0.906	
AI	1.I intend to engage in technological innovations in the near future 2.I advise other growers to engage in technological innovations	Moons and De Pelsmacker (2012)	3.56	0.835	r=0.407
SN	To what extent do you consider the following information that you receive from others important when taking a decision to engage in a technological innovation (such as LED lighting system, low-value heat system, multi-layer cultivation, balancing screens) 1. Information by fellow growers 2. Information provided by government 3.Information from grower organizations 4. Information provided by test and other knowledge centers	Based on Haustein et al. (2009) and on qualitative research	3.62	0.588	Cronbach Alpha = 0.631 (no improvement when items are deleted)
IDT	CompSimp (Perceived ease of use) 1. Must fit in my current greenhouse	Rogers (2010)	4.02	0.687	r=0.393

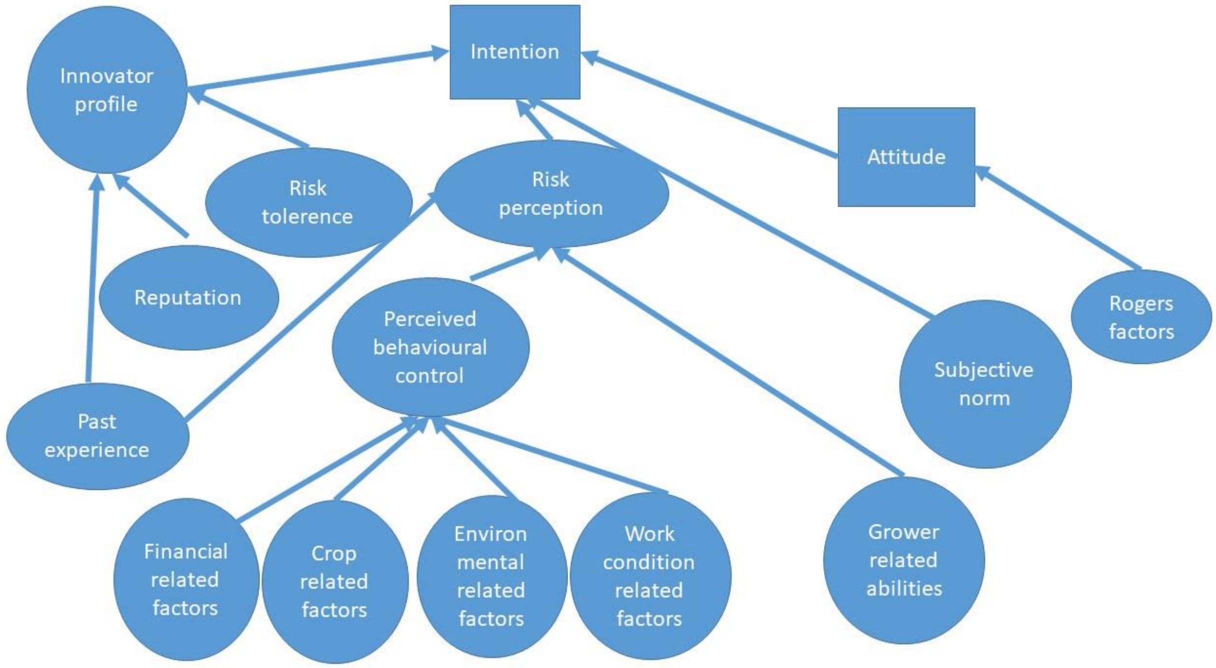
	2. Must be easy to use				
	Reladv (Perceived usefulness): 1. Must have advantages over current system	Rogers (2010)	4.39	0.691	
	TriObs: 1. Must have already been applied by others 2. Must already demonstrate visible results	Rogers (2010)	3.60	0.814	r=0.507
PBC	To what extent are the following factors important when making a decision about technological innovations? Financial factors (FR)	Qualitative research	4.39	0.781	
	Effect on Working conditions (WC)	Qualitative research	4.13	0.740	
	Effect on the Environment (ER)	Qualitative research	3.89	0.768	
	Crop Cultivation Factors (CR)	Qualitative research	4.24	0.789	
RT	The risk associated with implementing these technological innovations scares me.		3.04	1.067	
IN	1. Innovations benefit the image of the greenhouse horticulture sector 2. I strive for an innovative image with my company 3. Innovations make the cultivation sector in our region more competitive 4. Innovations are needed to adapt companies in our region to the future	Adapted from Midgley and Dowling (1978) and qualitative research	3.78	0.563	Cronbach Alpha= 0.746

OL	1. To what extent do you agree with the following statement? Fellow growers consult me for advice on innovations in the greenhouse.	Grewal et al. 2000 Qualitative research	2.90	0.975	
GI	1. I see myself as an environmentally conscious business leader 2. I think I am concerned about the environment. 3. I see my company as an ecological company 4. I have already made several efforts for the environment with my company	Adapted items from Roe and Bruwer (2017) and Van der Werff et al. (2013)	3.57	0.612	Cronbach Alfa= 0.691 (no improvement when items are deleted)

(*) https://www.cbs.nl/nl-nl/nieuws/2017/32/vooral-tomaten-in-de-kas

AT = Attitude; AI = Adoption Intention; SN = Subjective Norm; IDT = Innovation Diffusion Theory factors; PCB = Perceived Behavioral Control; RT = Risk Tolerance; IN = Innovativeness; OL = Opinion Leadership; GI = Green Identity

Appendix D: Advanced coding scheme of the qualitative research



Appendix E: results of principal components and Cronbach's Alpha analyses

Subjective norm

KMO measure of sampling adequacy: .632
Bartlett's test of sphericity: p<.001
Extraction criterion: Eigenvalue >1 – one factor extracted, explaining 47.8% of variance

Component matrix

Item	Component
Information by fellow growers	.715
Information from grower organizations	.704
Information of test and other knowledge centers	.718
Information provided by government	.624

Cronbach Alpha analysis

'How important are the following information channels for you when you take decisions about technological innovations?'

Cronbach Alpha: .631

Item	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's Alpha if item deleted
Other growers	10.46	3.495	.429	.549
Grower organizations	11.08	3.318	.427	.550
Test centers and other knowledge centers	10.57	3.638	.445	.541
Government	11.39	3.539	.351	.607

Innovativeness

KMO measure of sampling adequacy: .736
Bartlett's test of sphericity: p<.001
Extraction criterion: Eigenvalue >1 – one factor extracted, explaining 52.2% of variance

Component matrix

Item	Component
Innovations benefit the image of the greenhouse horticulture sector:	.700
I strive for an innovative image with my company:	.740
Innovations make the cultivation sector in our region more competitive:	.740
Innovations are needed to adapt companies in our region to the future:	.747

Cronbach Alpha analysis

Cronbach Alpha: .746

Green identity

KMO measure of sampling adequacy: .729
Bartlett's test of sphericity: p<.001
Extraction criterion: Eigenvalue >1 – one factor extracted, explaining 53.4% of variance

Component matrix

Item	Component
I see myself as an environmentally conscious business leader:	.799
I think I am concerned about the environment:	.753
I see my company as an ecological company:	.667
I have already made several efforts for the environment with my company:	.698

Cronbach Alpha analysis

'To what extent do you agree with the following statements?'

Cronbach Alpha: .691

Item	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's Alpha if item deleted
I see myself as an environmentally conscious entrepreneur	10.493	3.656	.570	.570
I am concerned about the environment	10.678	3.571	.501	.609
I see my company as an ecological company	11.493	3.298	.426	.680
In my company, I already did several environmental efforts	10.224	4.360	.457	.648

Innovation Diffusion Theory factors

KMO measure of sampling adequacy: .600
Bartlett's test of sphericity: $p<.001$
Extraction criterion: Eigenvalue >1 – two factors extracted, explaining 80.0% of variance

Rotated component matrix:

Item	Components	
	1	2
Compatibility	.721	-.258
Ease of use	.846	-.069
Relative advantage	.566	-.353
Triability	.176	-.860
Observability	.343	-.858

Appendix F: Clusters of growers: innovativeness, opinion leadership and adoption intention

Clusters	Cluster membership	% of sample	Mean IN	Mean OL	Mean AI
Wait and see	13	8.6	2.63	3.46	2.88
Innovators	78	51.3	4.02	3.60	3.80
Open-minded growers	61	40.1	3.72	1.89	3.39
Significance			$F(2,149) = 62.159$ $p<0.001$	$F(2,149)=206.084$ $p<0.001$	$F(2,149)=9.884$ $p<0.001$
Total	152	100.0			

IN = Innovativeness; OL = Opinion Leadership; AI = Adoption Intention

Appendix G: Description of innovators and open-minded growers

	Crop	Frequency Innovators	Frequency open minded growers	Test	Sign
What kind of crops do you grow? (more than one answer possible)	Lettuce	6	4	chi^2	p=0.797
	Cucumber	30	13	ch^2	p<0.05
	Tomato	19	13	chi^2	p=0.170
	Bell Pepper	16	11	chi^2	p=0.135
	Strawberrie	10	11	chi^2	p=0.394
	Other	20	21	chi^3	
	Total	101	73		
How long have you been active in the industry?	<3 years	5	2	chi^2	p=0.496
	3-5 years	1	4		
	6-10 years	6	4		
	11-20 years	13	10		
	>20 years	53	41		
	Total	78	61		
When were the greenhouses in your company last thoroughly renovated?	<3 years	15	4	chi^2	p<0.1
	3-5 years	12	6		
	6-10 years	7	6		

	11-20 years	32	26		
	>20 years	12	19		
	Total	78	61		
Are you the… generation from your family in this company?	First generation	27	16	chi²	p=0.185
	Second generation	25	15		
	Third generation or more	20	25		
	Total	72	56		
	Does not apply	6	5		
With regard to succession, do you plan to hand over the business within five years?	Yes	14	18	chi²	p=0.347
	No	64	43		
	Total	78	61		
Which of the following applies to you? Whenever I want to stop.	Follow-up is assured	12	10	chi²	p=0.108
	I sell the company to another (cultivation) company	12	10		
	The company stops	5	7		
	I don’t know at the moment	49	34		
	Total	78	61		

How large is the company in terms of greenhouse area?	Up to 1 ha	6	9	chi²	p<0.05
	1 to 5 ha	36	38		
	6 to 15 ha	22	10		
	More than 15 ha	14	4		
	Total	78	61		
Gender	Male	73	53	Chi²	p=0.178
	Female	5	8	Chi²	p=.178
Age		Mean=47.80 SD=10.215	Mean=50.28 SD=9.255	t-test	p=0.297
GI		Mean=3.65 SD=0.681	Mean=3.45 SD=0.067	t-test	p<0.05
AT		Mean=3.82 SD=0.936	Mean=3.59 SD=0.067	t-test	p=.103
SN		Mean=3.68 SD=0.494	Mean=3.65 SD=0.604	t-test	p=.764
PCB(FR)		Mean=4.55 SD=0.550	Mean=4.38 SD=0.756	t-test	p=.133
PCB(WC)		Mean=4.23 SD=0.682	Mean=4.18 SD=0.533	t-test	p=.625
PCB(ER)		Mean=3.88 SD=0.789	Mean=3.97 SD=0.605	t-test	p=.486
PCB(CR)		Mean=4.33 SD=0.767	Mean=4.28 SD=0.636	t-test	p=.647
RT		Mean=3.10 SD=0.1.088	Mean=3.2.90 SD=0..961	t-test	p=.251
CompSimple		Mean=4.00	Mean=4.07	t-test	p=.569

		SD=0.739	SD=0.616		
RelAdv		Mean=4.49 SD=0.575	Mean=4.31 SD=0.743	t-test	p=.130
TriObs		Mean=3.53 SD=0.831	Mean=3.76 SD=0.762	t-test	p<0.1

GI= Green Identity; AT = Attitude; SN = Subjective Norm; PCB(FR) = Perceived Behavioral Control, financial reasons; PCB(WC) = Perceived Behavioral Control, working conditions; PCB(ER) = Perceived Behavioral Control, Environmental Reasons; PCB(CR) = Perceived Behavioral Control, Crop Condition Reasons; RT = Risk Tolerance; CompSimple = Compatibility and Simplicity; RelAdv = Relative Advantage; TriObs = Trialability and Observability

Appendix H: Regression analysis: Effects on adoption intention

	Overall sample		Innovators		Open mind growers	
	Beta	Sign.	Beta	Sign.	Beta	Sign.
Constant	0.237		2.384		-0.129	
AT	0.312	$p<0.001$	0.453	$p<0.001$	0.348	$p<0.05$
SN	0.144	$p<0.1$	0.163	$p<0.1$	0.196	$p=0.123$
PCB (FR)	0.048	$P=0.590$	-0.223	$p<0.05$	0.048	$p=0.741$
PCB (WC)	0.217	$p<0.05$	0.241	$p<0.05$	0.071	$p=0.622$
PCB (ER)	-0.025	$p=0.764$	-0.289	$p<0.05$	0.120	$p=0.358$
PCB (CR)	0.040	$p=0.638$	0.040	$p=0.751$	0.076	$p=0.558$
RT	0.086	$p=0.251$	0.071	$p=0.516$	-0.022	$p=0.864$
R	0.497		0.518		0.478	
R^2	0.211		0.195		0.126	
Sign.	$F(7,144)=6.754$ $p<0.001$		$F(7,70)=3.672$ $p<0.001$		$F(7,53)=2.241$ $P<.05$	

AT = Attitude; SN = Subjective Norm; PCB(FR) = Perceived Behavioral Control, financial reasons; PCB(WC) = Perceived Behavioral Control, working conditions; PCB(ER) = Perceived Behavioral Control, Environmental Reasons; PCB(CR) = Perceived Behavioral Control, Crop Conditions Reasons; RT = Risk Tolerance)

Appendix I: Regression analysis: Effects on attitude

	Overall sample		Innovators		Open mind growers	
Constant	4.837		5.756		4.453	
CompSimple	-0.10	p=0.243	-0.144	p=0.245	0.4	p=0.483
RelAdv	-0.05	p=0,558	-0.785	p=0.435	-0.098	p=0.759
TriObs	-0.079	p=0.255	-1.31	p=0.277	-0.183	p=0.198
R	0.165		0.271		0.235	
R^2	0.008		0.036		0.005	
Sign.	p=.249 F (3,148)=1.387		p=.127 F (3,74) =1.961		p=0.354 F (3,57)=1.106	

IDT = Innovation Diffusion Theory factors; CompSimple = Compatibility and Simplicity; RelAdv = Relative Advantages; TriObs = Trialability and Observability