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# ► To cite this version:

Marianne Lefebvre, Yann Raineau, Cécile Aubert, Niklas Möhring, Pauline Pedehour, et al.. Green Insurance for Pesticide Reduction: Acceptability and Impact for French Viticulture. 28. Annual conference of the European Association of Environnmental and Resource Economists, Jun 2023, Limassol, Cyprus. hal-04154920

# HAL Id: hal-04154920 https://univ-angers.hal.science/hal-04154920

Submitted on 27 Nov 2023

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# Green Insurance for Pesticide Reduction: Acceptability and Impact for French Viticulture

November 27, 2023

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#### Abstract

8 Green insurance can help producers manage the risks of transitioning to more environ-9 mentally friendly practices. We investigate the uptake determinants and potential pesticide 10 reduction in the viticulture sector, a major pesticide user, using a Choice Experiment with 11 412 French growers. Correcting for sampling bias, we find that between 48% and 60% (de-12pending on contract features) are likely to take out insurance offering compensation for 13 yield losses caused by the failure to contain diseases of a Decision Support Systemtargeting pesticide-reduction. Green insurance can be a cost-effective tool for achieving the EU 1415ambitious pesticide objectives, with an average 45% reduction in fungicide use for adopters.

- 16 **JEL codes:** Q18, Q14, D81, C99
- 17

18 Keywords: Choice experiment, Pesticides, Viticulture, Insurance, Decision Support System,
19 Integrated Pest Management, Index, Mutual fund.

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Acknowledgments: We would like to thank Max-Régis Ogounchi and Adrianne Moreau for 21their help in programming the survey, the REECAP network for providing initial feed-back 22during the "check before you collect" webinar, as well as participants to the FRIES webinar 2324organized by ETH. The results have been discussed with insurers, crop protection advisers and policy makers during a workshop organized by the European Commission on "Alternative 25business models for pesticide reduction" (November 2023). We acknowledge funding by Région 26Pays de Loire (project BEHAVE) and the support of the Grand Plan d'Investissements d'Avenir 2728through the program Territoires d'Innovation (PIA VitiREV) as well as support of the French 29National Research Agency (ANR) under the grant 20-PCPA-0010 (VITAE). Access to some confidential data, on which is based this work, has been made possible within a secure environ-30 ment offered by Centre d'accès sécurisé aux données (Ref. 10.34724/CASD, French agricultural 31 32 ministry 2022).

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## 33 1 Introduction

Pest management is central for ensuring crop yield and quality (Savary et al. 2019) and its importance is expected to further increase under climate change (Chaloner, Gurr, and Bebber 2021). Current pest management strategies are mainly based on pesticide use, with increasing evidence of pesticides' adverse effects on the environment and human health (IPBES 2019; Geiger et al. 2010; Edlinger et al. 2022; Willett et al. 2019; Snelders et al. 2012). As a consequence, reducing pesticide use and risks has become an important public policy goal on regional and global levels (Möhring, Ingold, et al. 2020; Möhring, Kanter, et al. 2023).

Decision support systems (DSS) for farmers to optimally time applications according to actual local disease pressure have the potential to reduce pesticide use while maintaining yield levels (Pertot et al. 2017; Chen et al. 2020; Anastasiou et al. 2023, and fungicide in particular (Lázaro, Makowski, and Vicent 2021). However, their uptake is often low. One important reason is that expected risks of yield losses are perceived as higher when adapting management strategies (Gent, De Wolf, and Pethybridge 2011, Shtienberg 2013; Möhring, Wuepper, et al. 2020).

48Green insurance, which insures potential yield losses when switching practices, is not currently included in policy toolboxes, despite its potential to increase farmers' uptake of DSS-based 4950crop protection strategies. With green insurance, the insured producer receives financial compensation in case of yield losses caused by the failure of best management practices (here the 51inability of the DSS to contain diseases).<sup>2</sup> If producers have biased perceptions regarding the 52effects of new practices on the level and variability of yields or profits (Feather and Amacher 531994), green insurance could help them revise these perceptions by allowing them to try these 5455practices risk-free (Mitchell and Hennessy 2003; C. Aubert et al. 2020). In other risk areas, it has been shown that sub-optimal insurance levels are observed when agents face an explicit or 56

<sup>&</sup>lt;sup>2</sup>To limit moral hazard, contracts include requirements to provide full documentation on the adoption of best practices, as well as the right to deny claims when evidence of lack of due diligence is apparent. The objective is to facilitate expert evaluation of losses, in particular, to distinguish losses ensuing from the adoption of best practices from losses related to other factors.

57 implicit cost to discovering the true probability of losses, but public subsidy can trigger optimal 58 insurance decisions (Kunreuther and Pauly 2004). It suggests that a subsidy for green insurance 59 could be needed. Compared to agri-environmental schemes (AES), subsidizing green insurance 60 can be more cost-effective since public support is triggered only for actual losses (Baerenklau 61 2005), and the level of support required to induce participation by risk-averse producers does 62 not need to include a risk premium.

A few green insurance contracts have been experimented with in the US and in Europe.<sup>3</sup> 63 But these experiments have only been conducted on a small scale, with no proper measure of 64 cost-efficiency nor evaluation of the levers to increase acceptability. Some authors have modeled 65 66 producers' decision to contract green insurance (Baerenklau 2005; Harris and Swinton 2012), but more empirical research is needed to evaluate its potential uptake and impact. A fundamental 67 challenge is to design insurance products that will be adopted by a large range of farmers, will 68 actually lead to best management practices' adoption and are more cost-efficient than other 69 instruments (Hazell and Varangis 2020). Ex-ante evaluation is thus important for industry 7071and policy to develop products and support programs that are attractive to producers. Such (subsidized) risk management tools for pesticide use reduction may have a high global relevance 7273- in the EU as well as beyond (Möhring, Kanter, et al. 2023).

Here we assess the effect of different insurance designs on acceptability, as well as the potential impact of a subsidized green insurance, targeting fungicide use in French viticulture. Grapevine production is globally among the most pesticide-intensive and economically relevant crops, and therefore represents a key entry point to reduce pesticide use in agriculture. In France, the iconic wine production covers only 3.3% of the agricultural area but is responsible for 14.4%

<sup>&</sup>lt;sup>3</sup>For example, in the US, producers who implement voluntary practices to minimize nutrient contamination of surface and groundwater, can be indemnified for yield losses (Harris and Swinton 2012). The same existed in the early 2000s for US corn producers following Integrated Pest Management (IPM) recommendations not to treat with insecticides against corn root-worm, with a similar contract (by IGF Insurance) for potato growers using IPM for potato blight (Mitchell and Hennessy 2003). In Veneto (Italy), corn producers following IPM recommendations can benefit from yield loss coverage in case of recommendations failure, paid by a mutual fund. Within the VitiREV project, in France, two wine cooperatives have tested such an insurance conditional on the reduction of fungicide use, in very specific conditions including a premium initially entirely covered by public subsidies (C. Aubert et al. 2020). A new experiment has just been launched between a different insurer and a large private wine group, a proof of viticulture actors' interest in such contracts.

of total agricultural pesticide use (Butault et al. 2010). Fungicides represent more than 80% 79 of pesticides used on vines in France (French agricultural ministry 2022). Due to their high 80 technical efficacy and low cost, they are sometimes referred to as a very attractive "insurance" 81 82 (although they are more adequately termed a prevention mechanism than an insurance properly speaking).<sup>4</sup> In our analysis, we begin with developing a theoretical model to explain decisions to 83 subscribe to green insurance and to comply with DSS recommendations (therefore reducing the 84 protection offered by chemical pesticides). We then conduct a large discrete choice experiment 85 with 412 French grapevine growers on the uptake and design of the insurance and combine it with 86 field experimental data on the pesticide use reduction potential. We evaluate the acceptability 87 88 of both loss-based and index-based insurance, since the latter is perceived as having a large potential, also in developed countries, to contribute to better farm-level risk management and 89 more efficient use of natural resources (Dalhaus, Musshoff, and Finger 2018). Doing so, we 90 contribute to the very narrow literature on insurance covering pest attacks and diseases, which 91 92 accounts for only 0.9% of the agricultural insurance literature (Vyas et al. 2021).

Adjusting for sampling bias, we find that between 48% and 60% of the vine growers are 93 likely to subscribe to the green insurance, depending on contract design and prices. Producers 9495transitioning to organic certification are more interested in the contract. This result suggests that green insurance could – in addition to intensive margin effects on pesticide intensity – also 96 97 have extensive-margin effects: it could help reduce pesticide use by supporting transitions to organic farming. Clear preferences emerge for contract design: all producers exhibit less interest 98 in group and index-based contracts. Using data from field experiments on the DSS impact on 99 fungicide use, we estimate that adopters could reduce their fungicide treatments by 45% on 100101 average. The chosen set-up would entail higher potential subsidy costs, compared to existing 102 policy tools in France, but also a higher pesticide reduction potential. Our results remain valid 103 throughout a series of robustness checks.

<sup>&</sup>lt;sup>4</sup>An insurance improves outcomes in bad states of the world, whereas a prevention tool reduces the probability of these bad states occurring. In the following, we model fungicides as reducing the probability of suffering very low yields because of diseases, in line with the definition of a prevention mechanism.

This paper is structured as follows. In Section 2, we present the insurance scheme and model vine growers' decisions to subscribe to green insurance. In Section 3, we explain the DCE approach and describe the experimental setting and methods used for data analysis. Results are presented in Section 4 and further discussed in Section 5.

### 108 2 Modelling vine growers' decisions

We analyze the conditions under which a risk-neutral producer will choose to subscribe to a green 109 insurance scheme, that partly covers yield losses due to fungal diseases in grapevines. The scheme 110 111 entails free access to a DSS that provides treatment recommendations based on climatic and fungus pressure information. If producers follow the DSS recommendations, a public subsidy is 112113 added to the indemnity paid by the private insurer (which is independent from compliance with 114 DSS recommendations). By subsidizing indemnities rather than the premium, public money is not disbursed for each policy-holder, but only for those suffering a loss.<sup>5</sup> Directing public 115 support to increasing the indemnity is more efficient than reducing the premium (or paying 116 a fixed subsidy as in an AES) when vine growers are risk-averse or pessimistic about losses 117 118 associated with greener practices since it induces participation at a lower cost. Vine growers tend to apply fungicides too early in the season and repeat applications as soon as the previous 119 120 application has been washed away by rain, whatever the actual disease pressure – thus they overtreat (Davy et al. 2020). The subsidy provides an incentive to producers to follow the DSS, even 121 when it recommends treating less than they would have done, thus reducing the externalities of 122 123 pesticide use.

Pesticide use is measured by the Treatment Frequency Index (TFI), i.e. the applied quantities over the course of an agricultural season normalized by their standard treatment dosage (Lechenet et al. 2017). We focus on changes in pesticide use per hectare, i.e. intensive-margin effects of the insurance scheme.<sup>6</sup>

<sup>&</sup>lt;sup>5</sup>In the EU, multi-peril crop insurance premia are subsidized, but compensation rates are considered too low to foster adoption (Descrozaille 2022).

<sup>&</sup>lt;sup>6</sup>Previous studies have found that risk management tools can also have important extensive margin effects

We first describe the green insurance contract, and then derive theoretical expectations on the impact of pesticide reduction, profits and the producer's decision to subscribe to the insurance.

#### 130 2.1 The features of a green insurance contract

131 A green insurance contract is characterized by its price P (per unit of insured capital), and the way the indemnity I is computed and granted.<sup>7</sup> The indemnity typically does not fully cover 132losses: contracts entail a deductible, to induce farming efforts.<sup>8</sup>. To incentivize producers to 133134 reduce fungicide use, the insurance scheme entails a bonus in the form of increased indemnity, financed by public authorities, for vine growers respecting the treatment protocol (timing, doses) 135provided by the DSS, and not carrying out any treatment other than those recommended by 136137 this protocol. This is verifiable since it is mandatory for producers to record data on treatments 138(date, product, quantity) and legal audits take place.

139 While the delivery system of agricultural insurance varies widely among different countries

140 (Smith and Glauber 2012), we restrict our attention to two characteristics: loss-based vs. index-

141 based trigger; individual vs. collective contract.

(changes in land use decisions), resulting in effects on producers input use (Möhring, Dalhaus, et al. 2020; Wu 1999; Goodwin, Vandeveer, and Deal 2004). These studies mostly focus on arable farming. Significant extensive margin effects are unlikely to occur for grapevine production in France, at least in the short- to midterm. Grapevine production in France is historically very established and follows a plethora of local, regional and national customs, rules and regulations, as well as established consumer preferences, which strongly limit both extending production areas and switching to other varieties. In addition, most adequate soils for grapevine production are already under production. Such rules, regulations, and customs may however evolve, especially in the long run, and risk management tools should then carefully be evaluated with regard to their effects, for example for the decision to plant resistant or climate change adapted varieties - which is out of the scope of this study. However, note that extensive margin effects comprising switches to different production conditions, such as organic production, might be possible.

<sup>7</sup>In the insurance literature, insurance premia are customarily expressed as a proportion m of the indemnity, where m is the "loading factor" (as in, e.g., Clarke 2016). This factor is 1 for "actuarially fair" insurance (meaning that a risk-neutral insurer makes no profit, as is customarily assumed under perfect competition). This approach assumes that one can compute the expected indemnity (paid ex-post) to assess the corresponding premium (paid ex-ante). In our context however, the probability of losses is endogenous to the contract, since it depends on the incentives of the producer to reduce fungicide use and to follow the DSS. One can therefore not express the price P as a function of I.

<sup>8</sup>Here, the green insurance is intended to induce a shift towards greener, IPM practices, which can increase yield losses, so the deductible runs contrary to the green objective. However, it remains needed to avoid negligent care.

Loss-based vs. index-based trigger. Under loss-based insurance, the indemnity is paid 142when there are actual losses, as assessed by an expert mandated by the insurer. Under index-143 144based insurance, the indemnity is triggered when the realization of an index reaches a defined threshold, rather than based on verifiable losses.<sup>9</sup> Index-based insurance has the advantages of 145being less costly for the insurer (who saves on audit costs) and less contestable for the producer 146(who may resent the expert's assessment). It has been gaining much interest, first in developing 147 countries where audit costs were prohibitive and more recently in richer countries (Ahmed, 148McIntosh, and Sarris 2020). Index-based insurance can help reduce moral hazard, adverse 149selection and administrative costs, but may also create new issues (Jørgensen, Termansen, and 150151Pascual 2020). Its risk-reducing effectiveness depends on how well the actual yield correlates with the index (Glauber 2004). While for climatic insurance, an index correlated with actual 152153losses can be devised using meteorological data, at this date, no adequate index is available for pest attacks on vines. Although hypothetical at this date, a suitable index is the object of much 154155research and might become available in future years. Producers' interest in such index-based 156contracts therefore deserves to be evaluated.

**Individual vs. collective contract.** Most frequently, commercial insurance companies offer individual contracts, sometimes with public support. Alternatively, a mutual fund relies on group contracts, where targeted producers compulsorily adhere to the fund. Mutual funds establish financial reserves, built up through participants' contributions, which can be withdrawn by the members when losses occur, according to predefined rules.<sup>10</sup> The preference for individual vs. group contracts is likely to depend on beliefs and norms that are difficult to capture in the theoretical model and are therefore only assessed in the Discrete Choice Experiment.

<sup>&</sup>lt;sup>9</sup>We follow the widely-used convention of referring to this type of contract as "index insurance" although it is technically an index security, and is not an insurance in the US Generally Accepted Accounting Principles (Clarke 2016).

<sup>&</sup>lt;sup>10</sup>Mutual funds are one of the instruments subsidized by the European Common Agricultural Policy in its risk management toolbox and currently operate in Italy, the Netherlands and France.

#### 164 2.2 Modelling the impact of pesticide reduction on profits

165The producer's financial yield without pesticide reduction is  $\overline{y}$ . Reducing treatment intensity entails the risk of production losses or deterioration of grape quality, at rate  $l \in [0, 1]$ , that reduces 166financial yield to  $(1-l)\overline{y}$ . This happens with a probability that decreases in treatment intensity.<sup>11</sup> 167 Each producer's conditions vary with regard to fungal disease. These conditions translate into 168an initial fungicide treatment frequency index TFI, that the producer chooses if they do not 169contract the green insurance. This level is (weakly) higher than the environmentally optimal 170one,  $TFI^*$ , which is the lowest achievable treatment level for the targeted yield ( $TFI^* \leq TFI$ ). 171We assume that this optimal level is achieved when one follows DSS recommendations. 172

The percentage of reduction in fungicide use reachable thanks to the DSS is  $k \equiv (TFI -$ 173 $TFI^*$  /TFI. Reducing fungicides by k% reduces the financial costs of applying fungicides, 174denoted  $C^k$ . To simplify, we assume that a producer not following DSS recommendations will 175not reduce its pesticide use at all (k = 0). In that case, the cost of applying fungicide is  $C^0 > C^k$ . 176The probability of facing losses l is  $\rho^k$ . We assume  $\rho^k$  is increasing in the reduction of treat-177ment intensity k, since for a given  $TFI^*$ , producers with higher initial TFI are less experienced 178with low-fungicide management practices. While overestimation of probabilities cannot be sys-179tematic in an expected utility model, producers may overestimate the risks from a lower TFI, 180 compared to the true probability of losses as assessed by experts (e.g., on research plots). 181

We focus here on the analysis for a risk-neutral producer. The case of a risk-averse producer is detailed in Appendix A. Under risk neutrality, the expected profit of a producer reducing her pesticides use by k > 0, thanks to the DSS but in the absence of insurance, would be  $\mathbf{E}U_k^{No} = (1 - \rho^k)\overline{y} + \rho^k(1 - l)\overline{y} - C^k = \overline{y}(1 - \rho^k l) - C^k$ .

186 Most French vine growers currently do not use such a DSS despite its low cost.<sup>12</sup> We therefore

<sup>&</sup>lt;sup>11</sup>We assume that the probability of a loss depends on treatments but not the extent of the loss. Because we consider risk-neutral farmers in the main text, this has no impact on our description of the choice made by the grower.

<sup>&</sup>lt;sup>12</sup>The DSS used in the green insurance experimentation run since 2019 in the Bordeaux area, Decitrait, is available at a fixed price of about  $\in$ 250, which is quite small compared to expected cost savings of about  $\in$ 200 per hectare for a 50% reduction in TFI.

187 assume that the following inequality holds:  $\mathbf{E}U_0^{No} > \mathbf{E}U_k^{No}$ , that is:  $(\rho^k - \rho^0)l\overline{y} > C^0 - C^k$ . 188 The cost savings on fungicides are not enough to compensate for the higher risk of losses when 189 reducing one's TFI, even with the help of the DSS. This is why additional incentives are needed, 190 such as those provided by a conditional green insurance.

#### 191 2.3 Modelling the subscription to green insurance

192 We assume that  $\overline{y}$  is both the maximum yield and the one insured under the contract, at price P. The indemnity I is paid depending on i) whether there are actual losses (l > 0%) in the case 193 194 of loss-based insurance, or ii) whether the realization of an index reaches a threshold, in the case 195 of index-based insurance. The insurance coverage is  $\alpha$  in [0,1] (due to the positive deductible). If 196 the producer follows DSS recommendations and thus reaches  $TFI^*$ , her indemnity is increased by a bonus b funded by public authorities, so her indemnity is equal to  $\alpha + b$  % of losses. We 197 198 assume that  $\alpha + b < 1$  so that losses are never fully covered by the contract. We define the 199 participation and incentive constraints for a risk-neutral producer for both types of insurance: loss-based and index-based. Appendix A. details the more general case of a risk-averse producer 200 and contains proofs and illustrative simulations. 201

**Loss-based insurance** With loss-based insurance, the indemnity  $(\alpha + b)l\overline{y}$  is received in case of yield losses l, as assessed by an expert, which happens with probability  $\rho^k$  for a reduction in TFI of k. Under this insurance, a producer complying with the DSS obtains an expected profit of  $\mathbf{E}U_k^{LB} \equiv (1 - \rho^k)\overline{y} + \rho^k[(1 - l)\overline{y} + (\alpha + b)l\overline{y}] - C^k - P$ , which can be rewritten as:

$$\mathbf{E}U_k^{LB} = \overline{y}[1 - \rho^k l(1 - (\alpha + b))] - C^k - P$$

A producer who does not reduce pesticide use and does not subscribe to green insurance faces a probability of loss of  $\rho^0$  and obtains an expected profit of  $[1 - \rho^0 l]\overline{y} - C^0$ .

The producer's participation constraint  $(PC)^{LB}$  to the insurance contract is therefore met if the expected profit without insurance  $\mathbf{E}U_0^{No}$  is lower than the expected profit with insurance, that is if:

$$(PC)^{LB}$$
:  $[\rho^0 - \rho^k (1 - \alpha - b)] l\overline{y} \ge P - (C^0 - C^k)$ 

or equivalently

$$(PC)^{LB}: (C^0 - C^k) + \rho^k (\alpha + b) l\overline{y} \ge (\rho^k - \rho^0) l\overline{y} + P.$$

204 Participation is ensured if the cost savings on fungicides plus the expected indemnity compensate205 for the higher risk of losses plus the insurance premium.

If the producer was to subscribe to the insurance contract without following the DSS, the expected profit (without bonus), under risk neutrality, would be  $[1 - \rho^0 l(1 - \alpha)]\overline{y} - C^0 - P$ . An incentive constraint  $(IC)^{LB}$  must be satisfied for the insurance contract to induce effective TFI reduction. Complying with the DSS is more attractive than not reducing fungicide use, while insured, if and only if

$$(IC)^{LB}$$
:  $(C^0 - C^k) + \rho^k b l \bar{y} > (\rho^k - \rho^0)(1 - \alpha) l \bar{y}.$ 

206 The green insurance will indeed induce a reduction in TFI if the savings on fungicides and the bonus compensate for the higher risk of losses. Recall that we assume the cost savings are not 207 208 sufficiently attractive in the absence of insurance. With green insurance, the foregone revenues 209 in case of losses are reduced, and even more with the bonus triggered by compliance with DSS 210recommendations. The larger the bonus b, the smaller the residual losses borne by the producer, 211 and the more likely it is that the producer prefers to follow the DSS and reduce her TFI. The bonus is therefore an effective complement to the green insurance in inducing fewer treatments. 212213The bonus thus causes an increase in both participation and compliance with the DSS recommendations. It helps make the insurance contract more attractive and more effective. 214The intuitions are similar under risk-aversion (cf. Appendix A.). 215

If individual experience with fungicide reduction is limited or the DSS does not manage to reduce loss frequency ( $\rho^k$  is high), producers will be both less likely to participate and less likely to comply with the DSS due to the increase in residual losses. A countervailing effect arises from the savings on treatments, which favors both participation and compliance. In this respect, a tax on fungicides, by increasing these cost savings, would be complementary to the insurance bonus. Such a tax would have an impact not only from direct incentives to reduce use, but also by facilitating the adoption of the DSS supported by insurance.

The constraints also yield ambiguous results regarding the relative participation of high-use producers vs. low-use ones. For producers who initially had a high TFI, the DSS will likely induce a large reduction k, with the direct negative impacts on participation and compliance noted above. However, for such high-use producers, who tend to face adverse conditions or lack the expertise needed to reduce fungicide use, the initial cost of treatment  $C^0$  will be higher, which tends to make compliance more beneficial.

**Index-based insurance** The indemnity is triggered by the value of an index, built in order to correlate with the realization of yields, but correlation is imperfect. The premium P equals to  $\beta P$ , with  $\beta \leq 1$ , since index-based insurance is assumed to be less costly to implement.

We define four scenarios corresponding to discrete states of nature (as in Clarke 2016 and Lichtenberg and Iglesias 2022). Associated probabilities are denoted  $\rho_{A+B}^k$  where  $A \in \{l, nl\}$ takes the value l in the event of a loss and nl otherwise, and  $B \in \{i, ni\}$  takes the value iin the event of the index triggering the indemnity, and ni otherwise (cf table A.1). The total probability of a loss is  $\rho^k \equiv \rho_{l+i}^k + \rho_{l+ni}^k$  and the total probability of receiving an indemnity is  $\rho^i \equiv \rho_{l+i}^k + \rho_{nl+i}^k$ . The probabilities with which losses are suffered but no indemnity is paid, and vice-versa, are an essential determinant of the insurance properties of the index-based contract.

Under index-based insurance, expected profits are equal to the actual yields in the two states of nature, plus the indemnity when triggered by the index, minus the costs of pesticides and insurance. The expected profit for the risk-neutral producer is  $\mathbf{E}U_k^{IB} = (1 - \rho^k)\overline{y} + \rho^k(1 - l)\overline{y} + \rho^i(\alpha + b)l\overline{y} - C^k - \beta P$ , or equivalently

$$\mathbf{E}U_k^{IB} = \overline{y}[1 - (\rho^k - \rho^i(\alpha + b))l] - C^k - \beta P$$

The participation constraint is

$$(PC)^{IB}: (C^0 - C^k) + \rho^i (\alpha + b) l\overline{y} \ge (\rho^0 - \rho^k) l\overline{y} + \beta P$$

that is: as in the case of loss-based insurance, the expected indemnity plus the cost savings on fungicides must compensate for the higher risk of losses plus the insurance premium.

The incentive constraint for a risk-neutral producer is

$$(IC)^{IB}: (C^0 - C^k) + \rho^i b l \overline{y} \ge (\rho^k - \rho^0) l \overline{y}$$

where the only insurance term playing a role is b. The savings on treatments and the bonus in 241case of indemnification should exceed the increase in losses. Contrary to the case of loss-based 242243insurance, the probability with which the indemnity is paid is independent from compliance with the DSS.<sup>13</sup> But receiving the bonus depends on this compliance. A subsidy to reduce the 244premium, granted to all subscribers, would not improve compliance, contrary to the bonus. Our 245results therefore show that a green index insurance, in order to maximize chances of inducing 246the adoption of greener practices, should be clearly conditional on these practices. Because the 247248 bonus is paid *ex-post*, it is a more efficient form of subsidy than a reduction in the premium, even 249if this reduction was also made conditional on compliance (because it would have to be adjusted 250months after the premium has been paid, which would create implementation difficulties). 251Comparative statics are similar to loss-based insurance, but low DSS performance in terms

of reducing the frequency of losses (high  $\rho^k$ ) makes both participation and compliance less attractive and does not change the probability of receiving the compensation.

<sup>&</sup>lt;sup>13</sup>The probability of obtaining the indemnity and the indemnity paid by the insurer both depend only on the index and not on treatments. So the expected value of the indemnity cancels out in the incentive constraint: it is paid exactly in the same way whether treatments have been reduced or not. This is different for loss-based insurance as the probability of actually suffering losses, and therefore obtaining an indemnity, does depend on whether the farmer has reduced treatment intensity.

**Loss-based vs Index-based insurance** The index-based insurance contract is more attractive to a risk-neutral producer than the loss-based one if and only if

$$\mathbf{E}U_k^{IB} \ge \mathbf{E}U_k^{LB} \Leftrightarrow (\rho^i - \rho^k)(\alpha + b)l\overline{y} + (1 - \beta)P \ge 0.$$

Index-based insurance is thus always more attractive than loss-based insurance to a riskneutral producer if the probability of indemnity  $\rho^i$  is larger than the probability of actual losses  $\rho^k$ , or if the index-based contract is sufficiently cheaper.

If producers *overestimate* the probability of losses  $\rho^k$ , they will tend to find loss-based insurance more attractive. Moreover, our model predicts that the growers further away from  $TFI^*$ will be less likely than the other growers who depend on the same index (same  $\rho^i$ ) to prefer index-based insurance since they face a higher probability of losses  $\rho^k$ .

Under risk aversion, the analysis is more complex since the index increases the variability 261 262in the producer's return: it creates a very positive state where indemnity is received in the 263absence of losses and a very negative state in which no indemnity is received despite losses. Although an increase in variability is costly to a risk-averse producer, the index-based insurance 264can still be more attractive if the probability of receiving a bonus even when not suffering losses 265 $(\rho_{nl+i})$ , is sufficiently large. Knowing the producer's risk-aversion is not sufficient to determine 266 the overall effect, since it depends on both the shape of the utility function and the beliefs about 267the probabilities of the four states. The more pessimistic the producer is about  $\rho^i$ , the less 268attractive the index-based insurance, as the variance effect will tend to dominate. 269

#### 270 2.4 The need for an empirical test

The model allows us to explore how the decision to subscribe to a green insurance is impacted by the probability and value of losses  $(\rho^k l \bar{y})$ , the increase in risk due to pesticide use reduction  $(\rho^k - \rho^0)$ , as well as by the cost savings from pesticide use reduction  $(C^0 - C^k)$ . We presented the impact of some insurance characteristics such as how damage is evaluated, the coverage  $\alpha$ and bonus *b* rate, and the premium *P*. Comparative statics are presented in Appendix A. The model focuses on one source of heterogeneity across producers, based on production context and expertise: the initial fungicide treatment frequency index (TFI), which impacts the probability of losses when less fungicide is used  $(\rho_k)$ . Other producers' characteristics such as risk-aversion or attitudes towards digital farming may also impact the decision to subscribe to the green insurance scheme under study. To account for this larger set of factors, we assessed the impact of insurance and producers' characteristics on subscription decisions through a choice experiment. The design is detailed in the next section.

### 283 **3** Method

To analyze preferences for a green insurance which is not available at the time of the study, 284285we rely on a Discrete Choice Experiment (DCE). DCEs are particularly valuable for investi-286gating individuals' preferences in hypothetical decision-making situations, when purchase or adoption data are not available (Louviere, Hensher, and Swait 2000). The method has been 287previously used to evaluate *ex-ante* programs targeting pesticide use reduction. For example, 288 in grapevine production, Kufhuss et al. (2016) and Lapierre et al. (2023) rely on DCE to ana-289 290 lyze the attractiveness of innovations in AES design, to better account for uncertainty on the costs and benefits associated with the adoption of new practices for herbicide reduction. The 291 292 method has also been used to analyze preferences for insurance schemes conditional on compliance with specific farm practices. Jorgensen et al. (2020) study the willingness to pay (WTP) of 293294 Danish crop producers for an insurance contingent on investing in sustainable soil management; and Heikkilä et al. (2016), that of Finnish producers for animal-disease insurance, conditional 295296on fulfilling bio-security requirements to reduce sanitary risks. Both include the contract price as monetary attribute and estimate the impact of best management practice requirements on 297298 WTP. Jorgensen et al.(2020) also estimate the impact of the insurance type (yield vs rainfall), 299 while Heikkilä et al. (2016) include an attribute on the insurance provider (private insurer vs mutual fund). In the next sections, we present our experimental design, data collection process 300 301 and methods for data analysis.

#### 302 3.1 Choice experiment design

303 Four attributes presented in Table 1 characterize the different types of green insurance systems tested in the choice experiment: individual or group contracts, loss-based or index-based damage 304 evaluation, level of coverage and premium. The first two correspond to binary qualitative 305 dimensions and the other two to financial attributes, with four levels for each. Attributes 306 307 and levels have been chosen to be relevant and realistic, taking into account literature and experience of pioneering contracts in the South West of France (VitiREV). We have then verified 308 the experimental design with experts, including insurers, vine growers, and agronomic advisers. 309 310 Finally, the attributes have been tested in two pilots in November 2022 and May 2023, with respectively 24 and 43 producers. The design has been pre-registered.<sup>14</sup> 311

312 The financial parameters of the contract are twofold: First, subscription to the insurance contract requires paying a premium, between 3% and 8% of the insured capital. This insured 313 capital is equal to the insured yield multiplied by the price at which the vine grower values their 314 production and by total surface. Note that, to reduce moral hazards, grapevine growers have 315 316 to insure their entire vineyard. The insurance premium is presented both in %, and in  $\in$ /ha 317 according to the insured yield and production value provided by the respondent in questions preceding the choice cards. Second, the coverage level defines the guaranteed fraction of the 318 losses (between 40% and 65%). There is a positive deductible but, to simplify, no supplementary 319 triggering threshold is applied. 320

Grapevine growers following DSS recommendations receive an additional 30% compensation, financed by public authorities. This amount was determined with policymakers and insurers and we decided not to vary it in order to reduce design complexity and to be able to analyze the impact of the total coverage (including the bonus) on the willingness to subscribe to insurance. Producers can choose to stop following DSS recommendations during the year if they turn out to be incompatible with their farm objectives and aversion to risk, which is an interesting flexibility for growers and possibly a factor of attractiveness. We also do not vary the level of

<sup>&</sup>lt;sup>14</sup>https://osf.io/mbvpa

best practice requirements, contrarily to Jorgensen et al.(2020) and Heikkilä et al.(2016), since
partial adoption of DSS recommendations is unlikely to reach the environmentally optimal TFI
and will lead to more subjective and complex control by insurers.

331 Behavioral interventions can be effective in increasing the adoption rate of programs aimed at influencing producer practices (Ferraro et al. 2022; Serfilippi, Carter, and Guirkinger 2020). 332 In particular, we know that equivalent descriptions of outcomes using different framing can 333 result in different choices (Tversky and Kahneman 1981). There is mixed empirical evidence on 334 the effectiveness of positively-framed versus negatively-framed information in influencing pro-335 environmental choices (Lopes, Tasneem, and Viriyavipart 2023). We contribute to this field of 336 337 research, by assessing whether a different framing of the bonus incentive has an impact. To do so, we rely on a split sample approach, comparing a bonus and penalty framing (Tonsor 2018). In the 338 339 bonus framing, the insurance coverage rate is presented as a base indemnity plus a 30% bonus in case of full compliance with DSS recommendations. In the penalty framing, the coverage 340 is presented as the full indemnity minus a 30% penalty in case of non-compliance with DSS 341 342 recommendations. From the behavioral literature, we know that the penalty framing is likely to reduce willingness to participate in the scheme (due to loss aversion since non-compliance with 343 344 DSS recommendations reduces compensation). On the other hand, loss aversion can reinforce the incentive to comply with DSS recommendations. As a result, we expect vine growers to be 345 346 more willing to pay for green insurance in the bonus framing, but less likely to comply with DSS 347 recommendations, compared to the penalty framing.

We created a Bayesian D-efficient design using NGENE on the basis of prior results from the pilot survey. To make the presented alternatives as realistic as possible, restrictions were included in the design: we rejected choice cards where the index insurance is more expensive than the loss-based insurance, unless it provides better coverage. This resulted in a design with 12 choice cards, divided into 3 blocks of 4 cards. Moreover, we control for order effects due to learning and lassitude by having 3 other blocks with the same choice cards, but presented in a different order. To measure framing effects, the 3x2 blocks are duplicated (6 with the penalty version of the indemnity attribute, and 6 with the bonus version). Thus, subjects were randomly
assigned to one of the 12 blocks. Figure 1 shows an example of a choice card, with two insurance
contracts labeled "A" and "B" and an opt-out option.



Figure 1: Example of choice card

Attributes	Levels			
Type of contract	<b>Individual</b> : Each vine grower decides individually whether or not to subscribe to the insurance (as for a classic insurance).			
	<b>Collective</b> : The vine growers subscribe to a group contract, for example within the framework of a mutual fund between vine growers of the same cooperative, appellation or wine basin. In this case, membership is compulsory for all the vine growers in the group concerned.			
Damage evaluation	<b>Loss-based</b> : Real losses are assessed by an expert, who comes to observe in each grower's plots the consequences of fungal diseases and then the harvest. The amount of the compensation depends on the expert's evaluation of real losses. The expertise allows an evaluation of the losses specific to each grower farm, but is subject to the subjectivity of the expert and is more expensive than index evaluation.			
	<b>Index-based</b> : Losses are estimated based on a local fungal pressure index measured, for example, in control vineyards near each grower's home. The amount of compensation depends on the value of this index. Real losses will be sometimes higher and sometimes lower than in the control vineyards, but the index can help to reduce insurance costs and make the assessment of losses more objective than expert evaluation			
Coverage	<b>Bonus framing</b> Base indemnity + <b>Bonus</b> 40+30%,50+30%,55+30%,65+30%	<b>Penalty framing</b> Total indemnity <b>- Penalty</b> 70-30%,80-30%,85-30%,95-30%		
	The coverage is a percentage of assessed losses. No triggering threshold is applied. The coverage is higher for growers respect- ing the treatment protocol (dates, doses) and not carrying out any treatment other than those recommended by this protocol, thanks to a bonus financed by public au- thorities.	The coverage is a percentage of assessed losses. No triggering threshold is applied. A part of this coverage is funded by pub- lic authorities. A penalty of 30% (the part funded by public authorities) will lower the total coverage for growers preferring not to follow the treatment protocol (dates, doses) and carrying out other treatments than those recommended by this protocol.		
	Coverage levels have been chosen such that used to: The 70% level corresponds to 30% insurance schemes (at the time of the exper- base contract for climatic risks in the new deductible). The 95% level for total covera under test in two cooperatives in the South pilot entails very advantageous conditions of We added an intermediary level of 85%.	vels have been chosen such that they correspond to values growers are 2 70% level corresponds to 30% deductible imposed by the EU to subsidize chemes (at the time of the experiment). The 80% level corresponds to the ct for climatic risks in the new French law on climatic insurance (20% The 95% level for total coverage corresponds to the contract currently n two cooperatives in the Southwest of France (VitiREV project); This very advantageous conditions as it is highly subsidized (5% deductible). n intermediary level of 85%.		
Premium	3%, 5%, 6%, 8% of insured capital Subscribing to insurance is costly and the price is defined in % of insured capital. Insured capital equals insured yield multiplied by the price value of production.			
	Price levels have been chosen such that the expected net gain from insurance is positive for producers in an average situation for France (average yield of 50 hl/ha with a value of $\leq 100/hl$ ( $\leq 5000/ha$ of insured capital), and expected losses of 10% per year). In most of these scenarios, insurers can also make money if the 30% coverage bonus is subsidized by public authorities.			

# Table 1: Attributes and levels

#### 358 **3.2** Data collection

In autumn and winter 2022, we first collected forecasts from experts on vine growers' preferences for the different attributes, and on impacts of producers' characteristics on these preferences (Appendix B). They helped us elaborate hypotheses to be tested (Appendix C).

The survey was administered online to around 20,000 vine growers (on some 59,000 vinegrowing farms in France), via a company selling inputs and material for vineyards and several other channels (the list of all these channels is available in Appendix G). The growers received no financial incentive to participate, but were told that their answers were important to design future pesticide policies. We received 412 complete answers (participation rate of approximately 2%).

The survey was structured as follows: The questionnaire started with a filter question to ensure that only vine growers taking financial and vineyard sanitary decisions were participating. Then, producers were asked to provide general data about their vineyard characteristics and crop protection strategy. Third, the green insurance scheme was presented. In the fourth part, the DCE was conducted with 4 choice cards, followed by questions to understand choice heuristics. The English version of the questionnaire is available in Appendix H.

#### 374 3.3 Data analysis

Based on DCE results and field data on DSS environmental performance, we provide estimates
on insurance adoption rate according to contract features, impact on fungicide use and efficiency
of public support to the insurance scheme.

#### 378 3.3.1 Adoption rate

The econometric estimation is in line with the behavioral framework of the random expected profit approach developed by McFadden (1974). Grapevine growers are assumed to choose their preferred insurance scheme such that the net expected profit from that contract is greater than either the other contract or opting out. For each vine grower i the expected profit obtained from alternative s in choice set t can be written as:

$$U_{ist} = V_{ist} + \epsilon_{ist} = X'_{ist}\beta_i + \epsilon_{ist}$$

The expected profit is a function of observable attributes  $V_{ist}$  plus an unobserved random com-379 ponent  $\epsilon_{ist}$  (the stochastic error term).  $X_{ist}$  refers to the vector of levels of the attributes, i.e. 380 the insurance scheme characteristics. We also include in  $X_{ist}$  an Alternative Specific Constant 381 382 (ASC) equal to one for the status quo alternative of not entering into any of the proposed con-383 tracts. The price and coverage for each alternative are specified as a continuous variable. For the other attributes, we include one dummy variable for each level of the attribute described 384in Table 1 except one. This excluded level per attribute represents the reference level for each 385 386 attribute.

To estimate preferences, we rely on the Random Parameter Logit (RPL) model which allows 387 388 parameters to vary randomly across respondents such that it gives a continuous distribution of 389 preferences (Boxall and Adamowicz 2002). We assume all respondents prefer contracts with a lower premium, and therefore consider log-normal distributions of individual price coefficients. 390 All other coefficients are assumed to be normally distributed. To further understand hetero-391 geneity, we also estimate a latent class model. Latent class models work similarly to mixed logit 392 models, except that the distribution of  $\beta$  coefficients is assumed to follow a discrete rather than 393 normal mixing distribution (Pacifico and Yoo 2013). 394

From RPL estimates, we obtain individual parameters for each attribute, and can calculate the utility of each respondent for different insurance types. In our analysis we focus on the three insurance schemes the most likely to be offered on the market. Scheme 1 (S1) is an individual and loss-based insurance: this disease insurance could be offered with similar features as the current multiple-peril crop insurance available to vine growers in France. Scheme 2 (S2) is an individual index-based insurance. Scheme 3 (S3) is a group index-based insurance.<sup>15</sup>

<sup>&</sup>lt;sup>15</sup>One example of such contract S3 is described by Harris and Swinton (2012): producers receive indemnities based on the annual deviation from long-run production averages among a cohort of nearby producers. This approach aims to lower monitoring costs by using county-wide information to inform claims. It also reduces moral

We assume that a grower subscribes to insurance if their utility from a given insurance scheme S defined by its X characteristics  $x_S$  is higher than their utility from the status-quo (as captured by the coefficient associated to the alternative specific constant ASC). For each respondent, we know whether they would subscribe or not to the insurance for different prices ranging from 3% to 8% (while we keep a fixed 50% coverage), and we can calculate an adoption rate at sample level.

#### 407 3.3.2 Impact on fungicide use

We then assess the potential of green insurance to reduce fungicide use. We assume that a grower willing to contract the insurance and to follow DSS recommendations can reach a  $TFI^*$ equal to those of the growers constituting the lower part of the TFI distribution in the same area, for the same type of practices (conventional or organic).  $TFI^*$  is thus considered regionand practice (organic vs. conventional)-specific, as agronomic intuition and data on different TFI levels across French regions suggest.<sup>16</sup>

In the field experiment conducted in the VitiREV project on around a hundred hectares 414 in the South West of France over the 2019-2022 period, growers have used the DSS under 415study here (C. Aubert et al. 2020). Organic vine participating growers reduced their fungicide 416 use less than their conventional peers. This can be measured with reference to the survey on 417practices in vine growing conducted by the French Ministry of Agriculture for the same year as 418the VitiREV experiment (French agricultural ministry 2022):  $TFI^*$  is equal to the TFI of the 419 second percentile in the same region for non-organic producers, and to the TFI of the thirty-fifth 420 percentile for organic producers  $(Q_{conventional} = 2; Q_{organic} = 35)$ .<sup>17</sup>. This difference between 421

hazard since losses evaluation cannot be manipulated by a single producer (Baerenklau 2005). If appropriately designed, these contracts can also incentivize change in aggregate behavior by motivating producers to improve production practices relative to neighbors.

<sup>&</sup>lt;sup>16</sup>Note that in the theoretical model,  $TFI^*$  was defined as the lowest achievable treatment level for the targeted yield. We therefore assume that this level can be empirically approximated by the treatment levels achieved by the group of most efficient producers of the respective population.

 $<sup>^{17}</sup>$ In the choice experiment, to facilitate respondents' understanding, and as supported by the IFV Technical Institute, we communicated that following DSS recommendations allows reducing fungicide use by 40 to 70%, depending on the year and fungal pressure. With our sample, we verify *ex-post* that the reduction potential calculated as explained above is between 0 and 90 %, with an average and median of 31%. This is in line with

422 organic and conventional viticulture is due to the different models used by the DSS. As organic 423 winegrowers can only rely on preventive products (as opposed to curative), the DSS advises them 424 to start chemical protection earlier. Following the assumptions on  $TFI^*$ , for each respondent, 425 we can calculate the TFI reduction potential k in % from their current TFI (average over the 426 last 3 years).

To adjust for sampling bias and extrapolate our results to the population of French vine 427 growers, we simulate the insurance uptake and impact at the national scale by approximately 428correcting for the sampling bias (over-representation of organic farmers). We define eight cells 429characterized by three variables: whether the farm follows organic practices or not, whether 430431 it is located in a high or low fungicide use region, and whether the farm has a high or low TFI compared with the other producers in the same region with the same type of practices. 432 433 To calculate the weights, we allocate the 57,878 French vine growers to the 8 cells (Table 2). The 22 French wine regions are ranked according to the average fungicide TFI in the region. 434435We name "high-use regions" the eleven regions with the highest average TFI. The number of 436 organic producers in each region is obtained from a national database covering organic producers 437 (Agence Bio 2020). This number is then divided into two groups: high-users are those with a 438 higher average TFI than the region median in the last 3 years for the same type of practices.

Table 2: Share of producers in each cell, used as weights to adjust for sampling biais and extrapolate results at population level (n=57878)

Non-organic(n=48034)	High users	Low users
High-use regions	23.6%	23.6%
Low-use regions	17.9%	17.9%
Organic (n=9844)	High users	Low users
High-use regions	2.8%	2.8%
Low-use regions	5.7%	5.7%

Source: Agence Bio (2020) for number of organic producers and French agricultural practices survey 2019 (French agricultural ministry 2022) for average TFI by region.

<sup>439</sup> We then transpose the cell-specific adoption rate and average impact of green insurance on a meta-analysis conducted by Lazaro et al. (2021) that shows that DSS can reduce fungicide treatments by at least 50% without compromising disease control.

440 fungicide use to the population, accounting for the weight of each cell. Finally, we conduct 441 a range of sensitivity analyses on the underlying assumptions on the efficiency of the decision 442 support system to reduce producers' pesticide use.

#### 443 **3.3.3** Cost-efficiency

We investigate whether public authorities would find it beneficial to finance the green insurance bonus, rather than other programs targeting pesticide use reduction. The cost-efficiency ratio CE is measured as the public cost in euro to reduce TFI by 1% :

$$CE = \sum_{i=1}^{n} \frac{b\rho_k l\overline{y_i}}{k_i}$$

where  $k_i$  is the pesticide use reduction of grower *i* and  $\overline{y_i}$  their insured capital. The cost for public authorities is the bonus *b* equal to 30% of the expected losses, which are assumed to equal 10% of insured capital annually ( $\rho_k l = 0.1$ ), in line with DSS predictions. We assume that the incentive constraint is satisfied for all growers, who are thus all eligible for the bonus.

## 448 4 Results

We test our pre-registered hypotheses (listed in Appendix C), and run complementary exploratory analyses. We first investigate the profile of vine growers more likely to adopt the green insurance. We then analyze contract features more likely to trigger adoption. In particular, we compare preferences for individual vs group contracts, loss-based vs index-based insurance, and a bonus vs penalty framing. We also provide estimates of the reduction in fungicide use likely to be obtained with green insurance, and the cost-efficiency of the instrument.

#### 455 4.1 Descriptive statistics

The final sample included in the analysis consisted of 412 responses. The sample is compared to the population of 57,878 producers growing vine for socio-demographic and farm characteristics

in Table 3. 75.24% of respondents are farm owners. The average farm size in the sample is 458twice as large as the French viticulture average (many owners of small vine areas use service 459460 providers for technical management of the vineyards, and therefore do not correspond to the 461profile sought in our survey), but heterogeneity is very high, both in the population and the sample (including an outlier of 6,000 ha). 42.2% are members of cooperatives. 26.9% of vine 462 growers are certified organic farming (17% in the population), 6.1% transitioning to organic 463 certification and 51.7% have obtained an alternative certification such as High Environmental 464 465 Value or Terra Vitis, two environmental certifications, dissociated from but compatible with organic certification, and giving access similarly to an official label on the marketed products. 466467 These numbers suggest that the sample is more experienced with fungicide reduction than the population. 468

Average survey completion time was about 22 minutes. We checked reading time of attributes
and interview time to be sure to avoid questionnaire-surfing in our responses.

Variable	Description	Sample mean	Population
Vine grower's characteristics			
Age	Years old	49.46	46.50
Gender	1 = male, 0 = female	0.876	0.781
Seniority	Years of work in vines	23.3	
Education in viticulture	1 = Yes, $0 = $ No	0.767	0.92
Vineyard's characteristics			
Land size (vineyard)	Hectares	45.8	22.1
Ownership of the vineyard	1 = Yes, $0 = $ No	0.752	
<b>Protected indication</b> (see Note 1)			
Protected denomination of origin (AOP/AOC)	1 = Yes, $0 = $ No	0.90	0.46
Protected geographic indication (IGP)	1 = Yes, $0 = $ No	0.37	0.28
Other	1 = Yes, $0 = $ No	0.20	0.08
Collective implication			
Member of a cooperative	1 = Yes, $0 = $ No	0.422	0.58
Collective score (see Note 2)	between 1 and 5	1.11	
<b>Certification</b> (see Note 3)			
Organic farming	1 = Yes, $0 = $ No	0.269	0.17
In conversion towards organic farming	1 = Yes, $0 = $ No	0.061	
Other (High Environmental Value, Terra Vitis)	1 = Yes, $0 = $ No	0.517	0.3
None of these certifications	1 = Yes, $0 = $ No	0.153	

#### Table 3: Sample characteristics

Note 1: Respondents can sell their production under several categories. The total therefore sums to more than 100%. The population statistics represent the share of total production under each indication, which cannot be directly compared to the share of respondents selling partly under each category.

Note 2: The collective score, between 1 and 5, is the sum of the grower's participation (yes=1; no=0) to a wine cooperative, a cooperative to share material (CUMA), a collective sale point, a group to share best environmental practices (GIEE) and institutions as representative of the vine producers.

Note 3: When a farmer has both the organic certification and another one, we identify it as organic. The total therefore sums to 100%.

#### 471 4.2 Adopters' profile

While we have a split-sample approach to compare the bonus and penalty framing, our analysis 472is performed on the full sample. Indeed, we found that framing has no significant effect on 473the number of insurance subscribers, nor on the TFI profile of the subscribers. Producers are 474not significantly less likely to opt out in the bonus framing (the coefficient ASC x Bonus is not 475significant, cf. Figure 3). Separate estimations for the bonus and penalty framing sub-samples 476confirm this result (Appendix D). Moreover, the framing has no selection impact: producers 477subscribing to insurance in the bonus framing group are not significantly different from those 478in the penalty framing group in terms of TFI reduction potentials (Figure A.3 in Appendix D). 479All the remaining analysis is therefore run on the full sample. 480

With the RPL model, we find that vine growers overall prefer the green insurance to the status-quo (the coefficient associated to the alternative-specific constant is negative), suggesting a significant interest for the scheme (Figure 3).

484 **Two classes of adopters.** Figure 2 displays interesting results regarding the distribution of the individual coefficients in the RPL model. The distribution of individual coefficients for 485486 the ASC and, to a lower extent, price and coverage is bimodal. This suggests that a share of our sample is more interested by green insurance (negative coefficient for the alternative-487 488 specific constant ASC) and another share is more sensitive to the financial parameters (with high coefficients for the price and coverage attributes). Latent class estimates in Table 4 confirm that 489 our sample can be divided into two classes. The number of classes has been chosen to ensure 490 interpretability, together with maximizing class membership prediction accuracy (Table A.6 in 491492 Appendix F). Class 1 comprises of about 59.5% of the respondents. For class 1, the coefficient estimates are close to those estimated by the RPL model. Given the negative sign associated with 493 ASC, growers belonging to class 1 are on average interested by the green insurance. Moreover, 494they have a lower price elasticity than class-2 respondents. On the contrary, respondents in 495 class 2 are not significantly more interested by the insurance than the status-quo, and have 496

497 no significant preference for the specific insurance attributes. However, they have a high-price498 elasticity.



Figure 2: Random Parameter Logit: Individual coefficients. Kernel density estimates

499 **Determinants of class membership** In order to test the two hypotheses on the influence 500 of the current pest management strategy and the risk profile of the producer on insurance 501 subscription, we study their impact as potential determinants of class 1 membership.

502 Concerning the pest management strategy, we find that transitioning towards organic cer-503 tification has the strongest influence on the probability of belonging to class 1. Organic and 504 other certifications also increase the probability of belonging to class 1 compared to having no 505 certification, but to a lower extent. Stated willingness to reduce fungicide use in the near future 506 (variable *sanitary strategy*) also increases the probability of belonging to class 1.

507 Concerning the influence of the risk profile on willingness to subscribe to green insurance, 508 we test the impact of the following variables: self-evaluated risk tolerance, being insured against 509 climatic risk, having diversified crops or having larger vineyards. None has an influence on the

- 510 probability of belonging to class 1.
- 511 In Appendix E (Table A.6), we present estimates on adoption rates by French region, to
- 512 highlight heterogeneity.

	Class 1	Class 2	
	(60%)	(40%)	
ASC	-1.587***	0.631	
	(-5.64)	(0.62)	
Group	-0.430***	-0.151	
	(-5.69)	(-0.34)	
Index	-0.294***	-0.430	
	(-4.17)	(-1.03)	
Coverage	$0.0192^{***}$	0.00203	
	(3.79)	(0.10)	
Price	-0.0982***	-0.535***	
	(-3.96)	(-3.83)	
Probability to belor	ng to class 1		
Organic	$0.929^{**}$		
	(2.74)		
Organic_transition	$2.293^{***}$		
	(3.38)		
Other certification	$0.911^{**}$		
	(2.95)		
Sanitary strategy	$0.348^{**}$		
	(2.77)		
Constant	$-1.354^{**}$		
	(-3.03)		
Ν	4944		
t statistics in parentheses			
* p<0.05, ** p	* p<0.05, ** p<0.01, *** p<0.001		

Table 4: Latent class: Probability to subscribe to green insurance

513 **4.3** Preferences for contract features

514 Better coverage increases the probability that the vine grower will adopt the insurance scheme 515 and higher contract price decreases this probability (Figure 3), confirming one of our pre-516 registered hypotheses. While both characteristics have a significant impact, their effect sizes 517 are very different: the contract price has a much bigger effect than the percentage of the base 518 coverage.

519 With regard to the contract design features, we find that on average, producers prefer in-520 dividual contracts to group contracts. We also find a preference for loss-based compared to 521 index-based insurance, but the absolute value of this coefficient is low.



Figure 3: RPL model: Probability to subscribe to green insurance

Note: The choice of contracting to green insurance is explained by contract attributes (Bonus, Group, Index, Coverage, and log-normal Price) and some interaction variables -selected according to pre-registered hypotheses.

We focus on two sources of heterogeneity with regard to preferences for the Group and Index attributes. We find that the growers engaged in groups of producers (such as cooperatives where wine-making or vineyard materials are mutualized, or collective sale points) are less reluctant to adopt group contracts (variable CollectiveScore). However, we find no evidence that knowledge or prior experience with index insurance has an influence on preferences for the index-based contract (variable IndexExperience).

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528 We also calculate the adoption rate for different types of green insurance contracts (S1,
529 S2, and S3 defined in section 3.3.1) (Table 5). In the sample, between 45% and 58% of the
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vine growers are likely to subscribe to green insurance depending on contract design and prices.
Adjusting for sampling bias, based on adoption rates such as the one presented in Table 4 for
contract S1, the adoption rates vary between 48% and 60%.

As expected from previous results on preferences for individual and loss-based attributes, the adoption rate is higher for scheme S1. Since differences in adoption rates across contract types and prices are limited, in the remaining analysis we focus on one contract: the preferred contract (S1), in the case of fair insurance (5% price and 50% coverage). This contract is considered fair since the loading factor is equal to one when one assumes an expected annual loss of 10%, as expected under production with the here selected DSS.<sup>18</sup>

Contract type	$\mathbf{S1}$	$\mathbf{S2}$	$\mathbf{S3}$
Price	Individual loss-based	Individual index-based	Group index-based
3%	58~(60)	56(58)	53 (54)
5%	54 (56)	51 (54)	48(51)
6%	51 (54)	49(53)	47(50)
8%	49(51)	48(51)	45 (48)

Table 5: Adoption rate by contract type and price (50% coverage)

Note: The first number in each cell corresponds to the percentage of adopters in the sample. The number in parenthesis corresponds to the percentage extrapolated at population level, after correcting for sampling bias.

#### 539 4.4 Impact on fungicide use

540 To estimate the potential impact of green insurance on fungicide use in French vineyards, we rely

541 on the pesticide use reduction (k) that could be obtained thanks to the DSS recommendations

- 542 for those willing to subscribe to insurance<sup>19</sup>. We assume that the incentive constraint is satisfied
- <sup>543</sup> and all subscribing vine growers fully comply with DSS recommendations.<sup>20</sup>

<sup>&</sup>lt;sup>18</sup>In practice, there may be only a limited number of agricultural insurers willing to offer a green insurance, so that perfect competition may not apply. However public authorities may be able to impose actuarial fairness as a requirement associated with the public bonus. Insurers may find this attractive if they expect their customers to subscribe to other products they may offer.

<sup>&</sup>lt;sup>19</sup>Recall that the following estimates focus on the adoption rate of the preferred contract (S1), in the case of fair insurance (5% price and 50% coverage)

<sup>&</sup>lt;sup>20</sup>After the choice experiment, we asked growers whether they would most likely follow the recommendations to be sure to benefit from the bonus, or would rather focus on the base indemnity and not reduce their pesticide use (an intermediary choice was also offered: "Follow the recommendations at the beginning of the season and stop

544Overall, we estimate that adopters in the sample would reduce their fungicide treatment by 35% on average and a quarter of them can reduce their fungicide treatments by more than 54555%. But the average TFI reduction potential hides important heterogeneity: the expected TFI 546 547reduction potential of those willing to subscribe to green insurance ranges from 0 to 84.9%. We 548highlight in Table 6 the differences across practices (organic or not), regions and users' relative position in the region with regard to their TFI. The highest impact is expected for non-organic 549producers treating more than the median TFI in low-use regions (-74.70% compared to their 550initial TFI on average). The impact is higher in low-use regions since other growers in these 551areas have managed to reduce their TFI, which indicates favorable environmental conditions and 552553lower pest pressure. Extrapolating results to the population, given that 56% of the population would adopt S1-type green insurance (at a 5% price and 50% coverage), fungicide use could 554555be reduced by 45% on average at national level (compared to 35% in our sample due to the over-representation of organic producers, who have on average a lower reduction potential). 556

Table 6: Average percentage fungicide reduction (with population weight in parenthesis)

Non-organic	High users	Low users
High-use regions	56.63~(23.6%)	27.65~(23.6%)
Low-use regions	74.70 (17.9%)	39.78(17.9%)
Organic	High users	Low users
High-use regions	37.34(2.8%)	1.56(2.8%)
Low-use regions	49.21(5.7%)	3.19(5.7%)

Kruskal-Wallis test for difference across cells  $\chi^2(7) = 395.088$ ; Prob = 0.0001

557 We run a sensitivity analysis on the impact of the assumptions on the efficiency of the DSS

if they do not suit you". Those who have selected this intermediary option are also considered as following DSS recommendations). We can distinguish "adopters" of green insurance and "full adopters": adopters are those with a utility from an insurance contract higher than their utility from the status-quo, so that their participation constraint (PC) is satisfied; full adopters are willing to follow DSS recommendations, so that their compliance incentive constraint (IC) is also satisfied. In the pre-registration, we indicated that we would measure the impact in terms of TFI reduction potential only for the full adopters. However, only 231 out of the 412 respondents answered the question on DSS adoption. And only 10% indicated they would not follow DSS recommendations and therefore only count on the base indemnity. We therefore decided to assume that those willing to subscribe to green insurance would also most likely follow DSS recommendations. Estimates of average TFI reduction are robust to dropping respondents who declared they won't follow DSS recommendations.

to reduce pesticide use on our results (Figure A.4 in Appendix F). To do so, we vary the target 558 percentile one can reach with the DSS for both types of practices  $(Q_{conventional}; Q_{organic})$ . We find 559560 that fungicide reduction will be substantial (more than 40%) only if conventional producers using 561the DSS can reach TFI levels that are lower than the 5% vine growers treating least intensively. This is in line with field experimental observations for the DSS, but underlines the importance 562of this parameter for results. The overall impact is less dependent on assumptions regarding 563 the DSS's efficiency for organic producers since the TFI distribution for organic producers is 564narrower. 565

We find limited evidence of windfall effects. 23% of the adopters in the sample have a null 566expected reduction since their TFI corresponds to TFI\* (63% of them being organic growers). 567 They would benefit from more secured revenues, partly thanks to the public support of the 568 569 bonus, without achieving additional fungicide reduction. Given the For conventional producers, the proportion of producers with null reduction potential is not significantly different at the 570571 5% level in the adopters and non-adopters groups. For organic producers, the proportion of 572producers with null reduction potential is significantly higher in the non-adopters groups. Both results suggest that the scheme does not particularly attract producers likely to benefit from 573574windfall effects.

#### 575 4.5 Cost-efficiency of public support

Adjusting for sampling biais, for an average annual loss of 10%, the program would cost on 576 average  $\in$  1457 per hectare and per year. In terms of cost efficiency, the average cost of public 577 bonus subsidy is  $\in 104$  per hectare for a 1% reduction in TFI. But we find significant differences 578 in the cost and cost-efficiency of green insurance subsidies across the eight cells in Table 7. 579 This heterogeneity is driven by different TFI reduction potential k, but also differences in the 580financial value of insured yields (since the cost of the bonus is proportional to  $\overline{y}$ ). Indeed, the 581 financial yield is significantly lower in low-use regions (which is driven either by lower yields in 582regions such as Côtes du Rhône or lower wine value in regions such as Val de Loire or Gaillac). 583

- 584 As a result, the public spending to compensate losses is lower in the low-use regions, compared
- 585 to high-use regions.

Table 7: Average public cost in  $\in$ /ha for a 1% reduction in TFI (with population weight in parenthesis)

Non-organic	High users	Low users
High-use regions	13 (23.6%)	221 (23.6%)
Low-use regions	16~(17.9%)	34~(17.9%)
Organic	High users	Low users
High-use regions	50(2.8%)	570 (2.8%)
Low-use regions	15~(5.7%)	145~(5.7%)

Kruskal-Wallis test for differences across cells:  $\chi^2(7) = 75.468$ ; Prob = 0.0001

#### 586 4.6 Robustness checks

We apply several tests to check the robustness of the results to different specifications (Ap-587 pendix F). We find no significant difference with the estimate for the full sample presented in 588 Figure 3 and the estimates for different sub-groups. As a further robustness check, to account 589 for inattention bias, we estimated a 3-classes latent class model with all parameters in one class 590 restricted to zero (Table A.7 in Appendix F). We find that 40.5% of the respondents were clas-591 592sified as making random choices, which is similar to what was found by Malone and Lusk (2018) . Estimates for the two other classes remain robust to this specification, but the proportion of 593 respondents sensitive to the green insurance attributes (belonging to class 1) is reduced to 25%594 (instead of 40% in Table 4) and we find no significant determinants of class 1 membership. 595

We also tested for overshooting, as defined by Glenck et al. (2023). The criterion compares the highest level of the price attribute with the willingness to pay (WTP) for the bundle of attributes yielding the highest utility (loss-based individual contract with a 65% coverage rate), without including utility captured via alternative specific constant. We find evidence of reasonable overshooting: the average WTP for the bundle of attributes yielding the highest utility is 13.46 (median 2.89). With the highest price level equal to 8, this corresponds to a 68% overshooting magnitude. As a comparison, over the 305 DCE studies considered by Glenck et al.(2023), the mean relative magnitude of overshooting is 337%, with a median of 102%.

### 604 5 Discussion

A high pesticide use reduction potential Our results indicate that green insurance is an innovative tool that has the potential to induce a shift in practices towards less pesticide use. More than half of the surveyed French vine growers are interested in green insurance, in particular if insurance contracts are similar to those offered for current multiple-peril crop insurance (i.e. individual and loss-based).

610 Producers transitioning to organic grapevine growing are more interested by green insurance 611 and have a lower price elasticity. A first reason could be that they are already more likely to have lower yields than their targets (higher  $\rho^0$ ), and are therefore interested in the financial security 612 offered by the scheme, suggesting some form of adverse selection. They may also be interested in 613 the technical assistance offered by the DSS to comply with the regulation on maximum copper 614 use (European Union 2018), reduced from 6 to 4kg/ha in 2018, technically constraining in some 615 616 years. However, being already committed and experienced in constrained technical itineraries, they may also simply have more confidence in their ability to safely decrease fungicide use and 617 618 obtain the 30% bonus by following DSS recommendations. In other words, the increase in the probability of losses due to lower pesticide use  $(\rho^k - \rho^0)$  appears to be lower for them compared 619 to other growers, not only because of higher  $\rho^0$  but also because of lower  $\rho^k$ . This could explain 620 why organic growers with the highest fungicide use in their region (compared to other organic 621 622 growers) have the highest adoption rates: observing their neighbours, they can be confident that they can safely reduce their fungicide use with limited risk on yields. In any case, these 623 results suggest that green insurance is perceived by growers as a useful tool to support the 624 625 transition to organic farming. Green insurance could thus be an interesting complementary tool to support the political objectives on the up-scaling of organic or pesticide-free production 626 systems, (Schebesta and Candel 2020; Möhring and Finger 2022), and secure transitions at a 627

628 time when market signals are currently negative. Beyond the substitution of chemical pesticides with other crop protection strategies, support for organic farming can also contribute to other 629 630 environmental benefits, such as better pest control based on biodiversity (Muneret et al. 2018). 631 The fact that the scheme is particularly attractive to producers transitioning to organic practices has two consequences: First, it could increase the overall risk to be covered by the in-632 surer, as organic growers already face a higher risk. Second, it reduces the overall environmental 633 performance since the DSS reaches higher TFI reduction for conventional producers. Yet, we 634 found that producers subscribing to the green insurance scheme can reduce by 45% on average 635 their treatment frequency index. 636

637 We observe regional heterogeneity in adoption rates and impact in terms of TFI reduction, probably driven by the local fungal pressure and wine value. Such results corroborate findings 638 639 from the theoretical model on the determinants of the participation constraint. To tailor insurance contracts to different circumstances and increase their attractiveness, insurers will have to 640 641 gather sufficient data to correctly price the contracts. This data is not yet available because not 642 enough growers are making the decision to use very low pesticide levels, and the ones who do 643 probably have specific characteristics. By inducing a switch to greener practices by a sufficient 644 share of farmers, subsidized green insurance can generate data on the actual losses incurred over a few years when using less pesticide. In addition, one may expect the quality of the DSS to 645 646 improve thanks to a wider pool of farmers providing feedback on the impact of its recommen-647 dations. The development of green insurance can improve the information available to farmers, insurers, and public authorities. 648

A gap between producers' preferences and insurers' opinions Despite high acceptability as assessed in the DCE, green insurance is a new product and both the performance of the DSS and the ability of all insurance subscribers to effectively follow it are still little known. Providers of green insurance will therefore face contract development costs. Low subscription rates would further increase transaction costs and delay learning. Our results shed light on producers' preferences for specific green insurance designs. While the insurers we interviewed
believe green insurance should be developed in priority under group and index-based contracts,we highlight a disinterest in such contracts by most producers.

657 Follow-up questions show that only 2% declared to have already subscribed to an index 658 insurance and only 27% have already heard about this system before. We could not detect a significant effect on knowledge and experience with index-insurance on preferences towards 659 such products to cover fungal disease risk, but the direction of the effect is consistent with 660 previous work. Farmers' limited understanding of a product is an important factor in their 661 reduced demand for index insurance (e.g. Cole et al. (2013) and Sibiko et al. (2018) among 662 others). Extension services and insurers will have to put effort into explaining to farmers how 663 664 index insurance works, including the basis risk, often mentioned as the major obstacle (Jensen, Barrett, and Mude 2016; Jensen, Mude, and Barrett 2018). In the DCE, the basis risk may have 665 666 been perceived by respondents as high since we were not very explicit about the specification of the index. Last but not least, respondents may have not perceived the potential cost-saving 667 668 associated with index insurance. It was underlined in the presentation of attributes that in-669 dex contracts might reduce transaction costs, and therefore allow insurers to offer significantly 670 cheaper contracts. But, in the choice cards, it was less explicit since some schemes had both an 671 index-based evaluation of damages and a higher price (for a higher coverage).

672 Moreover, while French farmers frequently complain about private insurance companies, they 673 show no interest in group-based contracts, that could be implemented in the form of a mutual fund, a typically low-cost non-profit organization (Meuwissen, Assefa, and Asseldonk 2013). 674 Beyond farming, group-based contracts are widely used for risk-sharing. They reduce problems 675 of asymmetric information and serve as a catalyst for risk prevention and knowledge sharing 676 677 (Meuwissen, Bottema, et al. 2019). French vine growers' reluctance could be explained by their willingness not to engage in contracts with collective commitments, but previous work with 678 679 French vine growers has shown that they value collective commitment when it can benefit the 680 environment (Kuhfuss et al. 2016). In the experiment, we defined the likely perimeter for group 681 contracts as the cooperative, the perimeter of the indication of origin or the wine region. But at 682 such a scale, fungal disease risk can be systemic and growers may lack trust in the mutual fund's financial robustness (Giampietri, Yu, and Trestini 2020). Insurance experts generally agree that 683 684 pools consisting of less than one-third of a sector cannot sufficiently spread the risks and are too 685 small to survive (Meuwissen, Assefa, and Asseldonk 2013). Offering index insurance to groups is foreseen as a promising opportunity to offer insurance products that are both attractive and 686 easy to implement (Trærup 2012; Santos et al. 2021; Meuwissen, Mey, and Asseldonk 2018). 687 Indeed, group index-based insurance can be more attractive if a common risk-sharing pool is 688 set up to transfer excessive payouts, as a remedy to the imperfect correlation between the index 689 and losses. This system could for example be implemented through cooperatives as follows: an 690 691 index-based contract is signed by a cooperative. If the index triggers the indemnity, payment is made to the cooperative, which then distributes it according to their local understanding 692 693 of growers' performance for the year. Loss evaluation is then in the hands of the cooperative, possibly reducing the cost of insurance and the basis risk perceived by growers. 694

695 Another option considered by insurers to reduce costs is to integrate climatic and green 696 insurance contracts (Meuwissen, Mey, and Asseldonk 2018). But crop insurance can have un-697 intended effects and lead to pesticide use increases (Möhring, Dalhaus, et al. 2020; Wu 1999; 698 Enjolras and M. Aubert 2020). The coverage of disease risk through green insurance could thus 699 further raise complex cross-effects. In a follow-up question (answered by 241 respondents), 58% 700 declared they would prefer green insurance remaining independent of climatic insurance. But 701 whether contracts should clearly delineate between losses due to direct weather and climate impacts and losses due to indirect consequences of different climatic conditions (such as fungal 702 diseases, which are more likely to develop in humid and warm weather conditions) remains an 703 704 open question.

705 Comparison with other pesticide programs While green insurance may potentially in-706 duce sizable pesticide use reductions, it should be compared with other tools. Based on sample 707 estimates, the program would cost less than  $\leq 480$  per hectare and per year for half of the 708 adopters ( $\leq 1580$  on average). This is much more costly than other programs designed to reduce pesticides. In 2018, the DEPHY network, a system of farm advisors implemented on a large sample of farms in France, cost  $\in$ 150 per hectare and per year (Lapierre, Sauquet, and Julie 2019). The Agri-environmental scheme (AES) payment to reduce herbicides in French vineyards from 2007 to 2014 ranged from  $\in$ 141 to  $\in$ 350 per hectare and per year. Another AES available to vine growers close to water catchments from 2014 to 2020 provided incentives to reduce TFI up to 80% of the local average TFI for a compensation of  $\in$ 301 per hectare and per year (EAFRD 2014).

716 However, the relatively low cost of these other programs does not imply a high effectiveness. First, because they attract a very limited number of producers. For example, only around 4,000 717718 hectares out of the 220,000 hectares of vine in the Nouvelle-Aquitaine region (including Bordeaux, Cognac, and Bergerac amongst others) have been engaged in an AES targeting herbicide 719 720 reduction over the period 2015-2022. Second, participation in the AES does not necessarily influence management practices. High windfall effects have been reported for some AES schemes 721722 (Chabé-Ferret and Subervie 2013; Ait Sidhoum, Canessa, and Sauer 2023). A public subsidy 723 to green insurance bonus is more costly per hectare, but it has the potential to attract more 724growers and generate more impact in terms of pesticide use reduction. Unfortunately, ex-post 725 evaluations of adoption rates and impact in terms of TFI reduction of other pesticide programs are scarce, limiting the possibility of comparing them with the ex-ante evaluation we conducted. 726 727 In any case, and whatever the program, the environmental and health benefits associated with 728 pesticide reduction should also be taken into account in these cost-benefit analyses, such as the reduction in exposure risk offered by the use of the DSS system (Tago, Andersson, and Treich 729 2014). 730

We also discussed in the theoretical model that a tax on fungicides, by increasing cost savings from using fewer pesticides, would be complementary to the insurance bonus to foster green insurance adoption. With a lower bonus and a pesticide tax, one could therefore reach similar adoption levels, and increase the cost-efficiency of the scheme.

735 Other risk management tools than green insurance exist and may better meet some produc-

ers' needs. As mentioned by several respondents, the financial risk can be managed by stocking 736 part of the wine of very productive years, to be included in the blend of the following year, as au-737 738 thorized by European law within the framework of inter-branch organizations (European Union 739 2013). Inter-annual wine transfers between producers (rather than money transfers through insurance indemnity) are preferable when producers fear to loose markets if they have no wine to 740sell in a given year. Regarding sanitary risks, an alternative to chemical protection is the adop-741 tion of resistant varieties (Finger, Zachmann, and McCallum 2023). This alternative instrument 742 has not been mentioned by the interviewed growers but is developing rapidly. Further research 743 744is needed to be able to compare the effectiveness and cost-efficiency of short-term solutions such 745 as reducing pesticide use with green insurance and longer-term ones such as the adoption of 746 resistant varieties.

The robustness of our results relies on the complementary between the theoretical 747 Robustness 748 predictions and the empirical test with the DCE, particularly relevant when predictions are 749 ambiguous or behavioral factors are coming into play. In particular, we found that high-use 750producers, who tend to face adverse conditions or lack expertise needed to reduce fungicide 751use, are less likely to subscribe to green insurance, suggesting that their higher cost savings due to less fungicide use (compared to low-use growers) are not sufficient to counteract the 752 high perceived risk of losses. The empirical evidence on growers' low interest for index-based 753 contracts is consistent with the model, if producers overestimate the probability of losses  $\rho^k$ 754or are pessimistic with regard to the probability of being indemnified  $\rho^i$ . This is likely in the 755 756 absence of detailed information in the DCE on the index specification. Furthermore, we predicted 757 that risk aversion had an ambiguous impact on insurance subscription, especially for index-based insurance. This is consistent with the absence of influence of self-evaluated risk aversion on green 758 insurance adoption in the DCE. This confirms the relevance of the risk neutrality assumption 759760 in our model, in particular given that agriculture professionals are known to be less risk-averse than the general population (Rommel et al. 2023, Vieider et al. 2015). 761

High adoption rates should be taken with a grain of salt given the hypothetical nature of

763 choices in DCEs. Respondents may indeed underestimate the costs of participating in such a new green insurance scheme, including the transaction costs to enroll in the program, but also 764 765 the opportunity cost of time to understand and enact DSS recommendations. Moreover, one 766 may wonder whether there have been some attributes non attendance. In particular, the small effect size of the coverage attribute suggests that respondents have focused more on the certain 767 financial cost of the contract (the premium), and less on the uncertain financial benefit (function 768 of the coverage level). This may also be due to an anchoring effect to the multi-peril insurance 769 coverage levels (70%, which corresponds to the lower level of the green insurance). This level 770 may have been perceived as standard and producers' choices were impacted to a limited extent 771772 by higher coverage rates. Note that given that the framing treatment concerned the coverage attribute, this may also explain why we found no significant impact of framing. This null result is 773 774 nevertheless in line with previous evidence on the limited impact of nudges on farmers (Davidson and Goodrich 2023, Chabé-Ferret, Le Coent, et al. 2019). 775

Our study focused on grapevine production in France, where both incentives to use pesticides, and uncertainties about the impact of reducing TFIs on financial yields, are especially high, suggesting that potential adoption of these tools would be even more important for other crops. Future research on green insurance should test results for other regions and crops.

# 780 6 Conclusion

Green insurance could be an important tool for supporting farmers' transition to more envi-781 ronmentally friendly production practices, by managing potential economic risks. We provide 782 783 evidence of French grapevine growers' interest in a green insurance scheme, coupled with free access to a Decision Support System, to secure yields while reducing fungicide use. By pro-784viding a secure environment to test reduced pesticide use practices, green insurance coupled 785 786 with a DSS can help producers revise their perceptions on the number of treatments needed to control fungal pressure. Among the 412 surveyed French grapevine growers, 54% are willing to 787 subscribe to a loss-based individual insurance for an annual price of 5% of the insured capital 788

and an 80% coverage of their losses (including the 30% bonus obtained by complying with DSS recommendations). Farmers transitioning to organic farming and organic farmers are more likely to subscribe to green insurance and are less sensitive to insurance price than other producers. More innovative schemes such as group and index-based contracts are less attractive, despite having the potential to reduce the costs of green insurance.

We also find that publicly subsidized green insurance could provide an innovative policy tool to reach ambitious pesticide reduction targets. Extrapolating the results to the population level, we estimate that insured producer would reduce their fungicide treatment by 45% on average, thanks to DSS recommendations. Having in mind the EU Green Deal target of reducing pesticide use by 50% by 2030, green insurance could significantly contribute to the objective for the wine sector.

Our results are of direct relevance for policymakers attempting to reform agricultural policy to achieve an up-to-now elusive reduction in pesticide use, but also to insurers designing new insurance products to cover disease risks. We believe that they are of relevance beyond the 'tough' context of wine-growing, and beyond France.

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# 1044 Appendix

#### 1045 Appendix A: Modelling vine growers' decisions

1046 This subsection presents general results for a weakly risk-averse producer (A.1). The case of 1047 strict risk-aversion is treated here, whereas the main text focuses on the case of risk neutrality. 1048 This appendix also presents simulations for different values of the bonus b and the probability 1049 of loss in case of pesticide use reduction  $\rho_k$  (A.2.).

#### 1050 A.1. The model

1051 Yields and treatments. We consider a producer with a maximum financial yield  $\overline{y}$  (in 1052  $\in$ /ha). The actual financial yield may be lower due to pest attacks. "Losses" are the difference 1053 between the maximum yield and the low yield, and are  $l\overline{y}$  where  $l \in [0, 1]$ . They occur with 1054 probabilities that depend on climatic and geologic conditions but also on treatment intensity.

1055 Each producer has an 'initial' fungicide treatment frequency index TFI. This is the TFI he would choose in the absence of an insurance scheme. We denote  $TFI^*$  the lowest achievable 1056 treatment level for the targeted yield. We assume that following DSS recommendations, thanks 1057 to the extensive expertise and information analysis embedded in the tool, allows to reach  $TFI^*$ . 1058 1059 The corresponding percentage reduction in fungicide is denoted k. In regions with more fungi 1060 pressure  $TFI^*$  will remain higher than in regions with lower pressure. To simplify, we assume that a producer not following DSS recommendations will not reduce its pesticide use at all. 1061 Thus, 1062

$$k = \frac{TFI - TFI^*}{TFI}$$
 if DSS recommendations are followed  
= 0 if DSS recommendations are not followed

1063 The cost of treatments  $C^k$  increases in the TFI and is therefore lower under DSS recommen-

1064 dations.

- $C = C^k$  if DSS recommendations are followed
  - =  $C^0$  if DSS recommendations are not followed, with  $C^0 > C^k$ .

1065 We denote by  $\rho^k$  the probability of a low yield when the producer commits to reduce fungicide 1066 by k.  $\rho^k$  is increasing in k: producers less experienced with less intensive practices will face more 1067 losses more frequently.

For a risk-averse producer with a strictly concave utility function u(.), expected welfare when following the DSS without insurance, is

$$\mathbf{E}U_k^{No} \equiv (1-\rho^k)u(\overline{y}) + \rho^k u((1-l)\overline{y}) - C^k.$$

1068 Under risk neutrality, the expression is  $\mathbf{E}U_k^{No} \equiv (1-\rho^k)\overline{y} + \rho^k(1-l)\overline{y} - C^k = \overline{y}(1-\rho^k l) - C^k$ . 1069 In practice in French vineyards, the TFI chosen by producers is widely recognized as too 1070 high (as discussed in the introduction). Moreover, producers do not choose to use a DSS despite 1071 its low cost. For instance, the DSS used in the green insurance experimentation run since 2019 1072 is available at a fixed price of about  $\leq 250$ , which is quite small compared to expected cost 1073 savings of about  $\leq 200$  per hectare for a 50% reduction in TFI. We can therefore assume that 1074 the following inequality holds, assuming that the cost of the DSS is incorporated in  $C^k$ :

$$\mathbf{E}U_0^{No} \ge \mathbf{E}U_k^{No} \Leftrightarrow (\rho^k - \rho^0)[u(\overline{y}) - u((1-l)\overline{y})] > C^0 - C^k.$$
(1)

1075 The equivalent inequality for risk neutrality is  $(\rho^k - \rho^0) l\overline{y} > C^0 - C^k$ .

1076 The cost savings on fungicides are not enough to compensate for the higher risk of losses 1077 when reducing one's TFI, even with the help of the DSS.

1078 The insurance contract. We denote P the price of the contract per unit of insured capital 1079 and I the indemnity in case of losses. We assume that  $\overline{y}$  is both the maximum yield and the 1080 one insured under the contract. The indemnity I depends on losses (in the case of loss-based 1081 insurance) or the realization of an index (in the case of index-based insurance). The insurance 1082 coverage is  $\alpha$  in [0,1[ (meaning there is a deductible of  $1 - \alpha$ ). If the producer follows DSS 1083 recommendations he receives an additional bonus indemnity b > 0 in case of yield losses, funded 1084 by public authorities. Otherwise, there is no bonus.

> b > 0 if  $k = k^*$  (DSS recommendations are followed) b = 0 if  $k \neq k^*$  (DSS recommendations are not followed)

1085 **The producer's decisions.** The decision to subscribe or not to the insurance (participation) 1086 is taken at the start of the grapevine growing season and the decision to comply with the DSS 1087 is made afterwards, during the season. We abstract from timing aspects here, but consider the 1088 two decisions, that translate into constraints for the insurance scheme to be effective:

Participation constraint (PC): The producer prefers to take up the insurance if it provides
a higher profit than not reducing their TFI and not benefiting from the contract.

Incentive constraint (IC): The producer prefers to take up the insurance and comply with
 the DSS if it provides a higher profit than taking up the insurance but not reducing her
 TFI.

The status-quo strategy, with no pesticide use reduction, yields expected profits of  $[(1 - 1095 \ \rho^0) + \rho^0(1-l)]\overline{y} - C^0 = (1 - \rho^0 l)\overline{y} - C^0$ . The participation constraint (*PC*) will be met if the profits obtained when taking up an insurance contract and reducing one's TFI are higher than this expression.

1098 Loss-based insurance. With loss-based insurance, the indemnity is perceived if and only if 1099  $y = (1 - l)\overline{y}$ , which happens with probability  $\rho^k$ . Indemnity is  $I = (\alpha + b)l\overline{y}$ . The expected utility for the producer is

$$\mathbf{E}U^{L}B_{k} = (1-\rho^{k})u(\overline{y}) + \rho^{k}u((1-l(1-\alpha-b))\overline{y}) - C^{k} - P$$

1100 under risk-aversion.

1101 Under risk neutrality, expected profits are

$$\mathbf{E}U^{L}B_{k} = \overline{y}[1 - \rho^{k}l(1 - (\alpha + b))] - C^{k} - P.$$
<sup>(2)</sup>

taking up the contract and following the DSS is profitable if and only if the following participation constraint (PC) is satisfied:

$$(PC)^{LB} \quad \mathbf{E}U^{L}B_{k} = (1-\rho^{k})u(\overline{y}) + \rho^{k}u((1-l(1-\alpha-b))\overline{y}) - C^{k} - P$$

$$\geq (1-\rho^{0})u(\overline{y}) + \rho^{0}u((1-l)\overline{y}) - C^{0}$$

$$\Leftrightarrow \rho^{k}u((1-l(1-\alpha-b))\overline{y}) - \rho^{0}u((1-l)\overline{y}) - (\rho^{k}-\rho^{0})u(\overline{y}) \geq P - (C^{0}-C^{k})$$

$$\Leftrightarrow (C^{0}-C^{k}) + \rho^{k}u((1-l(1-\alpha-b))\overline{y}) - \rho^{0}u((1-l)\overline{y}) \geq (\rho^{k}-\rho^{0})u(\overline{y}) - P.$$

1104 Participation is ensured if the cost savings on pesticides plus the benefit of receiving the indem-1105 nity (instead of bearing the full loss) at least compensate for the higher probability of a loss 1106 (and therefore lower probability of obtaining  $u(\bar{y})$ ) and the premium.

1107 The loss-based insurance contract ensures that the producer is perfectly insured when the 1108 deductible  $(1 - \alpha)$  is null and the insurance actuarially fair. They also benefit from a reduction 1109 in cost of crop protection. Moreover, taking up the insurance contract and complying with the 1110 DSS recommendations is more attractive than taking up the contract without following the DSS 1111 if and only if the following incentive constraint  $(IC)^{LB}$  is satisfied:

$$(IC)^{LB} \quad \mathbf{E}U^{L}B_{k} = (1-\rho^{k})u(\overline{y}) + \rho^{k}u\Big((1-l(1-\alpha-b))\overline{y}\Big) - C^{k} - P$$

$$\geq \qquad (1-\rho^{0})u(\overline{y}) + \rho^{0}u\Big((1-l(1-\alpha))\overline{y}\Big) - C^{0} - P$$

$$\Leftrightarrow \qquad (C^{0} - C^{k}) + \rho^{k}u((1-l(1-\alpha-b))\overline{y}) - \rho^{0}u((1-l(1-\alpha))\overline{y}) \geq (\rho^{k} - \rho^{0})u(\overline{y})$$

1112 Index-based insurance. The indemnity is triggered by the value of an index, imperfectly 1113 correlated with realized yields. Such insurance is cheaper than loss-based, and the premium is 1114  $\beta P$ , with  $\beta \leq 1$ . The producers receive an indemnity with probability  $\rho^i$  (even where the index 1115 triggers an indemnity). Note that  $\rho^i$  is the same for all producers whose contract depends on 1116 the same index. The distinct events "suffering losses" and "receiving an indemnity" lead to a 1117 partition in four states of nature, whose probabilities are given in Table A.1. For instance, with 1118 probability  $\rho_{l+ni}^k$ , the grapevine grower will suffer losses but no indemnity will be paid.

A.1: Probabilities associated to states of nature for index-based insurance

	Losses	No losses	Row total
No indemnity	$\rho_{l+ni}^k$	$\rho_{nl+ni}^k$	$1 - \rho^i$
Indemnity triggered by index	$\rho_{l+i}^k$	$\rho_{nl+i}^k$	$ ho^i$
Column total	$\rho^k$	$1-\rho^k$	1

1119 For a risk-averse producer, the four states of nature need to be distinguished:

$$\begin{split} \mathbf{E}U_{k}^{IB} &= \rho_{nl+ni}^{k} u\Big(\overline{y}\Big) + \rho_{nl+i}^{k} u\Big(\overline{y} + (\alpha+b)l\overline{y}\Big) \\ &+ \rho_{l+i}^{k} u\Big((1-l)\overline{y} + (\alpha+b)l\overline{y}\Big) + \rho_{l+ni}^{k} u\Big((1-l)\overline{y}\Big) - C^{k} - \beta P \\ &= \rho_{nl+ni}^{k} u\Big(\overline{y}\Big) + \rho_{nl+i}^{k} u\Big((1+(\alpha+b)l)\overline{y}\Big) \\ &+ \rho_{l+i}^{k} u\Big(1 - l(1-\alpha-b)\overline{y}\Big) + \rho_{l+ni}^{k} u\Big((1-l)\overline{y}\Big) - C^{k} - \beta P \end{split}$$

1120 And for a risk-neutral producer:

$$\begin{aligned} \mathbf{E}U_k^{IB} &= (1-\rho^k)\overline{y} + \rho^k(1-l)\overline{y} + \rho^i(\alpha+b)l\overline{y} - C^k - \beta P \\ &= \overline{y}(1-\rho^k l) + \rho^i(\alpha+b)l\overline{y} - C^k - \beta P \\ &= \overline{y}[1-(\rho^k - \rho^i(\alpha+b))l] - C^k - \beta P \end{aligned}$$

*Incentives to reduce TFI.* The incentive constraint is satisfied if the profits above are higher than the ones obtained when taking up the insurance contract but not reducing one's TFI. This strategy provides profits of

$$\begin{aligned} \rho_{nl+ni}^{0} u\left(\overline{y}\right) &+ \rho_{nl+i}^{0} u\left((1+(\alpha+b)l)\overline{y}\right) \\ &+ \rho_{l+i}^{0} u\left(1-l(1-\alpha-b)\overline{y}\right) + \rho_{l+ni}^{0} u\left((1-l)\overline{y}\right) - C^{0} - \beta P \end{aligned}$$

### 1124 The incentive constraint that ensures compliance with the DSS thus writes as

$$\begin{split} (IC)^{IB}: & \rho_{nl+ni}^{k} u \left( \overline{y} \right) + \rho_{nl+i}^{k} u \left( \overline{y} + (\alpha + b) l \overline{y} \right) \\ & + \rho_{l+i}^{k} u \left( 1 - l(1 - \alpha - b) \overline{y} \right) + \rho_{l+ni}^{k} u \left( (1 - l) \overline{y} \right) - C^{k} - \beta P \\ & \geq \rho_{nl+ni}^{0} u \left( \overline{y} \right) + \rho_{nl+i}^{0} u \left( (1 + \alpha l) \overline{y} \right) \\ & + \rho_{l+i}^{0} u \left( 1 - l(1 - \alpha) \overline{y} \right) + \rho_{l+ni}^{0} u \left( (1 - l) \overline{y} \right) - C^{0} - \beta P \\ \Leftrightarrow & \left( \rho_{nl+ni}^{k} - \rho_{nl+ni}^{0} \right) u \left( \overline{y} \right) + \left( \rho_{l+ni}^{k} - \rho_{l+ni}^{0} \right) u \left( (1 - l) \overline{y} \right) \\ & + \rho_{nl+i}^{k} u \left( (1 - (\alpha + b) l) \overline{y} \right) - \rho_{nl+i}^{0} u \left( \overline{y} + \alpha l \overline{y} \right) \\ & + \rho_{l+i}^{k} u \left( 1 - l(1 - \alpha - b) \overline{y} \right) - \rho_{l+i}^{0} u \left( 1 - l(1 - \alpha) \overline{y} \right) \geq -(C^{0} - C^{k}) \end{split}$$

1125 which can be writen as

$$(IC)^{IB}: \qquad (C^0 - C^k) + \left[\rho_{nl+i}^k u \left( (1 + (\alpha + b)l)\overline{y} \right) - \rho_{nl+i}^0 u \left( (1 + \alpha l)\overline{y} \right) \right] \\ + \left[\rho_{l+i}^k u \left( 1 - l(1 - \alpha - b)\overline{y} \right) - \rho_{l+i}^0 u \left( 1 - l(1 - \alpha)\overline{y} \right) \right] \\ \ge (\rho_{nl+ni}^0 - \rho_{nl+ni}^k) u \left( \overline{y} \right) + (\rho_{l+ni}^0 - \rho_{l+ni}^k) u \left( (1 - l)\overline{y} \right)$$

1126 Clearly, beliefs as to the probabilities of the four states, respectively when following the DSS 1127 and when not reducing one's TFI, are crucial determinants of the decision to reduce fungicide 1128 use within the insurance contract, together with the bonus b.

1129 Under risk neutrality, the problem becomes much simpler as one can group profit terms along 1130 the probabilities of the two events, suffering losses and receiving an indemnity. The value of the 1131 index is unrelated to the fungicide use of the producer, so that  $\rho_{l+i}^0 + \rho_{nl+i}^0 = \rho_{l+i}^k + \rho_{nl+i}^k = \rho^i$ . 1132 Under risk neutrality, the incentive constraint becomes

$$\begin{split} (IC)^{IB} : & (C^0 - C^k) + [\rho_{nl+i}^k \left(1 + (\alpha + b)l\right)\overline{y} - \rho_{nl+i}^0 \left(1 + \alpha l\right)\overline{y} \\ & + [\rho_{l+i}^k \left(1 - l(1 - \alpha - b)\overline{y} - \rho_{l+i}^0 \left(1 - l(1 - \alpha)\overline{y}\right)] \\ & \geq (\rho_{nl+ni}^0 - \rho_{nl+ni}^k) \,\overline{y} + (\rho_{l+ni}^0 - \rho_{l+ni}^k) \left(1 - l\right)\overline{y} \\ \Leftrightarrow & (C^0 - C^k) + (\rho_{nl+i}^k + \rho_{l+i}^k) b l\overline{y} \\ & \geq (\rho_{nl+ni}^k + \rho_{l+i}^k + \rho_{nl+i}^k - \rho_{nl+ni}^0 - \rho_{l+i}^0 - \rho_{nl+i}^0) \overline{y} \\ & + [\rho_{l+i}^k - \rho_{l+i}^0 + \rho_{l+ni}^k - \rho_{l+ni}^0] l\overline{y} - [\rho_{l+i}^k - \rho_{l+i}^0] \alpha l\overline{y} \\ \Leftrightarrow & (C^0 - C^k) + \rho^i b l\overline{y} \\ & \geq (1 - 1)\overline{y} + (\rho^k - \rho^0) l\overline{y} - (\rho^i - \rho^i) \alpha l\overline{y} \\ \Leftrightarrow & (C^0 - C^k) + \rho^i b l\overline{y} \geq (\rho^k - \rho^0) l\overline{y} \end{split}$$

1133 Since the conditions for the payment of the base indemnity are independent from fungicide use, 1134 the incentive to reduce one's TFI only depends on the associated cost savings and probabilities 1135 of yield losses (as without an insurance contract) and the bonus (triggered only in case of 1136 compliance with DSS recommendations). The higher b and the probability that the index 1137 triggers the indemnity,  $\rho^i$ , the more likely it is that the producer will indeed follow the DSS.

*Participation.* The participation constraint states that taking up the insurance contractand following the DSS, is more profitable than foregoing insurance:

$$\begin{split} (PC)^{IB}: & \rho_{nl+ni}^{k} u \left( \overline{y} \right) + \rho_{nl+i}^{k} u \left( \overline{y} + (\alpha + b) l \overline{y} \right) \\ & + \rho_{l+i}^{k} u \left( 1 - l(1 - \alpha - b) \overline{y} \right) + \rho_{l+ni}^{k} u \left( (1 - l) \overline{y} \right) - C^{k} - \beta P + \\ & \rho_{nl+ni}^{k} u \left( \overline{y} \right) + \rho_{nl+i}^{k} u \left( \overline{y} + (\alpha + b) l \overline{y} \right) \\ & \geq (1 - \rho^{0}) u(\overline{y}) + \rho^{0} u(1 - l \overline{y}) - C^{0} \\ \Leftrightarrow & \rho_{nl+i}^{k} u \left( \overline{y} + (\alpha + b) l \overline{y} \right) + \rho_{l+i}^{k} u \left( 1 - l(1 - \alpha - b) \overline{y} \right) \\ & \geq (1 - \rho^{0} - \rho_{nl+ni}^{k}) u \left( \overline{y} \right) + (\rho^{0} - \rho_{l+ni}^{k}) u \left( (1 - l) \overline{y} \right) + \beta P - (C^{0} - C^{k}) \end{split}$$

Participation is obtained if the utility gained in the two states of nature where there is indemnification is enough to compensate for the the situations with no indemnity, and for the premium reduced by cost savings.

1143 For a risk-neutral producer, the participation constraints simplifies into

$$(PC)^{IB}: \qquad \overline{y}[1 - (\rho^k - \rho^i(\alpha + b))l] - C^k - \beta P \ge \overline{y}[1 - \rho^0 l] - C^0 - \beta P$$
$$\Leftrightarrow \quad [\rho^0 - \rho^k + \rho^i(\alpha + b)]l\overline{y} \ge \beta P - (C^0 - C^k)$$

1144 Public support through b or premium subsidy to reduce the premium P favors insurance 1145 subscription, both for index-based and loss-based insurance. Contrary to a subsidy to the 1146 premium, a subsidy to the bonus b also favors complying with the DSS, making the green 1147 insurance an effective instrument to reduce fungicide use.

1148 Preference between loss-based and index-based insurance. The index-based insurance con-

1149 tract is more attractive to a risk-neutral producer than the loss-based one if and only if

$$\overline{y}[1 - (\rho^k - \rho^i(\alpha + b))l] - C^k - \beta P$$

$$\geq \overline{y}[1 - \rho^k l(1 - (\alpha + b))] - C^k - P$$

$$\Leftrightarrow (\rho^i - \rho^k)(\alpha + b)l\overline{y} + (1 - \beta)P \ge 0.$$

#### 1150 A.2. Simulation

1151 We simulate here the impact on expected profits of (A) one characteristic of the insurance scheme 1152 not varied in the DCE: the bonus b; (B) pesticide efficiency in reducing the risk of catastrophic 1153 loss  $\rho^0$ , capturing heterogeneity in the fungal disease pressure faced by producers.

1154 We focus on a set-up where producers are always better-off reducing their pesticide use by 1155 half with insurance than without. We focus on whether they are better off relying on chemical 1156 protection (k = 0) or reducing their pesticide use by half, covered by the green insurance 1157 (k = 0.5).

To do so, we rely on the following assumptions: (1) Producers are risk neutral; (2) The 1158 probability of loss  $l\rho^k$  when pesticides are reduced by half, and DSS recommendations are 1159 followed, is calibrated at 10% per year, which corresponds to a catastrophic loss of 100% one 1160 year out of ten, while the full yield is reached the nine other years ; (3) the probability to be 1161 indemnified is equal in loss-based and index-based contracts, and producers correctly perceive 1162 these probabilities  $(\rho^k = \rho^i)$ . Indeed, while no suitable index exists as yet in the context of 1163 1164 French grapevine growing, insurers would not offer a contract based on an index whose frequency 1165 was much higher than that of actual losses. And conversely, vine growers would not accept an index whose frequency was much lower than that of actual losses; (4) The insured capital  $\overline{y}$ 1166 is equal to  $\notin 5000$ /ha (yield of 50 hl/ha and economic value of  $\notin 100$ /hl, which corresponds to 1167 French averages); (5) the cost of treatments  $C^0$  is set at  $\in 400/\text{ha}$ , reduced to  $C^k = \notin 200/\text{ha}$ 1168 1169 when pesticides are reduced by half; (6) the price P of the loss-based contract is set at 5% of the insured capital, while the index-based contracts is 10% cheaper (4.5%), for a base coverage 1170

1171 of 50% of losses. In the first simulation (Figure A.1), the bonus is varied from 0 to 50%, such 1172 as the total coverage does not exceed 100% of losses. In simulation B, the bonus is set at 30%, 1173 as in the DCE. In the second simulation (Figure A.2),  $\rho^0$  is varied from 0 to 0.1, such the 1174 loss frequency does not exceed  $\rho^k$ , which is the frequency in the situation where pesticide are 1175 reduced. In simulation A,  $\rho^0$  is set at 0.05: all the harvest is lost 1 year out of 20.

#### A.1: Impact of bonus on expected profits



Parameters calibration:  $\rho^k = \rho^i = 0.1$ ; l = 1;  $\overline{y} = 5000$ ;  $C^0 = 400$ ;  $C^k = 200$ ; P = 0.05;  $\beta = 0.9$ ;  $\alpha = 0.5$ ;  $\rho^0 = 0.05$ 

Figure A.1 shows that in the absence of bonus, producer should stay in the status quo situation without reducing their pesticide use. For a bonus b = 5%, reducing pesticide use by half with index-based insurance is more profitable than not reducing pesticide use, while this is the case only for a bonus of b = 10% for loss-based insurance, given the higher price.



A.2: Impact of pesticide efficiency in reducing the risk of catastrophic loss  $rho^0$  on expected profits

Parameters calibration:  $\rho^k = \rho^i = 0.1$ ; l = 1;  $\overline{y} = 5000$ ;  $C^0 = 400$ ;  $C^k = 200$ ; P = 0.05;  $\beta = 0.9$ ;  $\alpha = 0.5$ ; b = 0.3

Figure A.2 shows that producer should stay in the status quo situation without reducing their pesticide use when the frequency of loosing all the harvest with pesticide is lower than one year out of 40 (0.025). When pesticides do not offer full protection and this frequency  $\rho^0$  is higher, reducing pesticide use by half covered by green insurance is more profitable. In this setup, index-based insurance is always more profitable since it is cheaper for the same probability of receiving an indemnity. If producers perceive the probability of being indemnified to be lower with index-based insurance than loss-based insurance, the opposite result would hold.

1187 With lower capital value ( $\overline{y} < 5000$ ) or more expensive pesticides ( $C^0 > 400$ ), producers 1188 could be better off reducing their pesticide without insurance than not reducing their pesticide. 1189 Other motivations (risk-aversion, health, environmental concerns,...) may also tilt the balance 1190 in favor of reducing treatments. Characteristics of the production context, beyond the fungal 1191 disease pressure as captured by  $\rho^0$ , may also impact the decision to subscribe to the green 1192 insurance scheme under study. These aspects are better captured in the choice experiment 1193 where the characteristics of the respondents capture a large diversity of individual situations.

#### 1194 Appendix B: Experts forecasts

1195 We conducted a prediction survey in autumn and winter 2022. We present here the question-1196 naire sent to forecasters and their forecasts. Experts' predictions have been used to formulate 1197 hypotheses, as adviced by Dellavigna et al. (2019).

#### 1198 B.1. Questionnaire sent to forecasters

We would like your opinion as a professional of the wine sector on the interest that vine growers could have for a new insurance scheme. This scheme would allow to mitigate the risks linked to fungal diseases in a context of limited use of fungicides. Currently, only the climatic risk (frost, hail) is concerned by a subsidized insurance scheme. Your answers are useful for us to guide the decisions of public authorities regarding new tools better adapted to the needs of vine growers.

1204 Our team only includes researchers working for public institutions Our study is totally anony-1205 mous and is conducted without any commercial or political purpose.

1206 Thank you for your time. [Institutional logos included here]

#### 1207 A. Your Profile

1208 A1: What is your field of activity?

1209 If you are a vine grower with no responsibility for representing of the profession, 1210 please do not answer the survey. You will have the chance to respond to the 1211 survey for vine growers during the winter of 2022-2023.

- 1212 O Production
- 1213 O Wine commercialisation
- 1214 O Consulting (oenology, technical support,...)
- 1215 O Financing (bank, insurance,...)

1216 O Research and Development

1217 O Other

1218 A2: Can you specify your organization or company?

1219

1220 A3: Do you know the insurable treatment protocol tested by IFV and Groupama on the wine

1221 cooperatives of Buzet and Tutiac ?

- 1222 O Yes
- 1223 O No

#### 1224 B. The system considered

1225 We are talking about a risk management system for fungal diseases. This insurance scheme is 1226 not available for vine growers. Your opinion will help us to think about the interest and the 1227 best way to conceive this device.

- 1228 The scheme provides for:
- 1229 1. Financial coverage for losses due to diseases. The diseases covered are downy mildew,
- 1230 powdery mildew, and block rot.
- 1231 2. A decision support system providing treatment recommendations to reduce fungicide
- 1232 treatments, formulated by the French Institute of Vine and Wine.
- 1233 3. A **bonus**, funded by the public authorities, if vine growers follow the protocol's
- 1234 recommendations.



#### 1235

#### 1236 Some details:

The IFV tool models the development of fungal diseases based on field observations and
 weather data. It advises vine growers on how to carry out fungicide treatments. These
 decision rules have been thought out beforehand with vine growers.

# According to the tests over 4 campaigns, following this protocol allows to save, depending on the year, between 40 and 70% of fungicides, while still achieving at least 90% of the yield target.

# The scheme is open to all, with or without certification. A specific version of the treatment protocol exists for organic farming.

- Subscription to this compensation scheme for losses due to disease is independent of the multi-risk climate insurance (MRC) which guarantees climatic risks (frost, hail...).
- The practices of the vine growers can be controlled (treatment booklet, visit).



To access to the scheme, vine growers pay a **price** which is a **percentage of their insured capital**.

The insured capital is equal to the insured yield multiplied by the price at which the production is valued.

The subscription is necessarily made for the whole of a wine-producing exploitation.

The coverage is a percentage of the evaluated losses, without any threshold.



All losses are compensated, according to a basic compensation percentage defined by the contract.

Grapevine growers who respect the treatment protocol (dates, doses) receive a higher coverage compared to those who carry out more treatments. This bonus is funded by the public authorities.

1250 B1: In your opinion, what proportion of vine growers would **never** be interested in such a 1251 guarantee (whatever its characteristics and price)? \_\_\_\_\_\_% of vine growers.

B2: For which of the two aspects do you think that the vine growers would be interested in thedevice?

- 1254 O Coverage for losses due to fungal diseases.
- 1255 O Treatment protocol to reduce fungicides while maintaining yields.
- 1256 O Other:
- 1257 Comment on your choice here:

1259	B3: The evaluation of the losses can be done:
1260	• by an expert, who comes to observe the consequences of the fungal diseases in the
1261	vineyard plots and then the harvest
1262	• by an index of fungal pressure, based on observations of control vines close to of the
1263	vine growers
1264	In your opinion, what proportion of vine growers would prefer a loss-based evaluation rather
1265	than an index-based evaluation of losses?
1266	% of vine growers.
1267	B4: Grapevine growers can join the scheme
1268	• Voluntary (as for a classic insurance)
1269	• <b>Compulsory</b> (as for a mutual fund between vine growers of the same cooperative,
1269 1270	• <b>Compulsory</b> (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)
1269 1270 1271	<ul> <li>Compulsory (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)</li> <li>According to you, what proportion of vine growers would prefer a voluntary membership</li> </ul>
1269 1270 1271 1272	<ul> <li>Compulsory (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)</li> <li>According to you, what proportion of vine growers would prefer a voluntary membership rather than a mandatory one as for a mutual fund?</li> </ul>
1269 1270 1271 1272 1273	<ul> <li>Compulsory (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)</li> <li>According to you, what proportion of vine growers would prefer a voluntary membership rather than a mandatory one as for a mutual fund?</li> <li>\[\[\] \[% of vine growers.</li> </ul>
<ol> <li>1269</li> <li>1270</li> <li>1271</li> <li>1272</li> <li>1273</li> <li>1274</li> </ol>	<ul> <li>Compulsory (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)</li> <li>According to you, what proportion of vine growers would prefer a voluntary membership rather than a mandatory one as for a mutual fund?</li> <li>% of vine growers.</li> <li>Use the criteria below to draw the profile of the winemaker who:</li> </ul>
<ol> <li>1269</li> <li>1270</li> <li>1271</li> <li>1272</li> <li>1273</li> <li>1274</li> <li>1275</li> </ol>	<ul> <li>Compulsory (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)</li> <li>According to you, what proportion of vine growers would prefer a voluntary membership rather than a mandatory one as for a mutual fund?</li> <li>% of vine growers.</li> <li>Use the criteria below to draw the profile of the winemaker who:</li> <li>In your opinion, is most likely to be interested in this type of tool;</li> </ul>
1269 1270 1271 1272 1273 1274 1275 1276	<ul> <li>Compulsory (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)</li> <li>According to you, what proportion of vine growers would prefer a voluntary membership rather than a mandatory one as for a mutual fund?</li> <li>% of vine growers.</li> <li>Use the criteria below to draw the profile of the winemaker who:</li> <li>In your opinion, is most likely to be interested in this type of tool;</li> <li>In your opinion, prefers expertise to the index;</li> </ul>
1269 1270 1271 1272 1273 1274 1275 1276 1277	<ul> <li>Compulsory (as for a mutual fund between vine growers of the same cooperative, appellation or wine area)</li> <li>According to you, what proportion of vine growers would prefer a voluntary membership rather than a mandatory one as for a mutual fund?</li> <li>% of vine growers.</li> <li>Use the criteria below to draw the profile of the winemaker who:</li> <li>In your opinion, is most likely to be interested in this type of tool;</li> <li>In your opinion, prefers expertise to the index;</li> <li>According to you, prefers voluntary membership to compulsory membership (as for a</li> </ul>

- 1279 Your answers will be compared to the choices made by vine growers in another survey.
- 1280 B5: Phyto user profile
- 1281 Choose the appropriate answer for each row:

		IFT lower than	IFT close to the	IFT higher than	
		the average of	average of the	the average of	No influence
		the wine basin	wine basin	the wine basin	
	Interested in				
	the insurance	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$
1282	scheme				
	Prefer expertise	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$
	to index	$\bigcirc$	$\bigcirc$		
	Prefer		$\bigcirc$	$\bigcirc$	$\bigcirc$
	voluntary				
	membership to	$\bigcirc$			
	membership in				
	a mutual fund				

- 1283 B6: Certification
- 1284 Choose the appropriate answer for each row:

		HVE	AB	Other certification	No certification	No influence
	Interested in the insurance scheme	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$	0
1285	Prefer exper- tise to index	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$	0
	Prefer volun- tary member- ship to mem- bership in a mutual fund	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$	0

# 1286 B7: Commercialisation

 $1287 \quad Choose \ the \ appropriate \ answer \ for \ each \ row:$ 

		Harvest vinified	Harvest vinified	Harvest sold as	
		in individual	in cooperative	fresh, juice or	No influence
		cellar	cellar	grape musts	
	Interested in				
	the insurance	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$
1288	scheme				
	Prefer expertise	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$
	to index		$\bigcirc$	$\bigcirc$	
	Prefer		$\bigcirc$	$\bigcirc$	$\bigcirc$
	voluntary				
	membership to	$\bigcirc$			
	membership in				
	a mutual fund				

# 1289 B8: Diversification

1290 Choose the appropriate answer for each row:

		Grapevine grower	Polycultivator	No influence
	Interested in the	$\bigcirc$	$\bigcirc$	$\bigcirc$
	insurance scheme		$\bigcirc$	$\bigcirc$
	Prefer expertise	$\bigcirc$	$\bigcirc$	$\bigcirc$
1291	to index		$\bigcirc$	$\bigcirc$
	Prefer voluntary			
	membership to	$\bigcirc$	$\bigcirc$	$\bigcirc$
	membership in a	$\bigcirc$	$\bigcirc$	$\bigcirc$
	mutual fund			

1292 B9: Production mainly in...

1293 Choose the appropriate answer for each row:
		AOC/AOP (protected denomination of origin)	IGP (protected geographic indication)	Without indication	No influence
1204	Interested in the insurance scheme	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$
1294	Prefer expertise to index	$\bigcirc$	$\bigcirc$	0	0
	Prefer vol- untary mem- bership to membership in a mutual fund	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$

1295 B10: Using Decision Support System

1296 Choose the appropriate answer for each row:

		Already DSS user	Without DSS	No influence
	Interested in the	$\bigcirc$	$\bigcirc$	$\bigcirc$
	insurance scheme	$\bigcirc$	$\bigcirc$	$\bigcirc$
	Prefer expertise	$\bigcirc$	$\bigcirc$	$\bigcirc$
1297	to index	Ŭ	$\bigcirc$	$\bigcirc$
	Prefer voluntary			
	membership to	$\bigcirc$	$\bigcirc$	$\bigcirc$
	membership in a	$\bigcirc$	$\bigcirc$	$\bigcirc$
	mutual fund			

1298 B11: Insurance

# $1299 \quad Choose \ the \ appropriate \ answer \ for \ each \ item$

		Already insured multi-risk and satisfied	Already insured multi-risk insurance and dissatisfied	Not insured multi-risk climate	No influence
1200	Interested in the insurance scheme	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$
1900	Prefer expertise to index	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$
	Prefer vol- untary mem- bership to memberstry in a mutual turd	$\bigcirc$	$\bigcirc$	$\bigcirc$	$\bigcirc$

# 1301 B12: Responsibility

# 1302 Choose the appropriate answer for each row:

		Owner	Manager	No influence
	Interested in the	$\bigcirc$	$\square$	$\bigcirc$
	insurance scheme	)		
	Prefer expertise	$\bigcirc$	$\bigcirc$	$\bigcirc$
1303	to index	)		
	Prefer voluntary			
	membership to	$\bigcirc$	$\square$	$\bigcirc$
	membership in a	$\bigcirc$		
	mutual fund			

# 1304 B13: Production value

		Production value	Production value	
		higher than the	lower than the	
		average for vine	average for vine	No influence
		growers in the	growers in the	
		same wine area	same wine area	
	Interested in the	$\bigcirc$	$\bigcirc$	$\bigcirc$
1306	insurance scheme			
	Prefer expertise	$\bigcirc$	$\bigcirc$	$\bigcirc$
	to index		$\bigcirc$	$\bigcirc$
	Prefer voluntary			
	membership to	$\bigcirc$	$\bigcirc$	$\bigcirc$
	membership in a			$\bigcirc$
	mutual fund			

1305 Choose the appropriate answer for each row:

#### 1307 C. What parameters?

1308 We would like to know your opinion on the parameters that could make the system attractive1309 to vine growers.

- 1310 C1: According to you, what minimum coverage and maximum price should be offered to vine
- 1311 growers to make the insurance scheme attractive?
- 1312 Coverage (in % of assessed loss)
- 1313
- 1314 Premium (in % of the insured capital)
- 1315

1316	C2: According to you, what difference in coverage should be applied between a grower who
1317	follows exactly the treatment protocol and one who treats more during a campaign?
1318	$\bigcirc$ % of losses
1319	C3: Do you think that vine growers would be more interested in an insurance scheme
1320	O with a compensation of 90-(Bonus)%, completed by a bonus of (Bonus)% if they follow
1321	the treatment protocol
1322	O with a compensation of 90%, reduced by (Bonus)% if the treatment protocol is not
1323	followed
1324	O This has no influence.
1325	C4: Do you think that vine growers would be more willing to follow exactly the treatment
1325 1326	C4: Do you think that vine growers would be more willing to follow exactly the treatment protocol under an insurance scheme
1325 1326 1327	C4: Do you think that vine growers would be more willing to follow exactly the treatment protocol under an insurance scheme O with a compensation of 90-(Bonus)%, completed by a bonus of (Bonus)% if they follow
<ol> <li>1325</li> <li>1326</li> <li>1327</li> <li>1328</li> </ol>	<ul><li>C4: Do you think that vine growers would be more willing to follow exactly the treatment protocol under an insurance scheme</li><li>O with a compensation of 90-(Bonus)%, completed by a bonus of (Bonus)% if they follow the treatment protocol</li></ul>
1325 1326 1327 1328 1329	<ul> <li>C4: Do you think that vine growers would be more willing to follow exactly the treatment protocol under an insurance scheme</li> <li>O with a compensation of 90-(Bonus)%, completed by a bonus of (Bonus)% if they follow the treatment protocol</li> <li>O with a compensation of 90%, reduced by (Bonus)% if the treatment protocol is not</li> </ul>
1325 1326 1327 1328 1329 1330	<ul> <li>C4: Do you think that vine growers would be more willing to follow exactly the treatment protocol under an insurance scheme</li> <li>O with a compensation of 90-(Bonus)%, completed by a bonus of (Bonus)% if they follow the treatment protocol</li> <li>O with a compensation of 90%, reduced by (Bonus)% if the treatment protocol is not followed</li> </ul>
<ol> <li>1325</li> <li>1326</li> <li>1327</li> <li>1328</li> <li>1329</li> <li>1330</li> <li>1331</li> </ol>	<ul> <li>C4: Do you think that vine growers would be more willing to follow exactly the treatment protocol under an insurance scheme</li> <li>O with a compensation of 90-(Bonus)%, completed by a bonus of (Bonus)% if they follow the treatment protocol</li> <li>O with a compensation of 90%, reduced by (Bonus)% if the treatment protocol is not followed</li> <li>O This has no influence.</li> </ul>

- 1333 D1: How long have you been working in the wine sector?
- 1334 Your answer must be between 1940 and 2022.
- 1335 D3: In which area do you work (department number)?
- 1336 E. To thank you for your participation

E1: Would you like to participate to a random draw for the first 50 people who completed theentire survey? To be won: Six bottles of Crémant de Loire made for the 50th anniversary ofthe University.

1340 O Yes

1341 O No

1342 E2: Please enter your email, the winner will receive an e-mail asking her to indicate her postal1343 address to receive the bottles at home.

1344 E3: Would you like to receive the results of the study by email in 2023?

1345 O Yes

1346 O No

1347 E4: Please enter your email address to receive the results

1348

# 1349 F. Comments

1350 F1: Thank you for your answers. They will be compared to the choices made by vine growers

1351 in another survey. You can indicate here any reaction or suggestion related to this

1352 questionnaire.

1354 Thank you for your time in answering this questionnaire.

1355 If you have any comments, please do not hesitate to contact us: [email address provided]

1356 Thank you for completing this questionnaire.

#### 1357 B.2. Forecast results

1358 We summarize here experts' forecasts on vine growers' preferences collected with the prediction 1359 survey. While the prediction survey included more questions, we focus here on the forecasts 1360 related to the pre-registered hypotheses.

1361 Experts anticipate more interest for green insurance from vine growers treating less than the 1362 average.  $\rightarrow$  Pre-registered hypothesis H3

1363 Concerning the impact of producers and farms' characteristics, most experts forecast that 1364 vine growers already committed to and satisfied with a climatic insurance, would be interested 1365 by green insurance.  $\rightarrow$  Pre-registered hypothesis H2

1366 According to the expert's estimates, 71% of vine growers would prefer a voluntary individual 1367 contract rather than a mandatory group one.  $\rightarrow$  Pre-registered hypothesis H5

1368 On average the experts believe that 64% of vine growers would rather prefer an expert-based 1369 insurance than an index-based insurance.  $\rightarrow$  Pre-registered hypothesis H6

1370 Most experts predict that vine growers would be more interested by the green insurance

1371 with the bonus framing, but have ambiguous forecasts concerning the impact of framing on

1372 compliance with DSS recommendations.  $\rightarrow$  Pre-registered hypothesis H7

#### 1373 Appendix C: Pre-registered hypotheses

1374 The following hypotheses are based on the literature on pesticide use reduction and Agri-1375 Environmental Scheme and insurance contract choices. They are also in-line with results from 1376 a prediction survey conducted in autumn and winter 2022 to collect experts' forecasts on vine 1377 growers' preferences for the different attributes, and impacts of farm and producers' character-1378 istics on these preferences.

H1: Grapevine growers have a positive willingness to pay for such a green insurance coveringyield losses due to fungal diseases.

H2: Risk and producers risk preferences will both influence producers willingness to adoptgreen insurance and to follow DSS recommendations to reduce their fungicide use.

H3: Self-selection into the scheme: H3a: Grapevine growers who are treating intensively will be (despite characteristics that make them treat more) attracted by the technical and financial assistance provided by the scheme, because this group likely includes the most risk-averse vine growers. H3b: Grapevine growers who are treating less intensively will be the most attracted by the scheme, as they are more likely to receive the bonus and get windfall benefits.

H4: Grapevine growers are more willing to pay for a green insurance contract with bettercoverage (lower deductible) and lower premium.

1390 H5: Vne growers are less willing to pay for a collective contract, but this effect is reduced 1391 for vine growers who are already working together, especially those members of a cooperative.

1392 H6: Grapevine growers are less willing to pay for an index insurance, but this effect is 1393 reduced for those who have already experienced such insurance and those more innovation-1394 oriented (proxied by producers' characteristics).

H7: Grapevine growers are more willing to pay for green insurance in the bonus framing,but are less likely to comply with DSS recommendations, compared to the penalty framing.

H8: Green insurance is an effective instrument to achieve fungicide reductions in line withtargets of the French National Action Plan (Ecophyto) and the EU green deal.

78

#### 1399 Appendix D: Framing effect - Results

1400 To test for the impact of framing on preferences towards green insurance, we estimate the RPL model for the bonus and penalty framing sub-samples separately. The hypothesis that we have 1401 1402 significant effects in presenting the indemnity as a bonus or penalty is verified by the means of a 1403 likelihood ratio (LR) test (Höhler and Schreiner 2019; Contini et al. 2019). The value of the LR (-2(-1276.68-(-724.825-516.79)) test is lower than the critical value for  $\chi^2$  statistic at 5% with 1404 10 degree of freedom (18.307). We can therefore not reject the null hypothesis. This indicates 1405 1406 that presenting the indemnity as a bonus or penalty does not significantly change respondents' 1407 preferences, even when the scale differences between treatments are controlled for.

Moreover, we verified that the framing has no selection impact: producers subscribing to insurance in the bonus framing group are not significantly different from those in the penalty framing group in terms of TFI reduction potentials (Figure A.3), according to the Kruskal–Wallis equality-of-populations rank test ( $\chi^2(1) = 0.057$ ; Prob = 0.8112)

	Bonus framing		Penalty fra	aming
	Mean	SD	Mean	SD
ASC	-3.090***	2.871***	-1.169	8.353***
	(-4.57)	(3.65)	(-1.39)	(4.67)
Group	-0.425**	$1.240^{***}$	-0.882***	$0.800^{**}$
	(-2.56)	(4.59)	(-4.71)	(2.39)
Index	-0.418***	$0.639^{**}$	-0.347**	0.443
	(-3.30)	(2.38)	(-2.51)	(1.21)
Coverage	$0.0254^{**}$	$0.0510^{***}$	$0.0245^{**}$	$0.0375^{**}$
	(2.45)	(3.62)	(2.38)	(2.17)
Price	$-1.341^{***}$	$2.736^{***}$	$-2.564^{***}$	$-2.509^{***}$
	(-3.87)	(5.70)	(-4.15)	(-5.95)
N	2772		2172	
LL	-724.825		-516.795	

A.2: Framing impact on preferences for green insurance

A.3: Fungicide use reduction reached with green insurance and the DSS in the bonus and penalty framing subgroups - for those willing to subscribe to green insurance



#### 1412 Appendix E: Adoption rate by regions

1413We observe in Table A.3 that there are less adopters in regions where wine value is higher (Côtedu-Rhône Nord, Charentes, Champagne, Bourgogne) or disease pressure is lower (Languedoc, 1414 Provence). When the production value is high, the uninsured part of losses  $(1-\alpha-b)l\overline{y}$  dampens 1415 the incentive to get the green insurance. Where the risk of losses is lower, the premium P appears 1416 too costly and the cost savings from following the DSS are limited (low  $C^0 - C^k$ ). In both 1417 cases, the participation constraint (PC) is less likely to be satisfied. Nevertheless, due to the 14181419 interplay of different regional characteristics, there is no significant difference in the adoption rate between the regions where regional average TFI is below the national median (Low-use 1420 regions) compared to the other regions (High-use regions). Organic growers (including those 1421 in transition) are particularly likely to subscribe to green insurance if their are high users in 1422 1423high-use regions (Table A. 4).

Region	Low use/High use+	Adopter*	Sample	Population**
Bouches-du-Rhône	Low-use	$0,\!00\%$	$0,\!24\%$	$1,\!12\%$
Dordogne	High-use	$0,\!00\%$	0,97%	$0,\!92\%$
Côtes-du-Rhône Nord	Low-use	$25,\!00\%$	0,97%	$2,\!69\%$
Charentes	High-use	$38{,}23\%$	$8,\!25\%$	$7{,}51\%$
Champagne	High-use	44,00%	$12,\!14\%$	$21,\!44\%$
Languedoc hors PO	Low-use	$46,\!43\%$	$13{,}59\%$	23.20%
Bourgogne	High use	$46,\!66\%$	$7,\!28\%$	3.72%
Provence (Var-Vaucluse)	Low-use	$48,\!15\%$	$6{,}55\%$	$9{,}19\%$
Alsace	Low-use	50,00%	$2,\!43\%$	4,92%
Corse	High-use	$50,\!00\%$	0,97%	$0,\!58\%$
Côtes-du-Rhône Sud	Low-use	$50,\!00\%$	1,94%	
Bordelais	High-use	$55{,}36\%$	$13{,}59\%$	10,41%
Pyrénées-Orientales	Low-use	$60,\!00\%$	$1,\!21\%$	2,09%
Val de Loire	Low-use	$63,\!88\%$	$17{,}48\%$	2,55%
Beaujolais	High-use	66,00%	$2,\!18\%$	$5,\!81\%$
Lot-et-Garonne	High-use	$66,\!66\%$	0,73%	0,71%
Cher	Low-use	$66,\!67\%$	$1,\!46\%$	$0,\!52\%$
Bugey Savoie	High-use	$71,\!43\%$	1,70%	0,57%
Jura	Low-use	$77,\!77\%$	$2,\!18\%$	$0,\!45\%$
Gaillac	Low-use	85,71%	1,70%	$0,\!29\%$
Gers	High-use	85,71%	1,70%	0,85%
Cahors	High-use	100,00%	0,73%	0,44%

A.3: Respondents and adopters by region

+ "Low-use regions" are the regions where regional average TFI are below the national median (according to French agricultural practices survey 2019)

\* Adopter of the S1 contract (5% price and 50% coverage)

\*\* Grapevine growers population according to French agricultural census 2020.

A.4: Adoption rates of the S1 contract (5% price and 50% coverage)(with population weight in parenthesis)

Non-organic	High users	Low users
High-use regions	55.17~(23.6%)	53.3~(23.6%)
Low-use regions	67.5~(17.9%)	51.72(17.9%)
Organic	High users	Low users
High-use regions	66.7~(2.8%)	39.13~(2.8%)
Low-use regions	56.52(5.7%)	51.02(5.7%)

Kruskal-Wallis test for difference across cells  $\chi^2(7) = 6.382$ ; Prob = 0.496

#### 1424 Appendix F: Robustness checks

1425 We run the same RPL model than the one presented in the main text (Figure 2) to different subgroups. In column (1), we first exclude responses to the first choice card seen by respondents, 1426to account for learning effects. In column (2), we exclude responses to the last choice card in order 1427 1428 to check for a lassifude effect. In column (3), we exclude respondents who indicated no interest in the scheme before answering choice cards, since they are more likely to have provided random 1429 answers. In column (4), we exclude those who have always opted-out. Finally, in column (5), we 14301431 exclude respondents who read the description of attributes, including the video presenting the 1432 DSS, in less than thirty seconds, which is considered as too short for a comprehensive overview of 1433 the green insurance scheme. In column (6), we exclude the 36 respondents who were interviewed face to face in order to keep only self-completed responses. 1434

Model	(1)Excl	(2)Excl	(3)Excl.	(4)Excl.	(5)Excl.	(6)Excl.
	first choice	last choice	not inter-	always opt-	low reading	Face to face
	(Learning	(Lassitude	ested	out	time	
	effects)	effect)				
Mean						
ASC	-3.134***	-2.143***	-4.970***	-2.547***	-4.355***	-2.177***
	(-4.19)	(-3.30)	(-5.52)	(-6.18)	(-3.37)	(-3.56)
Group	-0.642***	-0.641***	-0.751***	-0.577***	-0.960***	-0.621***
	(-4.36)	(-4.76)	(-4.83)	(-5.17)	(-2.78)	(-4.88)
Index	-0.456***	-0.436***	-0.450***	-0.370***	-0.614**	-0.387***
	(-3.80)	(-3.83)	(-3.88)	(-4.26)	(-2.12)	(-3.97)
Coverage	$0.0289^{***}$	$0.0197^{**}$	$0.0258^{***}$	$0.0249^{***}$	0.0118	$0.0236^{***}$
	(3.39)	(2.26)	(2.95)	(3.87)	(0.68)	(3.56)
Price_Inv	-1.844***	-1.888***	-1.824***	-2.009***	-1.191***	$-2.125^{***}$
	(-4.92)	(-5.61)	(-6.05)	(-8.28)	(-2.77)	(-5.73)
SD						
ASC	$6.300^{***}$	$5.743^{***}$	-3.466***	$-1.426^{***}$	$2.991^{**}$	$6.035^{***}$
	(6.37)	(6.54)	(-4.64)	(-3.87)	(2.16)	(7.65)
Group	$1.148^{***}$	$0.680^{**}$	$1.138^{***}$	$1.040^{***}$	$1.725^{***}$	$1.113^{***}$
	(4.80)	(2.49)	(5.11)	(6.30)	(3.84)	(5.68)
Index	$0.725^{***}$	$0.652^{**}$	$0.639^{***}$	-0.501**	$1.357^{***}$	$0.557^{***}$
	(2.85)	(2.50)	(2.83)	(-2.57)	(3.16)	(2.63)
Coverage	0.0269	$0.0421^{**}$	$0.0360^{***}$	$0.0276^{***}$	0.00906	0.00756
	(1.45)	(2.42)	(2.95)	(4.34)	(0.52)	(0.42)
Price_Inv	$2.760^{***}$	$2.014^{***}$	$-1.779^{***}$	-1.022***	$1.943^{***}$	$2.748^{***}$
	(8.27)	(8.67)	(-7.25)	(-5.35)	(4.84)	(7.39)
N	3708	3708	2544	3324	972	4512

A.5: RPL estimates for subgroups

t statistics in parentheses : \* p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01

A.6: Criteria for determining the optimal number of classes in the Latent Class model

Number of classes	Log-likelihood (LL)	AIC	BIC	Prediction accuracy:
				Average latent class
				posterior probability
2	-1294.102	2618.203	2678.52	98.24%
3	-1257.064	2564.128	2664.654	93.96%
4	-1219.810	2509.619	2650.355	89.69%

Notes: AIC (Akaike Information Criterion) is -2(LL-j) where j is the number of parameters to be estimated in the model; BIC (Bayesian Information Criterion) is -LL + (k/2)xln(N) where N is the number of observations.

A.4: Sensitivity analysis: Impact of green insurance on TFI reduction at the population level, according to DSS environmental performance



Note: the target TFI percentile (Q) is the TFI of the Q less-intensive producers in terms of fungicide use, by type of practices (conventional and organic), according to French agricultural practices survey (2019). It is considered as a metric for DSS environmental performance: the DSS performs better (in environmental terms) if one can reach the TFI of a lower percentile of the population.

	Class 1	Class 2	Class 3 (Random choice)
	(25%)	(34.5%)	(40.5%)
ASC	-4.502***	0.542	-1.220***
	(-4.18)	(0.51)	(-5.66)
Croup	1 086***	0.284	0
Group	(5.27)	(0.56)	$\left( \right)$
	(-0.21)	(-0.00)	(•)
Index	-1.140***	-0.631	0
	(-4.41)	(-1.34)	(.)
Coverage	0 0446***	0.00449	0
Coverage	(2, 22)	(0.21)	$\left( \right)$
	( <b>0.00</b> )	(0.21)	(.)
Price	-0.421***	-0.577***	0
	(-4.78)	(-3.66)	(.)
	Probability to belong	Probability to belong	
	to class 1	to class 2	(class 3 reference)
Organic	0.468	-0.717	
	(0.69)	(-1.52)	
Organic transition	-0.846	-2 547***	
organie_transition	(-0.87)	(-3.38)	
	( )	( )	
Other certification	-0.413	-1.080*	
	(-0.63)	(-2.56)	
Sanitary stratory	0.228	0.253	
Samtary strategy	(1.02)	-0.205	
	(1.02)	(-1.00)	
Constant	-0.965	1.632**	
	(-1.00)	(2.71)	
N	4944		

# A.7: Latent class with random response class

t statistics in parentheses \* p<0.05, \*\* p<0.01, \*\*\* p<0.001

# 1435 Appendix G: Survey dissemination

Chanel	Targeted population	
Agriconomie, an on-line shop selling inputs and	17000 vine growers who had bought at the shop	
equipment to agricultural producers	or opened their newsletter in the last 2 months	
Vitisphere (main professional information web- site for the wine industry in France)	Readers of the website	
Farm cooperatives national network (section	Regional federations, who have forwarded the	
vine growers)	email to vine growers	
The National and Nouvelle Aquitaine regional Federation of Organic Agriculture. (section vine growers)	Organic vine growers	
Regional Branch of Producers Organisations (Loire Valley, Bordeaux, Côtes du Rhône, Cognac, Champagne, Bourgogne)	Grapevine growers receiving newsletters	
Agricultural chambers national network	Technical advisors in different wine regions, who have forwarded the email to vine growers	
VitiREV Project network	Grapevine growers receiving the newsletter	
National network of <i>independent vine growers</i>	Grapevine growers receiving the newsletter	
De Sangosse (major agricultural inputs supplier)	Clients of the company, in particular those buy- ing biological control products	
Face to face interviews in wine fairs and other		
professional events		
Personal contacts of the authors		

A.8: Channels used for survey dissemination

#### 1436 Appendix H: English version of the vine grower survey

1437 We are looking for your point of view on new tools, designed to help you compensate the risks1438 associated with fungal diseases.

Currently, only the climatic risk (frost, hail) can benefit from a subsidized system. However,
the risks of losses associated with diseases also prevail for the wine sector, even more in a context

1441 of reduction of phytosanitary products use.

By responding to this study today, you are helping to guide the decisions of public authorities to design and implement new tools better adapted to the needs of vine growers.

Our team includes only researchers working for public institutions. Our study, totally anonymous and validated by an ethics committee, is conducted without commercial or political purposes.

1447 Thank you for your time.

1448 This project is funded by: [institutional logos included]

## 1449 INTRODUCTION

#### 1450 Expected answers

We are expecting answers from people in charge of financial decisions in a vineyard, but also in charge of decisions related to phytosanitary treatments. Do not hesitate to answer as a duo with the financial manager and the technical manager.

You will need to provide your Fungicide Treatment Frequency Index (TFI) for the last three years (it will not be disclosed). You will then be able to compare it with regional averages.

1456 Please have this information ready before you start. If you do not already have access to

1457 TFI, you can calculate it <u>here</u>. To get your Fungicide TFI from this calculator, enter only your

1458 fungicide treatments. The first value in the table  $(1^{st}$  line "TFI") is your fungicide TFI.

#### 1459 Data management

1460 This study is anonymous. Neither your name nor your company's name will be asked. 1461 In accordance with the principles of open science, and in compliance with the General Data

1462 Protection Regulation, data will be anonymized before archiving and made available for scientific

1463	use.
1464	Duration
1465	The survey takes about 12 minutes. You can stop at any time and return to the questionnaire
1466	later, by clicking on the same link. To return to the questions on the previous page, click on
1467	"previous" at the bottom left of each page but do not go back on the navigator, otherwise your
1468	answers will not be saved.
1469	Contact
1470	For any question : [contact email provided]
1471	B1: Consent
1472	O I confirm that I have read and understood the above information. I am at least 18 years
1473	old and I give my consent to participate in this study.
1474	$\Omega$ I do not give my consent
1475	(The survey ends here if the answer is "I do not give my consent.")
1476	Filters
1477	C1: Are you responsible for the financial management decisions of a vineyard ?
1478	O Yes
1479	O No
1480	(The survey ends here if the answer is "No")
1481	C2: Are you in charge of decisions regarding vineyard management, including treatments?
1482	O Yes, I am responsible for vineyard treatments.
1483	O Yes, I participate in the reflections on the treatments of the vineyard.

1484 O No, someone else is in charge and I am not consulted.

(The survey ends here if the answer is "No, someone else is in charge and I am notconsulted.")

- 1487 C3: What is your role in the vineyard ?
- 1488 O Owner
- 1489 O Manager (employee)
- 1490 O Other :
- 1491 C4: How long have you been working in viticulture ?
- 1492 If you have been working in viticulture for less than one year, put 0.
- 1493 Years
- 1494 Profile of the vineyard
- 1495 D1: In which grapevine-growing area is your vineyard located (or most of it if it is located in
- 1496 several regions)?
- 1497 O Alsace
- 1498 O Beaujolais
- 1499 O Bordelais
- 1500 O Bouches-du-Rhône
- 1501 O Bourgogne
- 1502 O Bugey-Savoie
- 1503 O Cahors
- 1504 O Champagne
- 1505 O Charentes

1506	O Cher
1507	O Corse
1508	O Côtes-du-Rhône Nord (northern part of the departments 07 and 26)
1509	O Côtes-du-Rhône Sud (southern part of the departments 07 and 26)
1510	O Dordogne
1511	O Gaillac
1512	O Gers
1513	O Jura
1514	O Languedoc hors Pyrénées-Orientales
1515	O Lot-et-Garonne
1516	O Provence (Var-Vaucluse)
1517	O Pyrénées Orientales
1518	O Val de Loire
1519	D2: Are the products from your vineyards commercialized under one or more of these
1520	designations?
1521	$\Box$ Protected denomination of origin (AOP/AOC)
1522	$\Box$ Protected geographic indication (IGP)
1523	$\hfill\square$ Without indication (e.g. Vin de France or Vin de la Communauté Européenne)
1524	D3: What is the size of your vineyard ?
1525	Only numbers are accepted

- 1526 Surface dedicated to wine grape production (ha)
- 1527 Surface dedicated to other productions (ha)
- 1528 D4: What is your dominant commercialization mode ?
- 1529 O Grape
- 1530 O Bulk
- 1531 O Bottle
- 1532 O Mixed (specify in the comment area)

# 1533

- 1534 D5: Are you in one or more of these situations ?
- 1535  $\Box$  Member of a cooperative
- 1536  $\Box$  Member of a CUMA
- 1537  $\Box$  Member of a GIEE
- 1538  $\Box$  Member of a collective sales outlet
- 1539  $\Box$  Elected official/vine grower representative

# 1540 Phytosanitary strategy

- 1541 E1: Concerning the management of vine diseases, for example to test new protection practices,
- 1542 how would you position yourself between very careful and risk-taking?

15/13	1 Very careful	2	3	4	5	6	7	8	9	10 very risk-taking
1045	0	0	0	0	0	0	0	0	0	0

1544 E2: Does your vineyard or wine production follow one or more of these specifications?

1545	$\Box$ Certified High Environmental Value (Level 3)
1546	$\Box$ Certified Organic Agriculture
1547	$\Box$ Certified Demeter or Biodyvin
1548	$\Box$ Certified Terra Vitis
1549	$\Box$ My vineyard was certified OA but is no longer certified
1550	$\hfill\square$ In conversion towards Organic Agriculture
1551	$\Box$ None
1552	$\Box$ Other :
1553	E3: Do you know your Fungicide TFI for 2020, 2021 and 2022?

1554 Reminder: If you do not already have access to it, you can calculate it here [link provided]. To

1555 get the fungicide TFI from this calculator, please fill in only your fungicide treatments. The  $1^{st}$ 1556 value of the table obtained ( $1^{st}$  line "TFI") will then be your fungicide TFI.

1557 O Yes

1558 O No

1559 Over the last 3 years, what has been the fungicide TFI (including copper) of your vineyard?

1560 Please also count the fungicides authorized in Organic Agriculture such as copper.

1561 [if E3 == Yes]

			Fungicide TFI
1569	E4:	2020	
1002	E5:	2021	
	E6:	2022	

- 1563 [if E3 == No]
- 1564 E7: Can you at least tell us the number of fungicide applications (including copper)?

	2020	
1565	2021	
	2022	

- 1566 E8: Considering the specificities of your farm, how would you rate your use of fungicides
- 1567 compared to other vine growers in your area?
- 1568 O You think that your use is much lower than that of others.
- 1569 O You think your use is slightly lower than others.
- 1570 O You think your use is about average.
- 1571 O You think your usage is slightly higher than others.
- 1572 O You think your usage is much higher than others.
- 1573 E9: Was your farm engaged in a AECM contract (Agri-Environmental and Climatic Measure
  1574 of the CAP) with a commitment to reduce the Treatment Frequency Index over at least part
  1575 of the period 2015-2022?
- 1576 O Yes
- 1577 O No
- 1578 E10: What is your current state of mind regarding your plant protection strategy?
- 1579 O For the moment, reducing my use of fungicides is not my priority.
- 1580 O I have already reduced my use of fungicides, it is difficult to go further.
- 1581 O I am trying to reduce my use of fungicides, but I find it complicated.

- 1582 O I am in the process of reducing my fungicide use.
- 1583 E11: Do you currently use a decision support system (DSS) to adjust your phytosanitary 1584 treatments ?
- 1585 By the term DSS, we are talking about the different digital tools offered to vine growers today,
- 1586 from various organizations (agriculture chambers, technical institutes, private companies), to
- 1587 advise you in the adjustment of phytosanitary treatments.
- 1588 O Yes and I am satisfied
- 1589 O Yes and it is not very satisfactory
- 1590 O No, not for now but I am thinking about it
- 1591 O No, I don't use it and I'm not interested in it

#### 1592 The insurance scheme

- 1593 We would like to know your opinion on an insurance scheme, still in reflection, for managing 1594 the risks associated with fungal diseases.
- 1595 [(]The participants were assigned randomly to questions on the scheme in the bonus **or** the
- 1596 penalty framing. Hereafter will be displayed the presentation of both bonus and penalty framing

1597 but the participants only read the parts they were assigned to.]

- 1598 [BONUS framing] The insurance scheme provides:
- Financial coverage for annual losses due to diseases. The diseases concerned are downy
   mildew, powdery mildew and black rot.
- 1601 2. The provision of a treatment protocol formulated by the IFV (French Institute of
  1602 Vine and Wine) to reduce fungicide treatments as safely as possible.
- 1603 3. A financial bonus, financed by the public authorities, if the vine growers follow the1604 recommendations of the protocol.

#### 1605 [PENALTY framing] The insurance scheme provides:

1606	1. Financial coverage co-funded by public authorities for annual losses due to diseases.
1607	The diseases concerned are downy mildew, powdery mildew and black rot.
1608	2. The provision of a <b>treatment protocol</b> formulated by the IFV (French Institute of
1609	Vine and Wine) to reduce fungicide treatments as safely as possible.
1610	3. If vine growers prefer not to follow the DSS recommendations, and use more fungicides, a
1611	<b>penalty</b> applies such that the <b>coverage is lowered</b> (no co-funding by public
1612	authorities in this case).

- 1613 Access to the insurance scheme is subject to the payment of a fee. The subscription is
- 1614  $\,$  necessarily made for the whole of a vineyard. The access to the decision support system
- 1615 communicating the treatment protocol is included in the subscription fee.
- 1616 You can view the testimony of a vine grower who has experienced this insurance scheme as
- 1617 part of the VitiREV project in New Aquitaine (Right click on the image).



## 1618

- 1619 The video is also available <u>here</u>
- 1620 Some details:
- 1621 The insurance scheme adoption is open to all, with or without certification. A specific
- 1622 version of the treatment protocol exists for vineyards in organic agriculture.
- 1623 The practices of the vine growers can be controlled (treatment notebooks, visits).

Subscription to this insurance scheme for losses due to diseases is independent of the
multi-risk climate insurance (MRC). You may wish to subscribe to one or the other, or
both but with no obligation.

#### 1627 Insurance scheme versions

- 1628 From the general insurance scheme presented above, several versions can be considered.
- 1629 Your opinion will allow us to think about the interest and the best way to conceive this
- 1630 insurance scheme if it is one day proposed to the vine growers.
- 1631 Here are the possibilities considered:

#### 1632 **TYPE OF CONTRACT** which can be:

# Individual



Each vine grower decides **individually** whether or not to subscribe to the insurance (as for a classic insurance).

# 1633

# Collective



The vine growers subscribe to a **group** contract, for example within the framework of a mutual fund between vine growers of the same cooperative, appellation or wine basin. In this case, membership is compulsory for all the vine growers in the group concerned.

# 1634 DAMAGE EVALUATION:



1635



Your real losses are assessed by an **expert**, who comes to observe in your plots the consequences of fungal diseases and then the harvest. The amount of the compensation depends on the expert's evaluation of your real losses. The expertise allows an evaluation of the losses specific to your farm but is subject to the subjectivity of the expert and is more expensive than the index evaluation.

Your losses are estimated on a local fungal pressure **index** measured, for example, in control vineyards near your home. The amount of compensation depends on the value of this index. Your real losses will sometimes be higher and sometimes lower than in the control vineyards, but the index can help to reduce insurance costs and make the assessment of losses more objective than an expert evaluation.

#### 1636 COVERAGE:



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[BONUS FRAMING] The **coverage** is a percentage of assessed losses (between 40 and 65% of losses). No triggering threshold is applied. The coverage will be higher for vine growers respecting the treatment protocol (dates, doses) and not carrying out any treatment other than those recommended by this protocol, thanks to an additional 30% bonus financed by the public authorities. With the bonus, the total coverage is between 70% (40%+30%) and 95% (65%+30%) of the losses.

[PENALTY FRAMING] The **coverage** is a percentage of assessed losses (between 70 and 95% of losses). No triggering threshold is applied. A part of this coverage is funded by public authorities. A penalty of 30% (the part normally funded by public authorities) will lower the total coverage for vine growers preferring not to follow the treatment protocol (dates, doses) and carrying out other treatments than those recommended by this protocol. With the penalty, when not following the treatment protocol, the coverage is between 40% (70%-30%) and 65% (95%-30%) of the losses.

## 1638 **PREMIUM:**



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#### 1641 Simulation

Subscribing to insurance is costly and the **price** is defined in % of the insured capital. The insured capital is equal to the insured yield multiplied by the price value of the production. To help your choice, in addition to the mention of the % of the insured capital (between 3 and 8%), a corresponding amount (in  $\in$  per hectare) will be provided, depending on the price at which you declare to value your production and the yield you have declared to insure. 1642 Let's simulate the case of your vineyard.

1643 Imagine that you want to sign up for this insurance scheme, please indicate below the pa-1644 rameters you would choose to view the compensation amounts at the bottom of the page.

1645 If you have several values in mind, please give us the one for your main production.

1646 H1: On average over the last 5 years, at what price do you value your production (in  $\in$  per 1647 hectoliter of wine)?

We need this information to provide you with compensation amounts that are appropriate for your situation. If you do not know or do not wish to give an exact amount, please give an estimate.

1651 (€/hL)

1652 H2: What level of return do you want to ensure ?

1653 You can set it to your potential return. The only constraint is that this level has been reached 1654 at least once in the last 5 years.

1655 (€/hL)

1656 H3: The following table shows you the level of compensation you would receive under this1657 insurance scheme for an amount of losses of 10% due to fungal disease.

As a reminder, following this DSS treatment protocol associated with the device allows to save, depending on the year, between 40 and 70% of fungicides, while allowing to reach at least 90% of the yield objective. Losses will therefore rarely exceed 10%.

1661 [BONUS FRAMING] Estimation of the compensation for **YOUR** vineyard:

	COVERAGE	COVERAGE
Coverage rate	Compensation evaluation payments 40% + 30%	Compensation evaluation payments 65% + 30%
Basis coverage in €/ha	€/ha (40%)	€/ha (65%)
Coverage with the <b>bonus</b> of 30% in $\in$ /ha	€/ha (70%)	€/ha (95%)

# 1663 [PENALTY FRAMING] Estimation of the compensation for **YOUR** vineyard:

Coverage rate	COVERAGE Demage Compensation evaluation payments 70% 30%	COVERAGE Demage Compensation evaluation payments 95%
Basis coverage in €/ha	€/ha (70%)	€/ha (95%)
Coverage with the <b>penalty</b> of 30% in $\in$ /ha	€/ha (40%)	€/ha (65%)

1665 H4: What do you think?

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1664

1666 O I might be interested in this device, depending on how it is set up and its price.

1667 O A priori, I am not interested in such a device to manage the risk of losses due to fungal1668 diseases, whatever its price and the way it is set up.

1669 [(]For the 4 following choices, the cards are displayed here in the bonus framing only but 1670 participants to the survey were assigned to bonus or penalty and saw the corresponding choice 1671 cards]

- 1672 Choice 1/4
- 1673 On each of the following 4 pages, you will see two insurance schemes with different charac-1674 teristics (Scheme A and Scheme B, shown below in columns).

Even if these schemes do not exist for now, please choose between the two schemes the one you would prefer for YOUR vineyard, as you would do in reality if these schemes were offered to you. It is like choosing between two menus in a restaurant: Drink/Entry/Main Course/Dessert, without being able to choose each menu item separately. If you are not interested in any of the proposed features, you can choose "No Guarantee".

1680 There is no right or wrong answer. Keep in mind the situation of YOUR vineyard. This is 1681 what will allow us to more reliably assess what is best for each individual situation.

1682 You can review what each pictogram means by clicking on (i). This opens a new information 1683 tab that you must close to return to the questionnaire.



# 1686 Choice 2/4

1684

1685

1687 You have to make a choice again. You do not have to worry about your previous choice 1688 to choose on this page because the scheme presented are different. You can review what each 1689 pictogram means by clicking on (i).



# 1692 Choice 3/4

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1693 You have to make a choice again. You may find this a bit long but we need your choice on 1694 several possible configurations of the scheme. Thank you.





1695

1696

1697 Choice 4/4

1698 Thank you for choosing again. This is the last one





1700

# 1701 To better understand your choices

You have almost finished, thank you! A few last questions to help us to understand yourchoices and your situation.

1704 M2: What are the reasons you chose not to purchase any of the guarantees presented? [Only

- 1705 for respondents who always choose no guarantee]
- 1706 You may choose up to 3 reasons and rank them in order of importance.
- 1707  $\Box$  I have few fungal diseases in my vineyards
- 1708  $\Box$  I am not interested in reducing my use of fungicides
- 1709  $\Box$  I manage my phytosanitary risk myself without needing anyone else
- 1710 I have organized my activity to support a financial loss one year (Individual Complemen-
- 1711 tary Volume, diversification, provision...)
- 1712  $\Box$  I do not trust that I will be correctly compensated in case of losses
- 1713  $\Box$  I do not see the interest because I already have a multi-risk climate insurance
- 1714  $\Box$  I imagine very heavy administrative procedures
- 1715  $\Box$  The price is too high
- 1716  $\Box$  Other (please specify in the next question)
- 1717 M3: Please specify for what other reason you have chosen not to purchase any of the guar-1718 antees presented.
- 1719

1720 M4: The insurance scheme has been designed to give you flexibility in following the DSS 1721 recommendations.

[BONUS] Reminder: If you do not follow the treatment protocol, you will receive the basic coverage. If you follow the treatment protocol (dates, doses) and do not perform any treatments other than those recommended by the protocol, you would receive the basic coverage + bonus.
[PENALTY] Reminder: If you follow the DSS recommendations (dates, doses) and do not perform any treatments other than those recommended by the protocol, you would receive the maximal coverage. However, if you do not follow the DSS recommendations, a penalty would lower the coverage and you would receive 30% less than the maximal coverage.

1729 If you had the opportunity to actually subscribe to this tool, how would you use the DSS 1730 recommendations?

1731 [BONUS]

O Not following the DSS recommendations at the beginning of the season, and therefore only
 receiving basic coverage for losses.

O Follow the DSS recommendations at the beginning of the season and stop if they do not
suit you.

1736 O Follow the DSS recommendations until the end of the campaign to be sure to benefit from
1737 the bonus, in addition to the basic coverage.

1738 [PENALTY]

O Not following the DSS recommendations at the beginning of the season, and therefore
 receiving the coverage reduced by the penalty of 30% in case of losses.

O Follow the DSS recommendations at the beginning of the season and stop if they do not
suit you.

O Follow the DSS recommendations until the end of the campaign to be sure to benefit from
the maximal coverage.

1745 M5: In the schemes we have proposed to you, the assessment of losses was sometimes based 1746 on an index. Were you aware of this type of insurance before you answer this survey?

1747 With index insurance, the compensation depends on an index and not on your own perfor-1748 mance.

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- 1749 O No, I did not know about it
- 1750 O Yes, I have heard of it but I have never bought it
- O Yes, I have already taken out index insurance (or parametric insurance) in a professional
  or private context.
- 1753 M6: What was the main reason for your interest in the insurance scheme we presented?
- 1754 O Compensation for fungal disease losses
- 1755 O The DSS recommendations to reduce my fungicides while maintaining yields
- 1756 O Both are equally important for me
- 1757 O Other:

1758 M7: If you were insured against climatic risks (with multiple risks, hail or frost guarantee)

1759 at least once in the last 5 years, what was your level of satisfaction?

- 1760 O I have not been insured
- 1761 O Very satisfied
- 1762 O Quite satisfied
- 1763 O Quite dissatisfied
- 1764 O Very dissatisfied

1765 M8: It is possible that this fungal disease insurance system could be systematically associated 1766 with an MRC contract. What would you prefer?

- 1767 O That the scheme we have presented to you remains independent of the MRC.
- 1768 O That this system and the MRC are associated in a global coverage contract

1769	Respondent's profile
1770	N1: Did you study viticulture ?
1771	O Yes
1772	O No
1773	N2: What is your level of education ?
1774	O No diploma
1775	O Primary school certificate (CEP)
1776	$\bigcirc$ Brevet des collèges (BEPC)
1777	O CAP, BEP
1778	O Bac or equivalent
1779	O 1st cycle (BTS, DUT, DEUG, Bachelor or equivalent)
1780	O 2nd, 3rd cycle or Grandes Ecoles (Master, DESS, DEA, Engineer, Doctorate, or equivalent)
1781	O Other :
1782	N3: What is your year of birth ?
1783	
1784	N4: Are you ?
1785	O Male
1786	O Female
1787	O Other

N5: Before answering this survey and watching the video, had you ever heard of the ex-1788perimentation conducted within the framework of Vitirev by IFV and Groupama in Buzet and 1789 1790 Tutiac ?

1791 O Yes

O No 1792

## 1793 Fungicides per grapevine growing area

1794 After answering all these questions, you may be interested in knowing the fungicide use of other vine growers in your wine basin. We share with you here data from the agricultural 1795 practices survey (2019) published by the French Ministry of Agriculture. In your area (NAME 1796 1797 OF THE REGION, in 2019, the average Fungicide-Bactericide TFI for all vineyard was RE-GIONAL TFI and the average number of treatments was NUMBER OF TREATMENTS 1798 In THE REGION. [For organic producers, we also indicated the numbers for organic plots] 1799

1800 Comments

P1: Thank your for your participation. Your comments and suggestions in the space below 1801 will be very useful for the analysis of the results. 1802

1803	Do not hesitate to write us anything that comes to your mind!
1804	
1805	P2: If you wish to receive the results of the study by email in 2023, please enter your email

1806 address here.

1807 It will be stored separately from your responses and deleted once the survey is over.

1808



1809

- 1810 Thank you for your time in answering this questionnaire.
- 1811 For all question or remark: [contact email provided]
- 1812 [institutional logos included here]