To what extent do an innovation system and cleaner technological regime affect the decision-making process of climate change adaptation? Evidence from wine producers in three wine clusters in France

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Abstract

This paper analyzes French winemakers' decision-making process to adapt to climate change, and how the institutional and relational context of an innovation system, including a clean technological regime, affect these decisions. Our study used a mixed method research based on original face-to-face interviews with 92 winemakers in three French regional wine clusters that have been affected by climate change: Bordeaux, Champagne and Languedoc. We perform a logistic model to tests how managers' personal backgrounds, wine-producing company characteristics, and innovation system components, including cleaner technological regime, might explain the adaptation decision-making process. Our results show that economic variables have little influence on climate change adaptation decision-making. On the contrary, variables expressing the relationship built by wineproducing companies within the Innovation System, their involvement in organic wine production, and the manager's personal background affect the decision-making process to adapt to climate change. Furthermore, many of the adaptation strategies rely on adopting cleaner production approach. Our findings show that the decision-making process depends on networks and clean technological regimes embedded in an innovation system, with regional and sector dimensions.

Keys Words: Climate Change, Adaptation, Innovation system, Decision-making, Wine industry, Clean production

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1. INTRODUCTION

According to the 2018 Intergovernmental Panel on Climate Change report, the effects of climate change (CC) will have a significant impact on many economic sectors, even though ambitious mitigation measures have limited global warming to 2° C above pre-industrial levels (IPCC, 2018). Developing adaptation strategies has therefore become essential, particularly at a company level, and this requires a better understanding of managers' decision-making processes towards adapting (Hallegatte et al., 2011; Wise et al., 2014; Patt et al., 2008; Niles et al., 2016). These decision-making processes are the subject of a growing literature inviting us to go beyond a cost-benefit analysis at any given moment, and rather, consider a succession of revisable decisions within a company's adaptation pathway (Adger et al., 2005; Jones et al., 2014). Recognition and understanding of CC issues by the company is thus fundamental, as it results in defining adaptation goals, and in selecting and implementing actions to achieve them (Van Duinen et al., 2015; Capela Lourenço et al., 2019; Orlove et al., 2020). However, since individual cognizance of CC impacts are limited in time and space, and climatic uncertainties are high, some chains of decisions could lead to maladaptive outcomes over time (Wise et al., 2014). This is why a good chain of decisions resulting in a suitable adaptation pathway is an iterative process of assessment and re-assessment that depends on the decision context (Risbey et al., 1999). This context includes socioeconomic agents, regulation and policies, available technologies and knowledge (including on CC), and financing mechanisms that can simultaneously orient, influence and constrain managers' decisions (Hallegatte et al., 2011; Wise et al., 2014).

Research and innovation can also play a crucial role in the adaptation-decision cycle because they provide knowledge towards a better understanding of the climate change (CC) phenomenon and its evolution at different levels, while generating solutions for good adaptation pathways (Füssel, 2007; Smit and Wandel, 2006; Stern and Treasury, 2006). However, studies into the role of research and innovation in the adaptation process are still scarce. They are mostly rely on linear models of innovation and knowledge transfer, while the complexity and speed of CC suggest developing more systemic and interdisciplinary approaches, through a consideration of interactions between agents and empirical knowledge on a local level in order to adopt more relevant technological options (Grin, 2010).

These studies are in keeping with developments in the “innovation systems approach” promoted by "Innovation Studies" literature (Fagerberg and Vespargen, 2009; Martin, 2012). An innovation system is defined as a set of institutions, relations between heterogeneous actors, knowledge-base, available technologies and knowledge transfer mechanisms, that promote research-based innovation and change (Lundvall, 1992; Malerba, 2002; Cooke et al., 1997). Innovation systems can also integrate different technological patterns or regimes (Malerba, 2004; Peneder, 2010; Gaziulusoy and Brezet, 2015) and be structured on different sectoral and territorial levels (Martin, 2012). In particular, the innovation system approach has found fertile ground in agriculture, where the existence of specialized research institutions and the co-existence of different technological regimes (especially organic vs conventional) play an important role in achieving sustainable development goals (Klerkx et al., 2010; Touzard et al., 2015), and thus potentially also in adapting to CC.

The purpose of this paper is to show how the innovation system and technological regime within a sector can affect company managers’ CC adaptation decision-making processes. We will address this issue i) by analyzing the adaptation decision-making processes of company managers’ in the French wine industry, which is highly sensitive to CC and ii) by using a mixed method that combines interviews with company managers and content analysis with a logit model that tests the influence of the innovation system on their adaptation decisions.

i) In France, the impacts of CC on grapes and wine production have been widely reported, and have effected different domains including earlier harvest dates, more frequent water stress in Mediterranean vineyards, increasing disease pressure in wetter regions, higher alcohol grade and lower acidity in wines, and loss of production as a result of more extreme climatic events (Jones and Webb, 2010; Hannah et al., 2013; Ollat and Touzard, 2014). These impacts are likely to have a negative effect on wine producers’ incomes and the competiveness of this highly strategic economic sector, as France’s second largest export. (Ollat et al., 2016). Moreover, wine producers already seem to be aware of CC issues and have developed adaptation strategies, while scientific research is exploring solutions such as new vine varieties, new viticultural and enological practices, and new locations for vineyards (Viguier et al., 2014; Alonso Ugaglia and Peres, 2017).

ii) Our research uses interviews with 92 wine company managers located in three of the more significant French wine regions (Champagne, Bordeaux, Languedoc). We characterize the different steps of their decision-making process when adapting to CC, and present a logit model to track the influence of different factors, including components of innovation systems and technological regimes to which these firms may be linked. This method is often used in innovation studies (Martin, 2016; Vagnani and Volpe, 2017), but rarely in research into CC adaptation, one of the first uses being in the wine sector (Nicholas and Durham, 2012).

Specifically, our study contributes to the literature by integrating the innovation systems approach in research into companies' decision-making towards CC adaptation, thus connecting two scientific communities which have few relations as yet (Touzard and Boutillier, 2017). We also demonstrate the benefit of using mixed (qualitative and quantitative) method research to explore and analyze decision-making processes towards adapting to CC, and we identify internal and external factors that influence this process. Finally, this paper provides new information for, and recommendations to wine producers and policy makers for the improvement of the adaptive capacity of the wine industry.

In this paper we will first explain our study's conceptual framework and formulate a set of hypotheses on how the innovation system could affect decision-making processes towards CC. We will then present our method of investigation, which uses interviews in wine-producing companies and a logit model that tests the influence of the innovation system. The results will be presented in section three, highlighting the innovation system components that affect the decision-making process. Finally, we will discuss our findings, showing that adaptation to CC not only depends on wine producers' personal backgrounds and companies' economic characteristics, but also on relational and institutional Innovation systems and clean technologies.

2. Theoretical Background

2.1. The Decision-making Process towards Adaptation to Climate Change

Simon's model (1984) is widely considered the most complete characterization of rational decision-making (Elden, 2019), influencing the current scientific community on decision-making processes towards CC adaptation (Harter, 2014; Orlove et al., 2020). The process can be characterized in four phases:

Firstly, **Intelligence** is concerned with the identification and analysis of the climate problem. It largely depends on the company's recognition and understanding of CC issues, including potential impacts on the company's activity. This phase involves information collection, and leads to the definition of adaptation goals ("to solve a problem or take an opportunity"). Adaptation to CC is therefore conditioned by a manager's intention to take the necessary measures against the consequences of CC as they recognize its effects (Fishbein and Ajzen, 1975; Ouédraogo et al., 2010; Van Duinen et al., 2015).

Secondly, **Design** explores and assesses various solutions and adaptation alternatives designed to counteract CC impacts: namely, the adoption of technological innovations, practices and organizational changes, and new collaborations or localization choices (Aigrain et al., 2019). This exploration phase requires the company to make a special effort to access relevant information, as CC is a "new", uncertain and complex issue, which makes it difficult to identify relevant solutions and perform comparative cost-benefit assessments (Ditrich et al., 2016).

Thirdly, **Choice** shapes adaptation decision-making through the selection of the best actions and means to achieve the adaptation objectives. These actions are then included in a strategic plan that takes into account the material, human and financial resources that will be mobilized by the company to organize their actual implementation,

Fourthly, **Monitor** insures the proper execution of the actions, (re)-adjusting decision-making processes and adaptation strategies based on an assessment of the implemented actions.

These four phases are not linear but form an adaptation decision-cycle (Wise et al., 2014). Owing to the variability of CC impacts and its evolution, one decision or a set of decisions towards adaptation is not permanent; actions that enable companies to adapt to various CC impacts at one period, might be not sufficient for new impacts at another. Continuous readjustments are necessary. It is necessary to (re)-adjust decision- making and adaptation strategies according to the evaluation of results of actions and means for setting goals, as well as the new impacts of CC and new solutions developed in the industry or in society at large. This is an adaptation pathway, defined as a series of adaptive learning decision cycles over time (Wise et al., 2014).

Beyond the firm's resources, competences, and capabilities, a good chain of decision depends on the decision-cycle context (Risbey et al., 1999). Wise et al. (2014) identified awareness communities, government and regulations, funding and research as elements of this. Besides interactions between companies, regional and sectoral governance, policy frameworks and effective financing mechanisms are essential in finding the right adaptation pathway (Hallegatte et al., 2011; Jones et al., 2014).

Furthermore, research and knowledge production play a vital role in the adaptation decision cycle or pathway, because current and empirical knowledge is no longer sufficient to deal with CC. Knowledge and adaptation solutions need to be constantly updated (Jones et al., 2014; Boyer, 2016). However, most studies into the role of research on the adaptation process are implicitly in line with the linear model of innovation and knowledge transfer. They often fail to explain how research influences decision-making in some contexts or industries where direct links between economic and research actors are weak. They also fail to use a systemic approach to better understand the role of research within the decision-making process of adapting to CC (Grin, 2010; Rodima-Taylor et al., 2012; Janetos, 2020). These questions are however being widely considered by researchers who contribute to "innovation studies" (Martin, 2012), through approaches in terms of "innovation systems".

2.2. The Innovation System and Decision-making Process towards Adaptation to Climate Change

An innovation system is a set of institutions, organizations and actors whose interactions in the production, development and diffusion of new technologies or change management determine a firm's innovative performance at sector, regional, national or international levels (Freeman, 1987; Nelson 1993; Malerba, 2004). Institutions, networks and knowledge bases are critical elements of an innovation system. The innovation system framework allows the description and analysis of relations between companies and organizations, including universities, research laboratories, R&D organizations, and the financial and public organizations involved in the innovation process and change management (Carlsson and Stankiewicz, 1991). These relationships may specifically concern inter-firm collaborations in the same region and sector (Porter, 1998), partnerships between companies and universities (Giuliani and Arza, 2009) and companies and intermediary agencies (Klerkx et al., 2009; Leydesdorff and Strand, 2012).

In the French wine industry over the past two centuries, research has been decisive in enabling wine producers to address different issues, such as fighting diseases (mildew, powdery mildew, phylloxera), yield increase, mechanization, and the improvement of wine quality (Paul, 2002). Relationships built locally between companies, research organizations, universities and innovation supporting organizations have been instrumental in innovation and management change, beyond the production and "dissemination" of scientific knowledge. These collaborations were also important in the growth of New World vineyards when seizing international market opportunities and adapting to their evolution (Feinsterseifert, 2007; Giuliani and Arza, 2009).

Components of the innovation system can intersect with the four phases of the adaptation decision-cycle (Asayehegn et al., 2017):

Firstly, knowledge developed within a sectoral and regional innovation system is better able to allow for the impacts of CC at the localized industry level, and thus avoid the trap of focusing on global and generic CC issues that academic research alone might fall into (Grin, 2010). Mechanisms and organizations dedicated to knowledge transfer to economic actors can then help better understand the climate problem, its evolution and impacts on the industry and companies (Pennesi et al., 2012).

Secondly, the knowledge exchanges within this innovation system make it possible to design solutions and adaptation pathways, and inform the economic actors' decision-making process. In the case of the French wine industry, the INRAE program LACCAVE[1] has gathered together researchers and economic actor communities such as producers and suppliers, to work on adaptation options through action-research (Ollat and Touzard, 2014). A wide range of adaptation options have been defined, including new vine varieties, soil and canopy management and enological practices. Even when direct links between academic research and industry are weak, brokers can act as go-betweens that allow firm-managers to access options and ways of adaptation (Klerkx and al., 2009). Adaptation can also stem from managers' empirical practices and tacit knowledge (Santha et al., 2010). These brokers' role is also to validate this tacit knowledge and expertise, by providing feedback to academic research organizations, with the aim of improving adaptation options and pathways.

Thirdly, components of the innovation system can intervene directly in managers' action choices, through the advisory function that provides technical support, especially to small companies or farms (Faure et al., 2019). This support can help farmers choose the best adaptation options according to the company's internal realities (resources and skills) and exogenous elements (strategic environment) (Wise et al., 2014). This requires developing

[1] https://www6.inrae.fr/laccave/

relationships with research or R&D organizations within the innovation system (Faure et al., 2018).

Fourthly, innovation system elements play a crucial role in the ongoing assessment and readjustment of adaptation strategies. Updating and improving knowledge about new impacts of CC and new adaptation pathways could help business leaders and farmers to improve their decision-making process over time by developing better strategies and avoiding maladaptive pathways (Wise et al., 2014). Collaborations with research and R&D organizations can also be a good way of getting technical guidance and advice on research proposals regarding how to adapt to CC and follow the right trajectory (Huggel et al., 2015).

Institutions within an innovation system are essential because they facilitate some choices and limit others. In the literature, climate policies and adaptation programs are generally identified as factors affecting the adaptation decision-making process (Wise et al., 2014). However, more specific institutions within an innovation system can be critical, and the same applies to the adaptation process; for example, the technological regimes or technological niches which are fundamental in the structuring and dynamics of innovation systems (Elzen et al., 2004; Peneder, 2010). A technological regime is a set of "rules, norms and practices that guide actors involved in innovative activities towards developing and resorting to certain heuristics, tactics, and objectives to solve a particular problem" (Nelson and Winter, 1982). It sets out the boundaries of what can be achieved. For example, in the agricultural sector, clean technological regimes such as organic production could be more favorable to CC adaptation (Magnan, 2009).

[INSERT FIGURE 1]

With respect to this research, we assume that an ***innovation system with regional and sectoral dimensions can affect the decision-making process for climate change adaptation***

Beyond considerations of institutional and relational components of an innovation system (as explained above), we propose that sectoral and regional innovation systems are part of the decision-cycle context for CC adaptation (Risbey et al., 1999; Wise et al., 2014).

Sectoral innovation system frameworks provide a key level of analysis that may be very useful for analyzing adaptation in agriculture and the wine sector (Boyer, 2016). This framework allows for sector-specific details, such as basic company structure and concentration, institutions, knowledge dynamics, networks, and interactions that structure a given sector. It also highlights how these elements evolve when sectoral changes occur as a result of a combination of internal and external factors (Malerba, 2004). In the agriculture sector, a first line of research is the Agricultural Innovation System" (AIS) as a declination of the sectoral innovation system approach (Klerkx and Jansen, 2010). Furthermore, CC has consequences that differ in nature and intensity according to the sector and industry (IPCC, 2014). The agriculture sector is the most affected by CC (Howden et al., 2007). Sectoral components of an innovation system could therefore be part of *decision-cycle context* in order to adapt to CC (Risbey et al., 1999; Wise et al., 2014).

The regional nature of innovation systems allows for local and territorial conditions (actors, institutions, geographic proximity) in the development of innovation processes and the adoption of new technologies, new practices, etc. (Cooke et al., 1997; Porter, 1992). As CC effects and climate variability differ across regions (IPCC, 2014), decision-making towards adapting to CC does not only consider the nature and intensity of climate effects at a spatial level, but also the local knowledge, institutions and organizations within the territories which facilitate the adaptation process (Pennesi et al., 2012; Adger et al., 2005).

Our general proposition is therefore subdivided into three assumptions focusing on the role of institutions (especially technological regimes), regional context and collaborations within an innovation system on the decision-making process towards CC adaptation.

H_1: Relationships and collaborations built with actors within an innovation system are instrumental in the decision-making process for CC adaptation.

H_2: Clean technological regimes such as organic wine production have a positive impact on the decision-making process for CC adaptation.

H_3: The regional context of an innovation system plays a vital role in the decision-making process for CC adaptation

3. MATERIALS AND METHOD

3.1. A Mixed Research Method

This study combines quantitative and qualitative methods (Fakis et al., 2014), in three French regional wine clusters, namely Bordeaux, Languedoc and Champagne, and focusses on wine producers' decision-making processes towards adapting to CC.

The choice of mixing quantitative and qualitative methods was informed by a literature review on the complexity of the CC adaptation issue, and by our objective of testing new determinants of CC adaptation in innovation system components (Baird et al., 2014; Fakis et al., 2014; Asayehegn et al., 2017). Understanding farmers' recognition of CC requires a more exploratory approach, as farmers and wine producers' recognition of the CC issue is very recent (Schattman et al., 2018, Sacchelli et al., 2016). The same is true for understanding concrete decisions taken by these actors (Harrison et al., 2013). Capturing the conscious character of the adoption of various solutions, practices, techniques and management as part of the decision-making process towards adapting to CC requires a more flexible research protocol that allows the respondent to explain clearly the causal link between the choices they have made and the fight against CC (Schattman et al., 2018).

However, identifying determinants that affect decision-making or adaptation strategies requires more quantitative methods, using statistical analysis and econometric models (Qazlbash et al., 2020; Yegbemey et al., 2014).

Qualitative methodology was useful for analyzing the first phase of the wine producers' decision-cycle, concerning recognition and understanding of CC issues, the nature and intensity of the CC effects being experienced, and how the specific climatic features of each regional wine cluster are taken into account (see point 3.3). The qualitative approach was also useful in exploring and analyzing concrete adaptation decisions, as well as the nature of these decisions, and which adaptation domains they effected (Ollat and Touzard, 2014).

The quantitative approach was useful in testing our study hypotheses empirically through econometric models, to identify which determinants of the innovation system have affected these concrete decisions (see point 3.5).

We implement a "concurrent mixed method" (Tashakkori, A., Teddlie C., 2010), gathering qualitative and quantitative data at the same time, during farmer's interviews. A hybrid interview guide was used, combining open-ended and close-ended questions (see 3.2) and we conducted these interviews face-to-face with wine producing company managers. Our data analysis continued this hybrid method, on the one hand by coding qualitative information based on content analysis, for both CC perceptions (see point 3.4) and adaptation decisions (see point 3.5) for inclusion in statistical tests, and on the other hand by using the richness of the responses to help interpret the tests.

3.2. Interviews and Sampling

Our research used original face-to-face interviews with wine producing company managers from the *Appellation d'Origine Contrôlée* (AOC) [1] area, and the original database from the LACCAVE project, which records wine producing companies clearly experiencing CC effects. We sent emails to schedule appointments to all 698 winemaking companies on the list for the three regional wine clusters, with 283 located in Languedoc, 226 in Bordeaux and 189 in Champagne. We received 41 responses from Languedoc, 34 from Bordeaux and 31 from Champagne.

Finally, we conducted face-to-face interviews with 92 wine-producing company managers (13% of the 698 winemaking companies on the database): 34 in Languedoc, 30 in Bordeaux and 28 in Champagne. These interviews took place in 2015-2016 and we ensured that the key factor "organic vs conventional wine production" was well represented and distributed among the three regions.

The interviews were organized in two parts, in accordance with the qualitative and quantitative approaches used.

The first part contained closed-ended and semi-closed questions on the presentation of the wine-producing company and its economic and structural characteristics (vineyard area, range of wines and prices, volume and value of wine production, turnover evolution, etc.); the manager's background, (age, experience, training, professional responsibilities); whether concrete decisions towards adapting to CC whose materialization through strategies have already been implemented in the wine-producing company; and finally, what kind of collaborations have taken place with other actors and organizations within the innovation system for management change and innovation (innovation egocentric networks).

The second part was an interview, and concerned the wine producer's awareness of CC effects on their farm in various areas (vine phenology, yield, quality…), and the intensity of this impact. We coded this part according to effects generally identified in the literature (see point 3.4). This part also focused on concrete decisions towards adapting to CC that have already been implemented in the wine-producing company: the nature of those

[1] AOC is a French label and certification granted to certain French geographical indications for wines and others agri-food industries (cheeses, butters etc.). It is based the concept of *terroir* and of geographical characteristics.

decisions, and which adaptation domains are involved (Ollat and Touzard, 2014). The aim was also to give to managers the freedom to express their ideas and their intentions, both on their CC awareness and on adaptation decisions taken in the wine producing company.

3.3. Regional Wine Clusters and their Innovation Systems

To conduct this research, we selected the three French regional wine clusters that are the most important in terms of turnover, and are located in different climatic zones: Bordeaux (oceanic), Languedoc (Mediterranean) and Champagne (continental). Climate scenarios differ in these three regions. Some models predict that areas available for quality wine production in Languedoc and Bordeaux (Hannah et al., 2013) will suffer a 67% decrease by 2050. Champagne, however, might be spared. In Languedoc and Bordeaux, scientific research predicts a reduction in yield, higher alcohol grades and less acidic wines (Ollat and Touzard, 2014). In Champagne, climate models also predict summer heatwaves, but rainfall is expected to increase (Briche, 2011). The impact of CC on wine quality seems less worrying, despite uncertainties about their decreasing acidity.

Boyer and Touzard (2017) describe the main components of the French wine innovation system. For the three regional wine clusters we have selected, figure 1 shows:

- **Research organizations, University and higher education organizations** (INRAE, ISVV, Research laboratories, University of Montpellier, University of Bordeaux, University of Reims Champagne-Ardenne, Bordeaux Sciences-Agro, Montpellier SupAgro…).
- **R&D organizations,** sometimes structured at a regional level (French Wine and Vine Institute IFV, Chambers of Agriculture, enology laboratories)
- **Inter-professional wine organizations, i.e.** associations that bring together producers and traders and develop technical services and experimentation, and promote, defend and manage regional vineyard interests.
- **Public organizations and local agencies,** these ensure the implementation of public wine policies, and encourage or limit innovations, but may also offer specific services (observatory, training, consultation…)
- **Financing organizations,** these support research and innovative projects and investments within the wine sector.

While these components are found in each regional wine cluster, their structuration and importance vary between regions. For example, the inter-professional wine organization in

Champagne (CICV) plays a crucial role in the innovation system of the Champagne wine cluster (Boyer and Touzard, 2016).

3.4. Data analysis

3.4.1. Analyzing the Climate Change Awareness of Winemaking Company Managers

One of the objectives of this study is to explore and analyze what kind of CC effects winemaking companies have experienced, and with what intensity. To this end, we used a qualitative method focusing on the interpretation of CC effects phenomena in terms of the meaning wine producers bring to them. We then analyzed statements from each wine producer. We constructed nine groups of CC effects (non-exclusive) based on those which have been identified in the literature. These groups are based on negative and positive effects (Parry et al., 2004; Cardell et al., 2019) on plant material, water stress/ drought, increased climatic variability, wine quality, vegetative cycle and phenological stages, agronomic components and plant disease (Ollat and Touzard, 2014; Quénol, 2014).

We used content analysis (Downe-Wamboldt 1992) to determine the presence of certain key words within wine producers' affirmation of the CC effects they are experiencing, to place them in each group of CC effects on wine production.

These groups of CC effects experienced by the winemaking companies and the main wine producers 'affirmation are presented in table 2.

3.4.2. Analyzing Concrete Decisions towards Adapting to Climate Change and Main Determinants

Characterizing adaptation decisions

We have also used content analysis to analyze and characterize decisions towards adapting to CC whose materialization through strategies have already been implemented in the wine-making companies. We used the five adaptation domains that were identified by the LACCAVE project (Ollat and Touzard, 2014; Quénol, 2014) in order to build five groups of adaptation strategies resulting from concrete decisions within winemaking companies. These adaptation domains are as follows: *plantation and localization management*; *plant material adaptation*; *vineyard management* including *water stress and drought management; fight against new pest pressures*; *enological practice.* We identified the presence of certain key words within wine producers' affirmation about decisions towards adapting to CC to place them in each group of adaptation domains. The principle concrete decisions taken by the winemaking companies related to these five adaptation domains are presented in table 3.

Testing determinants of adaptation decisions

One of the main objectives of the study is to test components of innovation systems on concrete decisions, taken by winemaking companies towards adapting to CC. To do this, we used a logit model of concrete decisions towards adapting to CC, whose materialization through strategies has already been implemented in the winemaking company. This choice of model was inspired by the binary nature of our dependent variable, as is used in a lot of recent research (Qazlbash et al., 2020; Omerkhil et al., 2020; Ahmed et al., 2021).

3.4.3 Specification of the model

The logit model we used in this study to test components of innovation systems on concrete decisions, taken by winemaking companies towards adapting to CC can be written in the following mathematical form:

$$Y_i = ln(\frac{P_i}{1 - P_i}) = \alpha + \beta X$$

Y is defined as the dependent variable and is a dummy variable that takes the value of 1 if the wine producer took at least one concrete decision towards adapting to CC, and 0 otherwise.

p= P (Y = 1), with P (Y = 1): is defined as the probability that the wine producer has taken at least one concrete decision towards adapting to CC.

X is defined as the vector of independent variables.

Determinants of decision-making towards adapting to climate change

According to our general proposition: ***Innovation systems effect the climate change adaptation decision-making process***, we use indicators and proxies for innovation system components. Table 1 presents all the variables included in the econometric models, and their characteristics.

Firstly, we use indicators that express collaboration between wine producers and actors or organizations within the French wine innovation system, knowing that relationships with heterogeneous actors including R&D organizations and universities, are one of the main components of innovation systems (Carlsson and Stankiewicz, 1991). We code and use a list of six dummy variables (*EL, CA, SU, WIN, PO, RC, PO*) that take the value of 1 if the wine producer is in the habit of collaborating with a given Innovation System main actor or organization (as identified in the point 3.3) for innovation processes and change management, and 0 otherwise (see table 1). To avoid multicollinearity problems, we have divided the general econometric model into six, in order to test each direct collaboration between the wine producing company and main actors or organizations in the innovation system.

Secondly, we use indicators for specific institutions within the French wine innovation system (Elzen et al., 2004). We consider organic wine production to be a clean technological regime. Organic wine production is an emergent and rapidly growing trend in the wine industry (González and Parga-Dans, 2020). We then code a dummy variable *BIO* that takes value of 1 if the company produces organic wine and 0 otherwise.

Thirdly, for the knowledge base (Carlsson and Stankiewicz, 1991), we assume that the wine producer's experiences accumulated over time are a proxy that captures empirical or tacit knowledge about climate variability and how to deal with it. (Pennesi et al., 2012). We use a count variable *SEN* that measures the number of years of experience in wine production the wine producer has.

The wine producer's education level, especially in agriculture or agronomy, is considered a proxy for scientific knowledge accumulated by the wine producer. For this, we code a scale variable *FORM* that expresses the wine producer's level of training. This variable takes the value of 1 if the wine producer has a lower level than a BTS diploma, 2 for a BTS level, 3 for a Bachelor's degree, and 4 for an engineering or Master's degree or higher.

To complete our analysis, we used the variable *SIZE* as a control variable that expresses the wine-producing company's size and economic characteristics (Ouédraogo et al., 2010; Yegbemey et al,. 2014).

We used Stata software to run these econometrics models

[INSERT TABLE 1]

4. MAIN RESULTS AND FINDINGS

Our results focused on two main components of the adapting to a CC decision-making process: i) recognition and understanding of the effects of CC change on winemaking companies and ii) concrete decision-making by those wine producers. Recognition/Concrete decisions is thus the common thread behind the presentation of our results. We also analyzed points of convergence and divergence between recognition of the effects of CC, and decision-making towards adapting to CC.

4.1. Awareness of Climate Change in French Regional Vineyards

The wine producers identified several areas of CC impact on wine production (table 2).

Firstly, we found that the most cited impacts were identified by around half the wine producers. They identified: i) impacts on quality and wine specificities, such as increasing alcohol grades, loss of acidity, modification of wines and vintage characteristic features; ii) impacts on vegetative cycles and phenological stages, such as advancement of harvest dates (2 to 3 weeks earlier), disturbance of the vegetative cycle, precocity of the phenological stages; iii) irregular seasons and greater climate variability, such as more irregular crop seasons, greater thermal amplitude, more extreme weather events, rainfall changes, and more frequent exposure to spring frosts.

Secondly, there were less generally mentioned impacts. Around 30% of wine producers identified: i) impacts on agronomic components, such as yield reduction; modification of the structure and size of grapes; more difficult work organization in the vineyard; ii) impacts on water availability such as water stress and drought.

Finally, there were the least mentioned impacts (around 20% of wine producers), namely on plant material and increasing pressure from diseases and parasites.

Very interestingly, 36% of wine producers in the Champagne vineyards recognized the beneficial effect of CC on wine production. Among these benefits, excellent harvests, cost reduction of chaptalization, disease reduction, and accessibility of new interesting *terroirs* (specific local types of land) were mentioned.

Furthermore, there is significant variability between regional vineyards (Fig 2). Water stress and drought are viewed as one of the major impacts of CC on wine production in Languedoc vineyards: around 60% of wine producers there consider water stress and drought to be one of the main impacts of CC on wine production, as opposed to 17% of wine producers in Bordeaux, and none at all in Champagne.

Increasing pressure from disease and parasites appears to be one of the CC impacts that affects Champagne vineyards. 36% of wine producers in Champagne vineyards identified it, while only 7% in the other regional vineyards did so.

Wine producers in Languedoc and Bordeaux were more concerned with impacts on wine quality and specificities (increasing alcohol grade, loss in acidity, modification of wine specificities and vintages) and on plant material than those in Champagne. Around two-thirds of wine producers in Languedoc and Bordeaux identified CC impacts on the quality and specificities of wine as opposed to 32% in Champagne. Finally, only 4% of Champagne wine producers identified CC on plant material while 30% or more did so in in Languedoc and Bordeaux.

These results show that recognition of the nature and intensity of CC impacts on wine production differ according to the production region. Research should therefore consider the regional and sector dimensions of CC impacts, in order to generate relevant adaptation solutions. Adaptation pathways should differ according to the impacts identified, and the same applies to the proposed relevant adaptation solutions.

[INSERT FIGURE 2]

[INSERT TABLE 2]

4.2. Adaptation Alternatives, Concrete Decisions and Adaptation Strategies

As shown in table 1, 59% of wine producers say they have already taken concrete decisions towards adapting to CC effects that have been materialized through strategies and concrete actions in the past five years. (65% in the Languedoc, 57% in Champagne and 53% in Bordeaux).

Globally, all alternative adaptation domains proposed by academic research are concerned with the adaptation strategies adopted by wine producers within the regional vineyards in our study. Most of the strategies are concerned with cleaner production approach.

However, we found substantial variability between these adaptation domains prioritized by wine producers in general, and between those who have selected an adaptation domain between regional vineyards.

As shown on Table 3, most wine producers' concrete decisions and adaptation strategies concern vineyard management. 67% of wine-producers who have taken concrete decisions towards CC adaptation have implemented *vineyard management strategies*. Among these strategies, we have found advanced harvest dates, night harvest, tillage optimization, management of trellis systems (decrease in trellising height), weed management, leaf-stripping management and agroforestry.

35% of wine producers had already developed adaptation strategies in the second main adaptation domain of *enological practices*, for example, chaptalization reduction, stopping the de-acidification of grape must, wine blending, and the use of new yeast.

Around 18% of wine producers have also developed strategies for *plant material,* such as using new rootstock or late grape varieties. Some have planted old grape varieties with later characteristics. As for the *plant material* domain, 18% of wine producers have taken decisions and developed strategies for *plantation and localization management,* for example, plot location management, planting at higher altitude or at a high elevation, adaptation of plantation density and row orientation.

Only 8% of wine producers have developed strategies for new pest pressures. This demonstrates that while fighting pests is a major issue for French wine production, wine producers have a balanced point of view between CC impact and the latter issue. For now, academic research into French wine production does not make a clear link between the emergence of new pest pressure and the impact of CC.

As mentioned above, substantial variability between regional vineyards can be observed, depending on wine producers' decision-making and strategies.

Firstly, no wine producers in Champagne have developed water stress and drought management strategies, while 31% of Bordeaux wine producers and 27% in Languedoc have done so. It seems that Champagne wine producers integrate fighting new pest pressure into their adaptation decision-making processes and strategies more frequently than those in Bordeaux and Languedoc, but they develop fewer strategies for *plant material*. These results are consistent with the wine producers' variability of recognition within these three regional vineyards. However, while Bordeaux and Languedoc wine producers identified CC impacts on wine quality and specificities, and enological components, those in the Champagne vineyards have developed a greater number of strategies for *enological practices*. This finding indicates that CC impacts directly affect a very traditional winemaking process in Champagne: chaptalization. Champagne wine producers have gradually reduced the amount of sugar they add to unfermented grape must.

[INSERT TABLE 3]

4.3. Determinants of the Decision-making Process for Climate Change Adaptation

The results of the logit model (table 4) show which factors influence the wine producers' decision towards adapting to CC.

Firstly, relations built within the regional vineyard innovation system play a key role in wine producers' decision-making processes, when trying to adapt to CC. Wine-producers who have collaborated with the Chambers of Agriculture for change management and innovation processes are more inclined than others to take concrete decisions and develop CC adaptation strategies. The same is true of those who have collaborated with enological laboratories. These findings are in line with previous research into adaptation strategies developed by wine producers (see point 4.2). The two main adaptation domains where wine producers' adaptation strategies converge are *vineyard management* and *enological practices.* Chambers of Agriculture advisors remain the interlocutors of wine producers who work with them on vineyard management. These farmers' organizations play the role of experimentation and extension in these domains of action. Enological laboratories are most often private organizations, which offer experimentation, tests, and technical support to wine producers in the enological domain. These two actors are in direct connection with academic research organizations and universities.

However, direct collaborations between academic research organizations and wine producers do not influence the decision-making process for adapting to CC. Moreover, academic research organizations and wine producers have very few connections in the French wine industry, as confirmed by our results (Table 1). Nevertheless, the two main adaptation domains where wine producers develop strategies are consistent with scientific publications on CC adaptation in the French wine industry, where *vineyard management* and *enological practices* are key words in 75% and 62% of publications on CC and wine respectively (Boyer, 2020). This finding demonstrates the relevance of a systemic thinking approach. Even though the direct connection between wine-producing companies and academic research organizations and universities is weak, brokers within the French Wine Innovation system foster indirect relationships, and there is positive knowledge exchange between these actors.

As for the knowledge base in wine producers' backgrounds, we have found that the higher the wine producer's level of training, the more able they are to adapt to CC, which suggests the role played by being able to integrate scientific knowledge in fostering adaptation. Secondly, the more experience wine producers have in wine production, the more able they are to adapt to CC – a determinant that indicates the importance of empirical knowledge drawn from experience.

Our findings also show that wine producers practicing organic or biodynamic agriculture are more inclined to adapt to CC, which highlights the role of a clean technological regime in the decision-making process towards adapting to CC.

Finally, our results confirm that wine companies' economic characteristics do not influence wine producers' decisions or strategies towards adapting to CC.

[INSERT TABLE 4]

5. DISCUSSIONS

5.1. Relationships Built within an Innovation System Influence the Decision-making Process towards Adapting

Previous studies highlight the role of relationships and collaboration between academic research organizations and wine-producing companies in the dynamics and growth of vineyards (Giuliani and Arza, 2009). Wise et al. (2014) showed the role of research in the decision-making process and adaptation pathway. Our empirical study shows that direct relations between wine producers and academic research organizations are weak in the French wine industry. However, as has already been shown in the scientific literature on the agricultural innovation system (AIS), intermediaries or brokers play an important role in the innovation system (Klerkx et al., 2009). Our study shows that brokers, such as enology laboratories and Chambers of Agriculture, play a key role in the wine-producers' decision-making process for CC adaptation.

As part of their missions, they experiment and transfer technologies and provide wine producers technical support in enology and vineyard management. Furthermore, they address the issue of CC by developing experimentations or by disseminating information on the challenges of CC, in collaboration with professional organizations.

We can, therefore validate the hypothesis H1.

5.2. Technological Regime also Influences the Decision-making Process towards Adapting

One of our main findings shows that wine-producers who develop organic or biodynamic agriculture are more likely to make concrete decisions and develop strategies towards adapting to CC. Organic or biodynamic wine producers are already on a trajectory that considers environmental issues. According to Magnan (2009), the adaptation trajectory for CC is part of a broader one: sustainable development. The CC issue can be seen as one environmental matter among others, leading to a reduction in chemical inputs, for example. As a result, these producers have already developed routines and environmental practices that enable them to follow a CC adaptation path to a greater degree than those who do not take a clear stand on sustainable development (Merli et al., 2018).

We can, therefore validate the hypothesis H2.

Overall, we have found that most of the strategies developed by wine producer companies relate to the cleaner production approach, even if they are not involved in organic production. This result shows the convergence between CC adaptation decisions and a broader commitment to a cleaner technology regime, to which wine consumers are increasingly sensitive (Hannah et al., 2013; Merli et al., 2018; Cardell et al., 2019).

5.3. Regional Components of the Innovation System, Decision-Making Process and Adaptation Strategies

Our empirical findings show that CC awareness differs according to regional vineyards, and this can be explained by the spatial variability of the nature or intensity of CC impacts (Adger et al., 2005). Our findings show that wine producers in Champagne vineyards are more likely to identify the beneficial effects of CC than those in the other regional vineyards. While wine producers in Languedoc identified water stress and drought as one of the major impacts of CC on wine production, Champagne wine producers are more concerned with the increasing pressure of diseases and parasites, and Bordeaux growers are more concerned with inter-vintage variability. Our findings confirm some projections on CC and other research results described in the literature (Hannah et al., 2013, Graveline and Gremont, 2021)

Our results, moreover, highlight differences in the design of adaptation options between the regional vineyards. For example, winegrowers in Bordeaux and Languedoc combine strategies for the management of water stress and the vine canopy, whereas winegrowers in Champagne combine the fight against new pest pressures with corrective actions at the oenological level. These results highlight possible different forms of adaptation pathway construction within regional vineyards that also depend on region-specific organizations and research (Ollat and Touzard, 2016).

We can therefore validate hypothesis H3.

5.4. Knowledge Bases and Decision-Making for Climate Change Adaptation

Our work also clarifies the role of certain forms of knowledge in CC adaptation. Firstly, we have shown that the level of training (mostly in agronomy and enology) affects the decision-making process towards adapting to CC positively. It would seem that it is easier to understand the complex CC phenomenon and the exploration of different technological solutions to cope with CC impacts with the acquisition of scientific knowledge (Pennesi et al., 2012), that a higher level of education in agronomy or enology would ensure.

We have shown the positive effect of wine-producers' accumulated experience on their decision-making process towards adapting to CC. Viticulture has always been prone to climatic variability (vintage effect, for example). The historical observation of the effect of climatic variability on wine and practical knowledge accumulation through experience are determinants for the decision-making process and adaptation strategies (Quénol, 2014).

In our analysis, academic training and tacit knowledge from experience in climatic variability management emerge as important factors. They constitute a personal background in regional organization that provides education and experience sharing, constituting "regional knowledge bases" that help wine-producers make good decisions towards adapting to CC.

5.5. There are Few Links between Adaptation and Economic Characteristics

Adaptation to CC and economic implications concern also cost/benefit analysis (Stern, 2008; Ditricht et al., 2016). Some might think a company's economic characteristics are decisive in CC adaptation strategies. Our findings do not confirm this, but are in line with other results from different agricultural contexts that show that size, economic outcomes the number of farmworkers per household do not correlate significantly with the producer's decision to adapt to CC (Yegbemey et al., 2014; Graveline and Gremont, 2021). This suggests that the awareness of CC is independent of the economic characteristics of the farms and that many solutions can be adapted to different categories of producers, including small ones. For example, risk management, which is increasing with CC, appears to have little to do with the economic size of the farm, at least in sectors such as viticulture. Moreover, company managers probably do not currently consider adaptation to CC to be a sufficiently economic or competitive strategy to justify the size and level of competitiveness of the firm (Galbreath, 2015).

6. CONCLUSIONS

In this paper, we have analyzed the decision-making process towards CC adaptation based on face-to-face interviews with wine producers from three main French regional wine clusters. We have characterized the decision-making process as a four-stage cycle where the firm's external environment and context play a key role. We have showed that the decision-making process for CC adaptation depends on the innovation system with regional and sector components. We have also shown that a clean technological regime is instrumental in the decision-making process and CC adaptation strategies.

Our research demonstrates that decision-making processes for CC adaptation depends on regional specificities that influence the nature of CC recognition, strategies, and relational resources towards adaptation. We have highlighted the role of intermediaries and R&D organizations – the components of the same innovation system at the sector level, but with layouts differing between regions. Over and above the production of knowledge on CC, universities and research centers participate in the decision-making process for CC adaptation, in particular through mechanisms connecting them with innovation brokers and intermediaries. Relationships and collaboration with enology laboratories and Chambers of Agriculture have been decisive in wine-producing companies' decision-making processes and adaptation strategies. The decision-making process for CC adaptation is also influenced by a company's technological regime. Our findings confirm this through the role of organic wine production in the decision-making process and adaptation strategies. We have found empirical evidence for the role of a cleaner production approach on CC adaptation. Knowledge from wine-producers' experiences (learning by doing) and their level of education play a key role, suggesting their personal backgrounds developed through interactions within the regional innovation system are also important in the decision-making process towards CC adaptation.

Finally, our findings call for recommendations for economic actors, researchers and policy makers jointly concerned with the CC adaptation of the wine industry. Promoting the adaptation capacities of this industry includes strengthening the innovation systems, taking into account regional specificities, in order to promote the co-construction and sharing of information and solutions. A better connection between the wine industry stakeholders and those involved in cleaner technological regimes such as organic farming must also be developed, as up until now these knowledge communities remain poorly connected in many regions. The growing integration of adaptation and mitigation issues into climate strategies and policies will strengthen the link between environmental and climate issues, in particular in viticulture. In addition, this study calls for the development of new research, comparing decision-making processes towards adaptation in other regions and other sectors. Longitudinal approaches would also better analyze managers' decision cycles within the adaptation pathways of their companies. In this research, we have not been able to follow longer adaptation decision-making processes, due to their still recent development, even though the wine sector is already very concerned by the issue of CC, and has initiated multilevel adaptation strategies, at company and policy maker levels.

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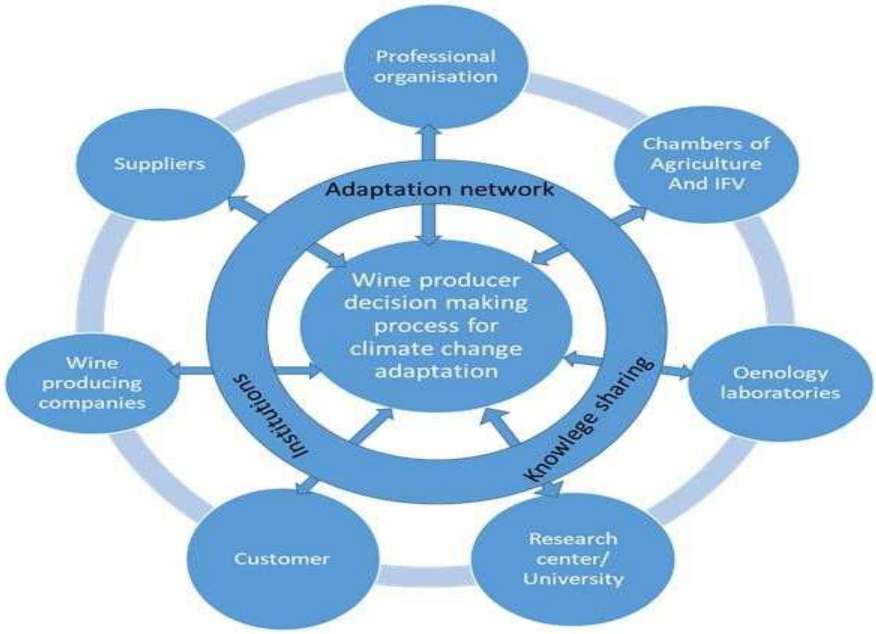
List of Figures

Figure 1
French Wine Industry Innovation and Production System Actors



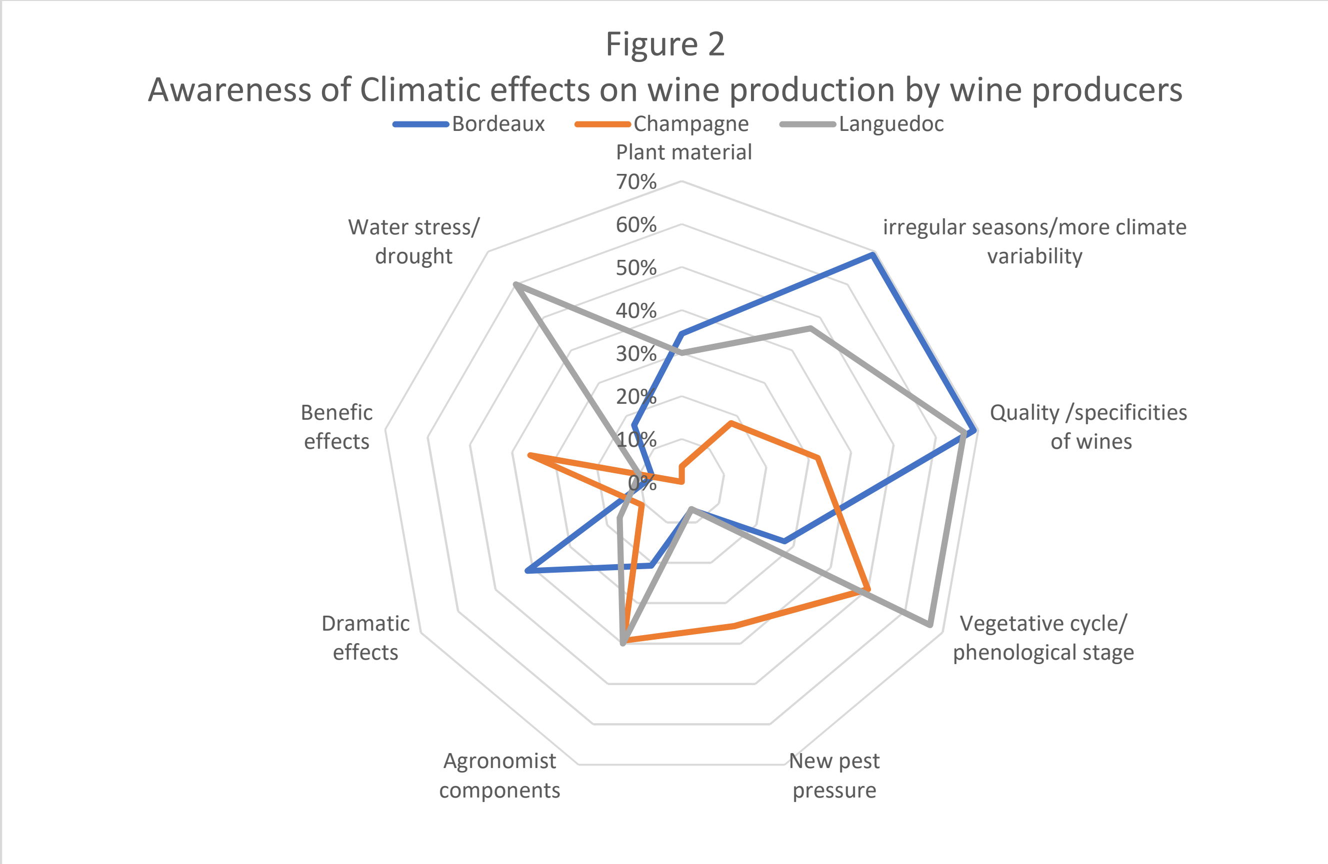


Figure 2
Awareness of Climatic effects on wine production by wine producers
Bordeaux
Champagne
Languedoc
Plant material
70%
60%
50%
40%
30%
20%
10%
0%
irregular seasons/more climate variability
Quality /specificities of wines
Vegetative cycle/ phenological stage
New pest pressure
Agronomist components
Dramatic effects
Benefic effects
Water stress/ drought

Table 1
Descriptive statistics

Label	Variables	Type of variables	Freq.	Percent/average
Variables that express regional wine clusters	Languedoc	***Dummy variable*** that takes value 1 if the wine producer is located in Languedoc and 0 otherwise	34	37%
	Champagne	***Dummy variable*** that takes value 1 if the wine producer is located in Champagne and 0 otherwise,	28	30%
	Bordeaux	***Dummy variable*** that takes value 1 if the wine producer is located in Bordeaux and 0 otherwise ,	30	33%
Variable that expresses Decision towards adapting to climate change	Y	***Dummy variable*** that takes value 1 if the wine producer has already taken at least one concrete decision towards adapting to climate change and 0 otherwise.	54	59%
Variable that expresses Economic characteristics	SIZE	***Count variable*** that measures the number of employees in the enterprise	-	9.45
Variable that expresses Technological regime	BIO	***Dummy variable*** that takes value 1 if the wine producer is organic or biodynamic and 0 if it is conventional	37	40%
Variables that express Personal background related to knowledge base	SEN	***Count variable*** that measures the wine producer's *seniority* = number of years of experience	-	18
	FORM	***Scale variable*** that shows the level of training that takes value 1 if the wine producer has a lower level than the BTS diploma, 2 if he holds a BTS level, 3 a Bachelor's degree, 4 an engineering or Master's degree	-	2.18
Variables that express collaboration between wine producers and actors or organizations within the French wine Innovation system	EL	***Dummy variable*** which takes value 1 if the wine producer is *used to* collaborating with e*nological labs* and 0 otherwise	74	80%
	CA	***Dummy variable*** which takes value 1 if the wine producer is *used to* collaborating with *Chambers of Agriculture* and 0 otherwise	59	64%
	SU	***Dummy variable*** which takes value 1 if the wine producer is *used to* collaborating with *suppliers* and 0 otherwise	57	62%
	WIN	***Dummy variable*** which takes value 1 if the wine producer is *used to* collaborating with peers and 0 otherwise	58	63%
	PO	***Dummy variable*** which takes value 1 if the wine producer *used to* collaborating with *professional organization* and 0 otherwise	29	32%
	RC	***Dummy variable*** which takes value 1 if the wine producer is *used to* collaborating with *research centers* or researchers and 0 otherwise	17	18%

Table 2

Awareness by wine-producers of the impacts of CC on vineyards and wine in the three regional wine clusters

Groups of climate change effects identified	Main statements made by wine producers about climate change effects they are experiencing	% Wine producers who identified climate change effects according to each group of effects			
		Bordeaux	Champagne	Languedoc	Total (sample)
Effects on Plant material	Current grape varieties become unsuitable	33%	4%	29%	23%
	Current vine rootstocks become unsuitable/ increased mortality rate of vine rootstocks				
Water stress/ drought	Water stress/ drought	17%	0%	59%	27%
	Vine irrigation problem				
Increased climatic variability	More irregular or modified seasons	70%	18%	47%	46%
	More extreme weather events				
	Changing rain patterns				
	More thunderstorms at the end of July-beginning of August				
	More recurring spring frosts				
	More intense climatic episodes				
Impacts on quality and wine specificities	Increased alcohol grade	70%	32%	68%	58%
	Decreased wine acidity				
	Wine quality decline				
	Modification of wine specificities				
	Mitigation or accentuation of the vintage effect				
	Modification of the enological components / Aromatic imbalance				
Impacts on vegetative cycle and phenological stage	Advancement of harvest dates (2 to 3 weeks earlier)	27%	50%	68%	49%
	Disturbance of the vegetative cycle				
	Shift between phenolic maturity and grape juice maturity				
	Precocity of phenological stage.				
	Earlier flowering, Earlier budburst				
Impacts on Plant disease	Increasing disease pressure/emergence of new disease problem	7%	36%	6%	15%
	Emergence of southern flora in northern vineyard				
	Increasing pressure of downy mildew and powdery mildew				
Impacts on agronomist components	Loss of control in vineyard management	20%	39%	41%	34%
	Tillage becomes insufficient				
	More seeds in grapes				
	Change in vine grape weight and structure				
	Changes in vegetative development				
	De-structuring of vineyards				
Dramatic awarenesss	More Intensive hail episode	40%	11%	18%	23%
	Recurring climatic accidents				

	More extreme climatic phenomena				
	Sudden changes in temperature				
	Increase in frequency of violent episodes				
	Strong reduction in AOC area				
	Strong reduction of yields				
	Death of grape in heat				
	New epidemics in the vineyards				
Beneficial effects	Excellent and more abundant harvest	7%	36%	9%	16%
	Cost reduction for chaptalization, ,				
	Disease reduction in the vineyards				
	Accessibility of interesting new terroirs				

Table 3

Adaptation strategies by Category in the three regional wine clusters

Adaptation domains	Main decisions for climate change adaptation	% wine producers that took concrete decisions according to the adaptation domains			
		Bordeaux	Champagne	Languedoc	Total
Adaptation Plant material	Use of new and later rootstock Plantation of more cabernet, cinsault, late mourvèdre (Languedoc-Rousillon vineyard) Re-use of old grape varieties with later characteristics	25%	6%	18%	18%
Adaptation Enological practices	Reduction of chaptalization(Champagne), Stopping de-acidification of grape must, Modification of wine blending, Use of new yeast more adapted to climate change effects Thermo-vinification Modification of extraction techniques in winemaking Cold management / investment to cool the grape must at harvest time. Modification of thermal insulation of the wine storehouse	19%	50%	36%	35%
Adaptation Fight against (new) pest pressures	Use of cleaner Phytosanitary treatments Use of new Phytosanitary treatments Adaptation and modulation of methods and Phytosanitary treatments Use of more efficient spraying equipment Earlier phytosanitary protection in the cultural season Phytosanitary treatments early in the morning	6%	13%	5%	8%
Adaptation Plantation and localization	Management of plot location, Planting at altitude or high elevation Use of "Rameal Chipped Wood" (RCW) technique to prevent erosion Project of new wine cellars and winery using natural temperatures to reduce energy consumption and facilitate winemaking management Plot choice well-suited to climate effects (location of the plantation) Change in vine rows density and orientation Agroforestry to face wind problems and reduce erosion	13%	19%	18%	18%
Adaptation Vineyard management	Advanced harvest dates Night harvest Tillage optimization Management of trellis systems (decrease in trellising height) Weed management Leaf-stripping management Agroforestry Use of new Agronomic approaches to soil management, allowing soil to restore water in difficult times Adaptation of ploughing methods so that water penetrates well into the soil Late pruning to change the flowering period	75%	50%	77%	67%
Adaptation Management water stress and drought	Precision irrigation Hill reservoir maintenance to optimize the use of storm water supplies. Use of new Agronomic approaches to soil management, allowing the soil to restore water in difficult times	31%	0%	27%	20%

TABLE 4

Estimation of the logistic model with variable Y (decision-making towards adapting)

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Languedoc	0.8015 (0.5145)	0.8515 (0.5448)	0.8722 (0.5436)	0.8904 (0.5683)	0.8430 (0.5305)	0.9904 (0.6521)
Champagne	--	--	--	--	--	
Bordeaux	0.4215 (0.2848)	0.4726 (0.3099)	0.4934 (0.3178)	0.5050 (0.3295)	0.4838 (0.313)	0.5589 (0.3733)
SIZE	1.0391 (0.0253)	1.0267 (0.0229)	1.0307 (0.0233)	1.0288 (0.0223)	1.0289 (0.0223)	1.0307 (0.0227)
BIO	3.6929 ** (2.1125)	3.6111 ** (2.0522)	3.1142** (1.6987)	3.0564** (1.6599)	3.0404 ** (1.6515)	3.2441** (1.7866)
FORM	2.0872*** (0.5808)	2.0254 ** (0.5692)	2.3034*** (0.6485)	2.2752*** (0.6297)	2.2381*** (0.6111)	2.2294*** (0.6051)
SEN	1.0538** (0.0274)	1.0611** (0.0288)	1.0575** (0.0268)	1.0569** (0.0266)	1.0566** (0.0266)	1.0537** (0.0271)
CA	3.1553** (1.6983)					
EL		3.7424** (2.4643)				
RC			0.7754 (0.5507)			
SU				0.8817 (0.4627)		
WIN					1.1058 (0.5683)	
PO						1.4995 (0.8756)
Cons	0.0402*** (0.039)	0.0285*** (0.0313)	0.0686*** (0.0623)	0.0744 *** (0.0673)	0.0692 *** (0.0635)	(0.0597)*** (0.0561)
Number of obs	92	92	92	92	92	92
Prob > chi2	0.0002	0.0002	0.0013	0.0013	0.0013	0.0011
Pseudo R^2	0.2276	0.2243	0.1902	0.1896	0.1895	0.1932

Notes: All results are marginal effects (odds-Ratio). Standard error is shown in parentheses.
*Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

TABLE 5

Correlation Matrix shows the relationship among variables using Pearson's Correlation coefficient method

	Y (decision)	Languedoc	bordeaux	champagne	SIZE	BIO	FORM	SEN	CA	EL	WIN	RC	SU	PO
Y (decision	1.0000													
Languedoc	0.0935	1.0000												
Bordeaux	-0.0758	-0.5326	1.0000											
Champagne	-0.0209	-0.5064	-0.4601	1.0000										
SIZE	0.1004	-0.0019	0.1859	-0.1873	1.0000									
BIO	0.2829	0.2446	-0.0504	-0.2053	-0.1146	1.0000								
FORM	0.3014	-0.1284	0.1164	0.0161	0.0018	0.1509	1.0000							
SEN	0.2199	0.1762	-0.0676	-0.1160	0.0305	0.2339	-0.1344	1.0000						
CA	0.2471	0.0561	-0.0599	0.0021	-0.0894	-0.0337	0.1679	0.0778	1.0000					
EL	0.2540	-0.0197	0.1093	-0.0906	0.0960	-0.0425	0.2464	-0.0211	0.0882	1.0000				
WIN	0.0895	0.1197	0.0042	-0.1298	0.0157	0.1228	0.1284	0.0285	0.1786	0.1333	1.0000			
RC	0.1150	0.0416	0.0870	-0.1323	0.1707	0.1807	0.2693	0.0970	0.0641	0.0936	-0.0416	1.0000		
SU	0.0247	0.1361	0.1630	-0.3089	0.0855	0.0491	0.1101	-0.0001	-0.1192	0.1215	0.2349	-0.0307	1.0000	
PO	0.0465	-0.1802	-0.1725	0.3648	-0.1540	-0.1748	-0.0305	0.1211	0.1172	-0.0192	-0.2076	0.0387	-0.1430	1.0000