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Sensing Technologies, Roles and Technology Adoption Strategies for Digital Transformation of Grape Harvesting in SME Wineries

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Abstract: The article improves understanding on leveraging new technology for DT (digital transformation) of grape harvest in SME wineries. It provides evidence on technologies used and workplace types deployed in grape harvesting, as well as strategic paths in deploying new technology, thereby contributing to the literature on networked sensing and seizing capabilities in the wine industry 4.0. The research approach is explorative and qualitative drawing on 31 interviews with wine industry 4.0 experts and managers, mostly owners of SMEs: wineries, wine software and wine machinery enterprises. Resulting findings serve as a roadmap for digital transformation of grape harvest process in SME wineries explaining technologies and work roles necessary for DWT (digital workplace transformation), as well as strategic paths of deployment of novel grape harvest technology. Previous research on the wine industry 4.0 has focused on BMI, while this research expands the focus to include a wider concept of technology adoption strategy as well as DWT. The research identifies two types of factors impacting the strategic deployment of grape harvest technology: pull factors, also termed servitization factors, as well as push factors, termed also digital transformation factors.

Keywords: industry 4.0; DWT-digital work transformation; servitization; networked innovation; SME innovation; push-pull strategies; family business

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1. Introduction

The study at hand provides an evidence-based sensing and technological forecasting roadmap to the field of the wine industry by deploying open innovation between different actors involved. Having in mind that no previous research has dealt with the changes in work roles and new technology adoption strategies for the wine industry 4.0, this article closes this research gap. Relevant practice-oriented implications for networked, open innovation of grape harvesting as well as theoretical contributions to the emerging field of open innovation in SMEs are delivered.

The paths to the digital transformation of firms are numerous, as are the theoretical approaches and practical tools available to navigate this change. One of the more notable theoretical approaches to digital transformation of firms is that of dynamic capabilities, which are essential for digital transformation: (1) digital sensing capabilities (filtering and evaluating digital opportunities), (2) digital seizing capabilities (prototyping and defining business model (BM) value proposition) and (3) digital transforming capabilities (governing and aligning assets in accordance with innovation ecosystem) [1–3]. Sensing and seizing, have also been identified as key activities related to open innovation of local innovation ecosystems, which precedes the transformation of the businesses [1]. Having this theoretical framework in mind, this study deals with collaborative sensing and seizing activity of relevant actors in a low-tech wine production ecosystem regarding future change

of the grape harvesting logistics in wine production SMEs. Logistical ecosystems and the potential use of digital platforms are identified to be one of the most promising future venues for digital ecosystem research [4]. The wine industry is an agricultural industry and is therefore considered to rather belong to low-tech and highly networked industry, where the implementation of new digital technologies for productivity growth is usually lagging behind other industries [5–9]. However, digital transformation of all processes is identified as an inevitable process of transition [10]. In order to research the collaborative efforts of SMEs towards transformation of grape harvesting logistics in the wine production ecosystem, two research questions have been created:

RQ1: What is the current state of the grape harvesting process among networked SMEs in a low-tech wine industry, regarding technologies used as well as work roles involved?
RQ2: What are possible digital transformation pathways of networked SMEs on the example of grape harvesting for wine production?

Open innovation is an innovation path which focuses on external sources and inbound paths of innovation towards the organization [11]. Open innovation is relevant for all the aforementioned research questions, because the higher the number of actors and the more diverse they are, the more they can benefit from tearing down knowledge barriers through collaboration [12–14]. There are, however, limitations to firms benefiting from open innovation which relate to firms capacity to absorb innovations as well as strategic focus of external cooperation [15]. Therefore, the research questions are based in open innovation as a research approach by considering both the demand pull of SME wineries as customers of wine hardware and software producers, as well as DT push, related to the new technologies being developed and offered inside industry 4.0. They are two basic strategic paths of technology adoption.

The workplace seems to be one of the central elements of open innovation, where compassion is important not only for fighting uncivil behavior, but more importantly for supporting organizational culture with open innovation at its core [16]. In order to understand the nature and scope of DT of grape harvesting, existing technologies and work roles need to be identified so as to understand the scope of changes for skilling and reskilling the workforce inside open innovation. Developing the right digital skills at the regional level appears to be the key to successful DT efforts [13].

Having this research framework in mind, the present research provides evidence regarding opportunities (sensing) for changing technologies and work positions (roles) for grape harvesting. It also maps major factors influencing organizational change strategies (seizing) around grape harvest innovation. In the discussion, it provides an outlook on the possibilities for governing and aligning assets inside wine SME network. This is especially important having in mind that presently no institutional arrangements exist for common, networked digital transformation of the researched SMEs, although they are located in several neighboring wine regions in Germany. The regions include the Mosel-Saar-Ruwer, Rheingau, Nahe, Rheinhessen, Palatinate and Hessische Bergstrasse.

It is important to notice that, digital transformation does not rely only on digital transformation capabilities, but is preceded by digital sensing and digital seizing. The digital transformation path of organizations also largely depends on the level of digitalization of the industries in which the company operates, and of the innovation ecosystems it takes part in. Organizations belonging to traditional industries, can be classified as traditional or pre-digital as opposed to born-digital organizations which developed from high-tech startups [17,18]. The pre-digital organizations are in clear need of catching-up in terms of new technology, but there is a research gap on how these processes happen in a networked industry setting, where born-digital organizations offer their services to traditional pre-digital organizations, while other pre-digital actors are well underway with their digitalization strategies? The wine industry is therefore a suitable pre-digital industry for observing these phenomena.

Having in mind the ever-increasing digitization of all societal processes from analog to digital, the digitalization is an inevitable transformative force shaping the way people

interact, communicate, model their business and generate revenue [19–22]. In recent years, digital transformation in SME's has been spurred by the industrial revolution 4.0 with the abundance of new technological opportunities [23,24]. Digital transformation should be a process of strategic value for SMEs, taking one of three basic trajectories: (1) customer value proposition, (2) operating model, (3) simultaneous transforming of customer value proposition and operating model [25]. Innovating the operating model is usually driven by technology push, while innovating customer value proposition is usually driven by demand pull, thereby forming two most important innovation trajectories [26]. An important aspect of innovating operating model is the question of the future workforce needs. New ICT technologies are blurring market boundaries and consequently disrupt roles of different actors while some actors are even deemed unnecessary- co-creation with customers, co-opetition with competitors [22]. The consequences of digital transformation on work have both positive (less routine work, more flexibility in place and time) as well as negative aspects (24 h online burnout, unsecure and underpaid freelance status, de-professionalization and substitution of certain jobs such are journalists, para-legals, educators and sommeliers) [27]. Therefore, digital workplace is and under-researched field with ample opportunities for new value creation, by disrupting the existing workplaces and creating new, digital ones [28].

Innovating in a strategic way is important for optimally deploying available technologies and radically transforming both overall sustainability as well as economic performance [29]. In this sense, new technologies need to be defined through business models, as key levers for understanding and effectively communicating competitive strategies [30]. SMEs in commercial settings seem to prioritize technologies which can contribute to overall SME results in a quick, tangible fashion, in order to manage the risk associated with innovation adoption [31]. While undergoing digital transformation, company shouldn't lose sight of their core objectives, which follow from the profit logic, and are based in the clearly identifiable and profitable target market [32,33].

Firstly, the existing knowledge on the changing nature of the work in relation to changing technological landscape inside digital transformation is presented. This review of existing knowledge covers technology adoption strategies in SMEs as well as the specificities of networked innovation in SMEs. Following, the qualitative research method deployed in this study is presented and discussed in detail, as well geographical distribution and positions of interviewees. The results section starts by the technologies deployed as well as work roles involved, along with the most interesting verbatim citations for both categories. Then, a unified framework on opportunities for digital transformation of grape harvest process is being presented. The second part of the results deals with pull strategies and push strategies of technology adoption, firstly by presenting the underlying verbatim citations, and then by presenting a unified theoretical framework of wine SMEs grape harvest technology adoption strategies. The discussion deals with the contribution of the findings to the human, technological and organizational literature on redefining the future of work as well as digital transformation of SMEs. The contributions are than discussed regarding the SME network aspects of the present research methodology. Results summarize both the theoretical contributions of the research as well as practical implications for furthering DT in the wine industry and creating the wine industry 4.0.

2. Literature Review

2.1. Work in the Age of Digital Transformation

Managers need to be aware of the different strategies for workforce training and associated costs (through rate of forgetting, technology depreciation and advancement) when considering the technology upgrade decision [34]. Having in mind the complexity involved in such investments, the phenomenon has been termed digital workplace transformation (DWT) in the literature. DWT includes several important dimensions which should be considered: physical space, culture, social system and technology [35]. At the level of the individual workers inside DWT, support needs to be provided in realigning and managing

their non-work identities with their work identity, as well as balancing between regular and dynamic routines [36,37]. Therefore, the use of digital technologies in the workplace should be designed to promote mindfulness, empower workforce through participation and alter leadership culture in order to reduce technostress and promote compliance [38–40]. Furthermore, workers should feel and effectively be enabled to be autonomous, competent and connected in order to support their performance and well-being [41,42]. Some authors classify DWT as a non-technological field of innovation, but nevertheless acknowledge its crucial importance for digitalization and acceleration of technological developments as well as industry-level competitiveness [40].

Creating digital workplace is not about emails and social media, nor is it about integrating digital technologies- it is about transforming personal, team and organizational performance [43–45]. This process of change includes also the process of deinstitutionalizing the entrenched workplace practices by deliberately delegitimizing and abandoning them [46]. A modern workplace should get rid of rigid rules and instead empower employee participation and networking through value-based guidelines—this provides the basis for an increasing workforce maturity, and consequently business innovation and growth [3,25]. However, this process is not straightforward nor is it without perils. Crafting a digital workplace in pre-digital organizations presents a disruptive process for what was previously approached as long-term information system planning [17]. In addition, the labor practices of new app-based platforms have sparked litigations around whether work provided through a platform constitutes employee status or not [47]. It has become a common place for all organizations to outsource activities relating to IT and software development to external companies, thereby creating different work positions with different skillsets sought for in non-IT companies (more technical skills) and IT companies (more business and project management skills) [48].

2.2. Technology Adoption Strategies in SMEs

Technology is a construct that goes beyond engineering and manufacturing only, to include the whole process of transforming production inputs (labor, capital, material, information) into production outputs (products, services) [29,49]. Technology adoption strategies are directly connected to the issues of business model transformation, as well as the interplay between path dependence, strategic flexibility and a number of business modules involved [24,50,51]. The business-level perspective of technology adoption inside industry 4.0 recognizes that the redesign of operating processes is an important element of this transitioning process which can take different pathways, from being dominated by demand pull (high servitization level), to being dominated by technology push (high DT level) [24,26]. This is why the present research orders the adoptions strategy factors into these two major groups—servitization challenges and digital transformation opportunities. The previous literature has recognized the need for industrial BMs to transition to solutions-based BMs [52], which is of particular relevance for industrial SMEs in the wine industry. This integrated, solution-based BM balances between the front-end push and back-end pull for delivering value to the customers [53].

Having in mind that a large proportion of SMEs in the researched wine industry are family owned, this factor is very important for understanding the adoption of new technology. Previous research has confirmed that the approach to technology adoption in SMEs depends also on the digital leadership style of the SME owners as well as on the impact a family has in the company [54]. Family influence is proven to negatively influence the pace of technology adoption in SMEs, especially if they are minority, rather than majority owners [55]. However, it has been proven that family influence has an impact only on the later identification of discontinuous change, while the implementation, once initiated, is being conducted more quickly and with more stamina [56]. SME wineries seem to be reluctant to adopt sustainability innovations which bring only environmental and social benefits, with no tangible economic or commercial benefits [57,58].

2.3. Networked Innovation in SMEs

The knowledge-based interdependence of SMEs is often termed coopetition (consisting both of cooperation as well as of competition) and motivates entrepreneurs to participate in innovation processes by boosting their network reputation and increasing cooperation with suppliers and consumers [59]. There are three major types of relationship coordination mechanisms inside SME networks: (1) market, (2) hierarchy, (3) social relations, which points to the fact that agents inside networks exchange knowledge even if no market or hierarchy is present, which is also called open innovation [60]. Having this in mind, many organizations are deliberately building open structures and systems which remain in a dynamic, spontaneous and multi-directional relation with the environment [61]. However, SME networks also need suitable governance models, in order to discourage participants from exiting or defecting and to manage the knowledge-based interdependence of firms in a common innovation process [62]. Therefore, researching innovation on the network configuration level is an important strategic instrument for increasing innovation performance and competitive advantage in open innovation approach [63]. SMEs have different strategies when interacting with the SME network both regarding network adaptation as well as external resource dependence [64]. However, it should be noted that for each set of network characteristics, a certain combination of organizational characteristics (goal complementarity, resource complementarity, fairness trust, reliability trust, and network position or embeddedness) correlates with superior performance [65,66]. This research does not deal with the SME network level phenomena directly. However, it takes an explorative, networked methodological approach, thereby providing relevant implications for different actors in a wine industry SME network, ranging from producers of experimental and commercial machinery and software to SME wineries. The results point to the complexity of the researched phenomena, thereby calling for a networked approach to DT and DWT in grape harvesting.

3. Methodology

Semi-structured telephone interviews have been deployed as a primary data collection method. Thirty-one interviews with SME winery CEOs, quality managers, R&D officers, owners and a professor have been conducted in total. All of the companies involved fulfill official requirements for an SME, as defined by the EU: less than 250 employees [67]. Other financial indicators have not been taken into detailed consideration. Another specificity of wine industry is the existence of cooperatives, which are a coordinated network of small grape producers with one big winery dealing with wine making and selling. Some of the respondents were also cooperatives. Sampling has focused on selecting interviewees that were either involved in the grape harvest process (twenty SME wineries), or were providers of commercial technology for grape harvest (five software companies and three harvester and/or cellar technology producers). One interview partner is both a winery owner and a is running a wine software company, one runs experimental wine software development at a university and one is a professor of robotics and geoinformatics in wine industry. Twenty-nine of the interview partners were located predominantly in the state of Rheinland-Pfalz (RLP) and two in the bordering region of Hessen, with links to the wine industry in RLP. This approach provided a network perspective across the state-level value chain. The sampling of data sources was expanded iteratively, allowing the emerging theory and the saturation of our knowledge of subject areas and practices to guide data collection. The data has been analyzed through MaxQDA by engaging in open coding in the first step, and then developing second order themes in connection with the aggregate theoretical concepts. The verbatim citations are presented in Tables 1–3, while the whole theoretical construct with underlying second order codes and connection to first order codes are presented in Figures 1 and 2. Additional tables presenting the first-order codes of push and pull strategies, along with their detailed descriptions and the underlying motivations, have been presented in the Appendices A and B. The two separate questionnaires (one for wine

producers and another one for software and hardware producers) used for conducting the semi-structured interviews are presented in the Appendix C, at the end of the article.

Table 1. Verbatim codes for types of new technologies deployed in SMEs.

Grape berry/must assessment	Inf. 28	*"Take a look at Bordeaux, they go and bite the kernels to check whether they taste bitter, woody or green. Sensory tests are essential! I think the consciousness of physiological maturity receives more attention in other countries* (than in Germany)."
Multi-year field data collection in a database	Inf. 24	*"We work in an Informix database . . . and the historical values of our company go back to the mid 80's . . . We are not in the cloud, the database is located in clients' servers . . . reverse tracking is important . . . this data is being backtracked by vintners themselves . . . our software makes that possible . . . the vintner can trace every wine to its creation, every processing step that he made, every substance that he had added, he can document, even above the wine law requirements. This infrastructure is available and is also used, at least partially."*
Fieldwork logistics and visualisation of processes	Inf. 12	*"A tremendous relief of the working day is useable information, no matter where one is located. I notice this now, that I can access my whole cellar book from my phone: as if I am standing on the tank and saying "how is the tank doing"?"*
	Inf. 16	*"If I optimize the interface and identify on the tablet that "he is there" or "this is going on there", and have that on the PC or on the screen, I have less stress. This is because I can than identify certain risks better. I have less tension and get a better picture; this is very important . . . We are three managers, and there is some degree of exchange between us, but we still need to know what's going on and plan accordingly. The important part of a day is that certain data and facts are being updated quickly."*
	Inf. 29	*" . . . our dream would be to visualize all our vineyards. It allows to visualize both the locations of my customers* (B2B), *my suppliers, as well as vineyards. A further dream would be to have must weight, acidity and rot-affected areas, so harvesting can be directed precisely."*

Table 2. Verbatim codes for challenges fueling the pull, servitization strategies of wine SMEs.

Management assistance	Inf. 16	*"The sensors are from company X . . . It costs money, no question, but the choice is between money and safety. And if I have safety, then I can work better with my people and my customers and not have that much stress. Especially in the harvesting phase, it's about avoiding stress and that's what we have to get rid of. We have to relieve the strain of the manager, that's what we need to do."*
	Inf. 30	*" . . . we had a lot of winery successions* (regarding wineries as customers of software producers) *and the people are just better educated, have different vision of running a winery, and this is an absolute plus point. The market is growing for these technologies and when I project this into the future, from monitoring of vegetation processes in the field to sales, everything will be one digitalized track that monitors all these processes."*
Fieldwork/cellar assistance	Inf. 6	*"I have to take a look at the spot how ripe the grapes are. We have Excel sheets where we write down what we want to do and this is than verified every day to check for changes."*
	Inf. 6	*"All possible* (communication) *options are present, from Email, WhatsApp, Phone and personal contact, depending on the situation. If it concerns everybody, then it is posted to WhatsApp group and when it is about instructions to the fieldworkers, then it is one on one."*
	Inf. 21	*"It is very important for us to see the progress of the work. During the last harvest, a voluminous harvest, it was very important to us to see how well did we progress and how much surface from which grape variety have we processed and how much is still left to be done. Also, regarding how much we are allowed to harvest: do we have to leave it as it is or how are we going to divide it? These are the things that one otherwise does more through gut instinct and rough estimates, and here it is pretty precise . . . It is about dividing the workforce and estimating how long do we still need with how much workforce."*
Gaining competitive advantage	Inf. 7	*"We are committed to innovation and plan accordingly. We have dealt with it intensively, we also have a conversation tomorrow, the grape selection plant, optical sorting. The cost pressure drives this decision. I think people cost us too much money. 15 people do a lot of work and I think this people management is a huge problem, also because I cannot get any German workers. So that means I have to do the work, but without workers. This will be a solution that will be faster, but I don't think it will be better."*
	Inf. 24	*"The more ambitious they* (the wineries) *are, and the higher the quality they produce, the more they ask for such quality-optimizing options: to select as soon as possible, what will I get when and whom do I assign the order. The Pino Gris- I don't need 14.5% as in the 2018 harvest. I would like 13.5% alcohol, so it is easily digestible, with higher acidity,* etc. *These are the elements that are interesting for quality and are of interest for many users, because there is an added value behind this that is reflected in the quality and thus in the revenues."*

Table 3. Verbatim codes for company opportunities, fueling the push, DT strategies of wine SMEs.

Advances in geoinformatics	Inf. 23	*"This foreknowledge capability, in which field do I have which oechsle degrees [measuring the sugar content in the grapes] or anthocyanin, that you can get with one hand pass. This is so advanced that there are this Eurorobots who tackle this. The research center X was also a partner on this project. But in Germany they are not allowed to drive through the field- in Spain yes, because they have different legislation. I see this from the perspective that our goal should than be harvester, that could provide different information- most weight,* etc. *This data should be delivered in order to support this smart spinning systems. Harvesters can already do a phenotype reading."*
	Inf. 29	*" . . . can we not attach a kind of scanner* (on the tractor)*? We have so many passes through the vineyard for crop protection, leaf trimming,* etc. *If a simple and affordable system had scanned the leaves to assess if they look dry, are they dark green or yellowish, you could detect the grape color. These would be simple sensory systems that could inform the application if there is a dry or wet zone. This would be helpful things, especially for harvesting later."*
Advances in technology convergence, connectivity, usability	Inf. 28	*"We often have the requirement for the process data to be sent digitally from the press to an external location and thereby do a proactive maintenance, because for example, a valve could break. In addition, to the oenological side, this is very interesting and useful story where digitalization could be applied. This is remote control, so that we as a manufacturer can make remote maintenance and the press is often ready for use much faster than if the serviceman had come."*
Advances in machine learning	Inf. 23	*"there are currently some companies in Germany which deal with precision viticulture. There is the Fraunhofer, there is the Geobox, there are several places that can do this, at least for precision fertilization. Some rely on satellite data, some measure with drones or with NDVI and others with sensors in the vineyard. They all have their algorithms . . . And they then also network the devices for fertilizer application, also zone-dependent fertilizing"*

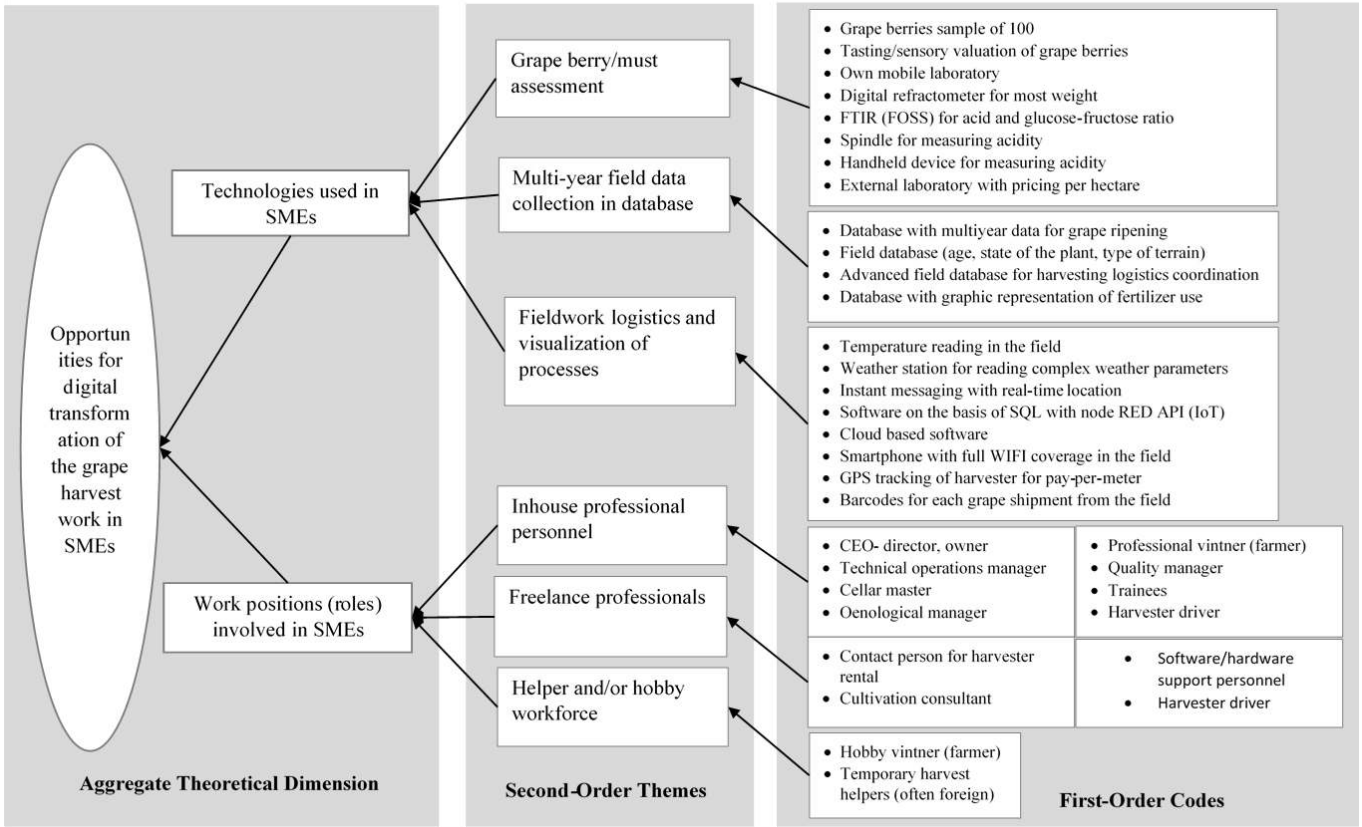

Figure 1. Current state of the grape harvest process regarding technologies used and actors involved.

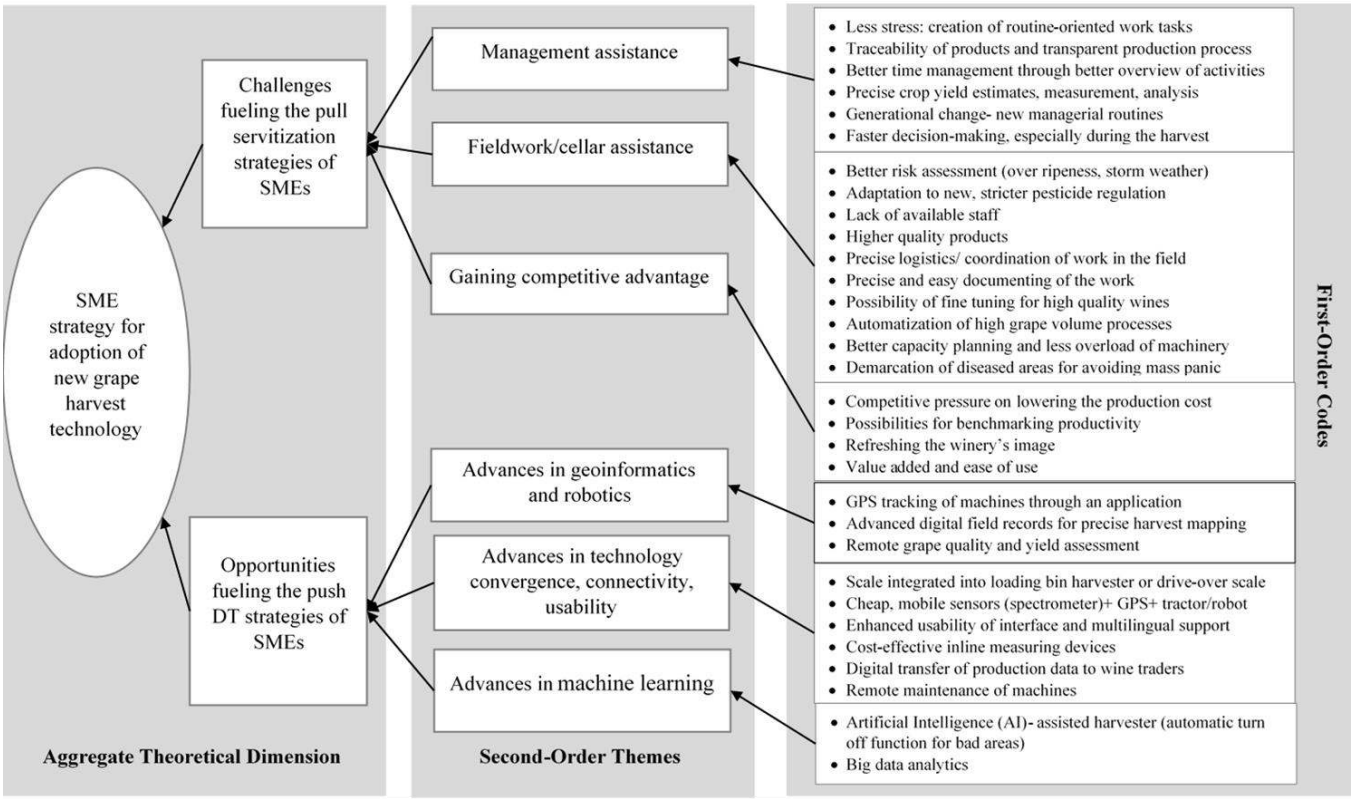

Figure 2. Adoption of grape harvest innovation- challenges acting as pull factors and new technologies acting as push factors.

4. Results

4.1. Technologies Deployed

Different types of technologies are being used in the grape harvest process in the state of Rheinland-Palatinate (RLP). They can all be grouped into three value-creation activities, according to the work task: (1) grape berry/must assessment, (2) multi-year field data collection in a digital database, (3) fieldwork logistics and visualization of processes, as presented in the Table 1 below and Figure 1 later in text.

Grape berry and must assessment take place in the various stages along the wine making process and it is of critical importance for getting accurate data about the state of the grape. This in turn is very important later, for product quality, as it enables conducting crucial activities (plant protection, watering, fertilizer use, harvesting) in the field at the precisely right point and with the right amount. However, acceptance of new routines for grape assessment has traditionally been rather low in Germany.

Multi-year field data collection in a digital database is a collection of data on all field parameters (weather, grape ripening, diseases, treatment, harvest, etc.) as well as later processing in the cellar. This could prove to be a very powerful basis for deploying new technologies like Big Data and Artificial Intelligence to support automated or semi-automated decision-making support systems for grape ripening, harvesting and further processing. Current databases build on SQL or Informix technology, with some new players in the market successfully offering cloud-based databases that facilitate mobile app usage. Some players possess databases that date back forty years, which could be of use for prediction algorithms and big data analytics.

Fieldwork logistics and visualization of processes is one the areas characterized by a big transformation in the recent years with applications across different industries. The advantages of new technologies for logistics are evident to some of the vintners, such as the Informant No. 16. For example, visualization of data serves also to relieve managerial stress, as observed by Informant 12. However, in the RLP wine industry commercial visualization capabilities are still limited as there only few offerings exist, which are predominantly

tailor-made solutions. These companies are still looking for ways to expand in terms of scale and scope. The potential of these technological advances is visible through several successful examples of technology transfer from other agricultural fields to big cooperative wineries. The potential of fieldwork data collection and use is still underutilized because of gaps in data collection and analytics for different purposes. Informant 29 reveals that, in terms of back tracing for new blockchain technologies.

4.2. Roles Involved

Numerous actors with different roles are involved in the grape harvest process, either as individuals or as groups. Three major types of roles are: (1) inhouse professional personnel, (2) freelance professionals, (3) helper and/or hobby workforce. Each group differs in terms of approach, seniority and level of involvement as well as in dedication. For this categories, no verbatim citations have been included, as this aspects have been the object of post-hoc analysis, and no direct referral to this roles have been made during the interviews, but only indirect. The three categories are represented in Figure 1.

The major differences are between entrepreneurial (family) wineries and cooperatives. The family companies' workforce core is made up of family members and salaried professional staff (usually cellar masters), while foreign and domestic helpers are added during the harvest. Cooperatives are marked by the existence of a team of professional staff working on the grape and wine processing and selling, while the grapes are grown by farmers that vary in surface size as well as their professionalism. Some cooperative vintners live off of wine and some are part-time or even hobby vintners. For the sake of the quality, cooperatives possess quality managers who coordinate between management and farmers in order to ensure the matching of the grape quality with the wine production plans for each product category.

4.3. Servitization Needs, Acting as Pull Factors

The market adoption of innovation and the underlying servitization needs of wine SMEs are major themes for technology companies trying to develop and market innovative solutions on the market. Major challenges which pull the new technology adoption in the harvesting process are the key levers that the wineries are trying to take advantage of: (1) management assistance, (2) fieldwork/cellar assistance, and (3) gaining competitive advantage. The most important challenge pushing innovation in both management and fieldwork/cellar assistance is the lack of (qualified) workforce. The three categories and the underlying verbatim citations are presented below in Table 2 as well as categories themselves in Figure 2 later in text.

Wine estate management needs to reduce the stress level through routine-oriented tasks, better traceability and overview of production process for faster decision-making, as Informant No. 16 contends. Furthermore, a new generation of wine estate managers and entrepreneurial vintners is adopting new technology, changing the way things are done, as noticed by Informant No. 30.

Fieldwork and cellar assistance are mostly concerned with possibilities of better assessment of weather and grapes, as well as efficient logistics and coordination of effort between workers. Informant 6 describes how they build their field record database using only Excel sheets. The same informant has also described the process of communication during the harvest, using the same tools as for private communication. In contrast, Informant 21 describes the change when using a specialized software for tracking the work in the field.

Adopting new technology is also connected to the lever of gaining competitive advantage, through lowering production costs but also refreshing winery's image and adding value to the customer offer. As the Informant 7 observes, the new technology is both cheaper and more reliable than the alternative human workforce which would be engaged in processes like grape sorting, therefore having huge impact as a cost-cutting measure. On the other hand, Informant 24 states that regarding field machinery and processing equipment, fine-tuning and quality optimizing options are interesting in the higher-quality segment.

4.4. New Technologies Acting as Push Factors

Technological advances that are perceived as adding the most value and hence motivating for enhancement of capabilities by adopting new technological processes are: (1) advances in geoinformatics and robotics, (2) advances in technology convergence, connectivity, usability, and (3) advances in machine learning. The three categories and the underlying verbatim citations are presented in the Table 3 below, while categories themselves are also presented in Figure 2 later on in text.

Advances in geoinformatics and robotics, the core of precision agriculture, are changing the way things are done in agriculture: from precision harvest mapping to pay-per-meter harvesting services or remote yield assessment. However, Informant 23 notes that although there are many useful technologies, some developments are being slowed down by legal framework in Germany. The informant 29 points to the need for affordable, multi-platform, flexible hardware that can extend functionalities of software in the wine industry.

Advances in technology convergence, connectivity and usability mainly relate to technologies like drive-over scale, cheap mobile sensors, remote machine maintenance. As observed by Informant 28, remote maintenance is one of the major servitization advances, adding considerable value to the users of wine machinery.

Advances in machine learning also seem to be very present and relevant topics in the viticulture, with no mainstream, commercially successful applications of AI or Big Data present, but some important R&D processes are under way, as presented by Inf. 23.

5. Discussion

Regarding the results presented in the Figure 1, previous systematic research of the literature on digital transformation has identified (1) technologies and (2) actors, as two relevant aggregate themes or dimensions. This dichotomy-based approach has previously been deployed by Nadkarni and Prügl [68]. Further relevant literature goes beyond these human and technological aspects, to include also organizational aspects as relevant for redefining the future of work [69,70]. The present research deals with human/work related aspects of DT in Figure 1, while organizational aspects are dealt with in Figure 2, by distinguishing between push and pull factors of SME digital transformation. Previous research has identified a multitude of drivers of digital transformation in SMEs: process engineering, new technologies and digital business development digital leadership and culture, the cloud and data as well as customer centricity and digital marketing [51]. However, present research distinguishes in Figure 2 between pull factors and push factors, as two distinct types of factors influencing the digital transformation strategy of grape harvesting in SMEs. Management assistance, fieldwork/cellar assistance and gaining competitive advantage have been identified as the most relevant pull factors for DT, while advances in geoinformatics, advances in technology convergence, connectivity and usability as well as advances in machine learning have been identified as the most relevant push factors driving the DT of wine SMEs. Previous research on wine industry 4.0 has acknowledged the importance of BMI (Business Model Innovation) [24], while this research contributes to this research stream by exploring technology adoption strategies and DWT, thereby expanding the range of researched phenomena related to a strategic DT.

The findings on the importance of winery business succession adds to the discussions of the impact of family status on the new technology adoption in SMEs, by expanding the understanding on the timing of change in family-owned business. The present study results demonstrate that the generation succession is the time of the greatest change and new technology adoption in a family-owned SME. These findings therefore confirm previous findings that family-influenced SMEs are later at an identification of a discontinuous change, and faster when it comes to implementation ones a discontinuous change has been identified [56]. The findings also contradict the identified a priori reluctance of SME wineries to adopt sustainability innovations if no tangible economic benefits can be identified [57,58], but point to the need to identify the generational cycle stage of family SME wineries. In this sense, future research should take into consideration the generational

cycle stage when considering new technology implementation: discontinuous change appears to be lower-than-average at the end of a generational cycle, and higher-than average at the beginning of a generational cycle, in the years after succession.

The present research explores work and technology as well as the organizational aspects of regional, networked innovation and transformation processes on the example of wine industry in the German state of RLP. Similarly, the regional and networked approach to innovation has previously been conducted on the example of the biotech industry [71,72]. However, the present research does not research network-related phenomena, such are the governance structure, external context or advantages/disadvantages of being part of the network, as there is no formalized network between the researched SMEs. The research deploys a sample of compatible SMEs, who deal with grape harvest innovation to provide insights into important aspects of grape harvest transformation—related to DWT and business transformation. In this sense, future research should carefully consider the possibilities of building wine industry 4.0 networks for digital transformation of work processes as well as whole organizations and industry. The questions of governance structures, external context and the benefits vs. drawbacks for SMEs to be part of the network, should be addressed by future research on wine 4.0 networks.

The results presented are of relevance for managers as they provide empirically based roster of work roles. This roster is suitable for further separate research of each role involved as well as cooperation arrangements inside/outside teams. In addition, a detailed specification of technologies used in the grape harvest process, in relation to the work roles involved has been presented. The results can help managers in identifying training and retraining needs for digital workforce transformation by providing a detailed ontology of roles involved in the grape harvest process. In addition, wine technology companies should be aware of generational successions and create different strategies for transforming family wineries with a stable family ownership and ones in the years after a succession. In this sense, the results provide the basis for digitalization efforts of both workplaces as well as work routines inside a digital workplace transformation in wine industry SMEs. The results can be of relevance for other agricultural SMEs dealing with complex harvest logistics operations. Future research needs to expand this explorative research by conducting quantitative research on work roles, cognitive aptitude and team organization in the wine industry. It also needs to delineate guidelines and major elements for future professionals in the wine industry on how to be successful in the emerging digital wine industry paradigm.

The major limitation of the study is its explorative nature. The models created are for exploratory purposes and therefore lack numeric relationship specification, which are important for theoretical purposes and could be achieved by quantitative studies and structural equation modelling. The creation of the codebook has undergone a rigorous process in an attempt to establish reliability, however biases still might exist regarding both data-driven first-order codes as well as second order themes, and to a lesser extent aggregate theoretical dimension. Further limitation is related to the interviewee selection. Interview partners have been recruited through a winery register, by contacting wineries undergoing or interested in digital transformation, as well as their partner companies in this process. The article does not deal with digital transformation capabilities, but only with its antecedents, namely digital sensing capabilities and digital seizing capabilities, thereby opening possibilities for future research on digital transforming capabilities in wine industry 4.0.

6. Conclusions

The findings of this study enhance the understanding of a still under-researched area of leveraging novel technologies by redesigning jobs and redefining business strategy of SMEs involved in the wine industry 4.0. The research further contributes to the literature on open innovation and redefining professional identity, by defining existing work roles beyond their professional boundaries: skilled permanent workforce, skilled temporary

workforce and amateur temporary workforce. The framework therefore provides ample space for dismantling knowledge boundaries for open innovation, by placing the traditional and future jobs into these three broad categories. Contrary to the findings in the previous literature [48], this research demonstrates the importance of digital tools for advancing managerial and business capabilities in non-IT, traditional SMEs. Managerial assistance tools are found to be important both in wineries dealing with grape harvest for providing grapes for low-cost wines, as well as wineries wanting to get a hold of fine-tuning mechanisms in grape harvest for achieving top quality wines.

The article identifies opportunities and challenges for strategic deployment of new grape harvest technology. It examines both pull-oriented servitization challenges as well as push-oriented, digital transformation opportunities. The results also explore the dynamics of the digital transformation by providing a detailed overview of work roles and technologies used for digital transformation of grape harvest process. Both of these areas contribute to better understanding of the strategic deployment of new technology for the wine industry 4.0. The results also point to the decisive role of work-related (work positions, work processes) and organizational (strategy, business model) aspects in the digital transformation of the wine industry.

The article provides implications on the level of digital sensing capabilities as it presents the multitude of opportunities for DT of grape harvesting process regarding grape berry/must assessment at different stages along the process, multi-year field data collection in a digital database as well as fieldwork logistics and visualization of processes. Contributions toward sensing the opportunities in the field of DWT are provided by defining three types of transdisciplinary work roles in grape harvesting: inhouse professional role, freelance professional role and helper/hobby workforce. These three types of workforce differ in terms of level of involvement in the wine SME as well as professional expertise needed for conducting tasks. The results also provide implications on the level of seizing capabilities. Firstly, two types of forces impacting strategic adoption of grape harvesting technology are presented: pull-oriented servitization strategies and push-oriented digital transformation strategies. Servitization aspects of a technology adoption relate to management assistance, fieldwork and cellar assistance ang gaining a more favorable competitive position or creating competitive advantage. On the other hand, digital transformation aspects involve advances in geoinformatics and robotics, advances in technology convergence, connectivity and usability, as well as advances in machine learning. The role of a technology adoption strategy on an organizational level is to balance between these two important aspects. The interviews have confirmed the critical importance of the grape harvest process for both SME wineries searching for cost-oriented competitive advantages as well as for SME wineries looking for quality-oriented improvements through more precise management of wine taste profiles.

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Appendix A

Table A1. Pull strategies for adoption of new grape harvest technology with detailed descriptions and motivations for overcoming the challenges.

	First-Order Codes	Description of the Challenge	Motivation for Overcoming the Challenge
Management assistance	Less stress: creation of routine-oriented work tasks	The work of a wine manager/entrepreneur is highly stressful and includes often long hours	Any tool promoting work task routinization can help in reducing stress-levels induced by the unstructured nature of the production process.
	Traceability of products and transparent production process	Traceability is being more and more demanded by certification bodies, but also consumers and new digital technologies can help these efforts	Better quality products and more direct risk management, better management options in a crisis situation of having to trace back production steps after a recall
	Better time management through better overview of activities	The work of a wine manager/entrepreneur is highly unpredictable and therefore stressful.	Any tool promoting real-time data tracking can help retain control over production process, while reducing stress-levels induced by a lack of data.
	Precise crop yield estimates, measurement, analysis	Using harvesters often reduces the capability to apply fertilizer and plant protection in the most optimal way, as well as to harvest the best grapes, which can be overcome by precise digital field records.	Better planning capabilities-building for reducing unnecessary work steps, optimize existing ones in scale and scope.
	Generational change- new managerial routines	New generation of vintners is more open to digital technologies and even demands them or even build them themselves. This is especially pronounced after company take-over.	The new generation of vintners and wine entrepreneurs are digital natives and see digital technologies as the only way of doing things, regardless of the previous managerial traditions.
	Faster decision-making, especially during the harvest	Wine entrepreneurs need to coordinate a large number of different stakeholders effectively under tight schedule	Wine entrepreneurs need the capability of being able to make fast decisions in order to keep the high pace of daily duties
Fieldwork/cellar assistance	Better risk assessment (excess ripeness, storm weather)	Wine professionals need reliable and networked tools for assessment of risks.	Making better decisions for reducing crisis situations, reducing unnecessary costs and achieving better quality of a product.
	Adaptation to new, stricter pesticide regulation	Wine professionals are bound by strict and changing regulation which needs to be addressed in a timely manner.	Fulfilling the law requirements with as least effort as possible.
	Lack of available staff	Reliable supply of skilled and unskilled workforce is hard to find.	Reducing the need for large workforce in the production process.
	Higher quality products	Higher quality product means the opportunity for higher prices.	Gaining competitive advantage over competition.
	Precise logistics/coordination of work in the field	Better time-management of the workforce as well as grape processing to in order to lose as least quality due to unforeseen events as possible, for example unwanted fermentation in the sun.	Reducing waste in the production process and thereby making savings.

Table A1. *Cont.*

	First-Order Codes	Description of the Challenge	Motivation for Overcoming the Challenge
	Precise and easy documenting of the work	Fieldwork is very hard to control and document without digital tools.	Better human resource practices in relation to the real work documented- rewards, breaks, productivity
	Possibility of fine tuning for high quality wines	High quality wines need different tuning possibilities along the production process.	Capability-building for answering to every taste profile change in the market and delivering precisely the taste notes needed by the market.
	Automatization of high grape volume processes	High volume grape sorting can be automatized.	No extra workforce needed, thereby reducing many extra work steps in finding, skilling and deploying workforce.
	Better capacity planning and less overload of machinery	Different technological solutions in the field and in the cellar need to be coordinated so that there are no excess capacities as well a no overloads.	Long-term investment planning to avoid incompatible technologies and/or possible losses incurred by misdirected investments
	Demarcation of diseased areas for avoiding mass panic	Having a capability of clearly identifying plants affected by certain disease can avoid treating the whole vineyard and potentially spreading the panic to other vintners in the area.	Clearly delineating risks and addressing them properly.
Gaining competitive advantage	Competitive pressure on lowering the production cost	The wine industry is very competitive and economies of scale are very important.	Providing the lowest price possible in certain price ranges.
	Possibilities for benchmarking productivity	Digital tracking of activities and productivity can enhance industry benchmarking,	Identifying the possibilities for further optimization of processes.
	Refreshing the winery's image	Deploying the newest or the most exotic technology can enhance the company image inside the industry itself.	Presenting the winery as future-oriented and innovative.
	Value added and ease of use	The new technology introduced needs to be highly practical and usable as vintners are no hackers or digital natives.	The vintner needs to see clear value added from new processes and he has to clearly understand the way it can be deployed.

Appendix B

Table A2. Push strategies for adoption of new grape harvest technology with detailed descriptions and motivations for seizing the opportunities.

	First-Order Codes	Description of the Opportunity	Motivation for Seizing the Opportunity
Advances in geoinformatics and robotics	GPS tracking of machines through an application	All the vehicles in the field can be controlled via one interface.	Increasing the coordination and planning capability, as well the quality of short-term decision-making.
	Advanced digital field records for precise harvest mapping	Digital records are the basis for connecting all other devices through an interface.	Reducing excess costs and new possibilities through different digital devices, many still in experimental use.

Table A2. *Cont.*

	First-Order Codes	Description of the Opportunity	Motivation for Seizing the Opportunity
	Remote grape quality and yield assessment	Getting the data from the field with no need to be present all the time.	Reducing field visits during ripening period and better resource planning.
Advances in technology convergence, connectivity, usability	Scale integrated into loading bin harvester or drive-over scale	Integrated scales can help with getting the data on the quantity of grapes for processing.	Better planning of the grape processing for lower costs and higher quality.
	Cheap, mobile sensors (spectrometer)+ GPS+ tractor/robot	New affordable sensors are being developed for different kinds of devices and for different uses.	Enhancing capabilities of existing hardware with low additional investments needed.
	Enhanced usability of interface and multilingual support	Interfaces between different hardware and software components need to be optimized as well as usability for a diverse workforce.	New devices need to be compatible with old ones and design for use by an international workforce.
	Cost-effective inline measuring devices	Affordable solutions need to be developed in order to enhance grape and wine processing even further.	Higher quality wine on a relatively tight budget.
	Digital transfer of production data to wine traders	The digitalization of production data enables automatic transfer of data to wine traders, enabling the customers to profit from better and more reliable data in an otherwise complex industry.	Providing production data in a modern and accessible way with no extra cost of additional certification.
	Remote maintenance of machines	There is a possibility to conduct remote maintenance for some high-end grape processing facilities.	Time and effort saving, better coordination with technical support.
Advances in machine learning	Artificial Intelligence (AI)-assisted harvester (automatic turn off function for bad areas)	New harvesters are being launched on the market, which can automatically recognize bad grapes and not harvest them.	Considerable quality improvement closer to hand harvest, with no extra effort needed by the harvester driver.
	Big data analytics	Putting to use an abundance of historical digital data in some historic companies in order to make better decision in relation to weather, ripening and harvest timing.	Harness the power of experience currently buried in decades of unused historical data, to enhance the vintner decision-making as well as capabilities of machinery.

Appendix C

Table A3. Questionnaire with open-ended questions used to conduct semi-structured interviews with SMEs on the left and software and hardware producers on the right.

Questions for Wineries	Questions for Wine Software and Hardware Producers
1. Please describe the harvest planning process in your company in detail (which actors are involved, which routines have been developed, which technologies are being used, how long does the whole process lst, which key competences and capabilities are needed?).	1. What are the latest Industry 4.0 technologies that could be used for grape ripeness measurement, harvest planning and harvesting itself? Which technologies have already been implemented, which are coming soon and which have already been used in other areas of agriculture?
2. How does the digitalization of data transfer between grape growing grape and grape must processing look like in your company?	2. Which key competencies and skills are required or will be required in the future? How well is the (university) education adapted to these changes? To what extent is (university) education pursuing or promoting these changes?

Table A3. *Cont.*

Questions for Wineries	Questions for Wine Software and Hardware Producers
3. Which data are available in digitalized form, at which pace, and what are the expectations/needs from the company in this sense? (Geolocated information, Vineyard types, GPS technology or other, planned vs. Actual harvest, grape variety, quality parameters, must weight, acidity, extent of decay, type of decay, etc.- which optimizations in this sense would benefit the most the production process?)	3. To what extent is the data transfer between grape production and grape processing already digitalized?
4. What motivates the optimization of interfaces between different IT systems in your company?	4. Which data is already digitalized (from a technical point of view), at what speed can they be delivered? (e.g., geo-positioning—via GPS or otherwise, harvest volume: estimated and actual, grape variety, quality parameters such as must weight/acidity, botrytis content, type of decay, etc.)
5. What is the structure of your employees when it comes to the digitization perspective or motivation for digitization? (Are there differences in the acceptance of digitalization? If so, which ones and why?)	5. Which data could be digitized (from a technical point of view) and at what speed could it be delivered? (e.g., geo-positioning-via GPS or otherwise, harvest volume: estimated and actual, grape variety, quality parameters such as must weight/acidity, botrytis content, type of decay, etc.)
6. If you use harvesters: how does the planning and consultation work with regard to harvester take place? (Do you harvest according to local availability or are quality aspects in the foreground?)	6. Which Industry 4.0 technologies could be used in terms of planning and consultation with the harvester?
7. How do you deal with purchased goods (grapes, must or wine)?	7. What could the latest technologies do when it comes to product traceability systems? (e.g., because of product safety and faster collection of defective series, traceability of sales of products back to raw material receipt)
8. What are the needs regarding tools/systems for product traceability? (e.g., because of security and quick collection of faulty series—from sales of the products back to raw material receipt)	8. How dynamic have changes and innovations in harvest planning been over the past 10 years? (What has changed? To what extent?)
9. How dynamic have the changes and innovations of harvest planning been over the past 10 years? (What has changed? To what extent?)	9. What is the outlook for the changes and innovations in the area of harvest planning in the next 10 years? (What will change? To what extent?)
10. Have measures to improve the harvest planning process and/or grape logistics already been planned? (If yes, which?)	
11. What are the priorities for innovation in your company? (Please give examples for each applicable category: increase in efficiency—less waste of resources, increase in effectiveness—achieve goals with greater success, increase quality—produce products with higher/more stable quality)	
12. How do you deal with innovations? (More carefully, step by step, or rather as a paradigm shift and one-off, radical change)	

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