**Supplementary Material**

1. **Background on the conceptual model**

The uptake dynamics for perennial crops like grapevines are characterized by taking longer between initial planting and first harvest which is followed by an extended period of regular output at an eventually declining rate (French and Matthews 1971). Modelling perennial crops must thus take long-term time and risk aspects into account (see Figure C1).[[1]](#footnote-1)

Figure C1: Model set-up for plantation dynamics

To conceptually model the uptake of fungus-resistant varieties we assume grapevine growers adjust acreage for fungus-resistant varieties by considering changes in (expected) utility over time (now and in the future) and across variety types (traditional and fungus-resistant varieties). We denote fungus-resistant with $FRG$ and traditional varieties with $TRAD$, respectively, which are the only planting alternatives. Current utility ($t=0$) from growing $FRG$ is $U\_{FRG}$ and depends on $FRG$’s land share that was planted $τ$ periods ago (i.e. $A\_{FRG,t-τ}$). Since grapevine planting does not necessarily change from one year to another, we use $τ\in Z^{+}$ as period index. Expected utility from $FRG$ in $τ$ periods is conditional on the desired land share the grapevine grower wishes to devote to $FRG$ for the next period, i.e. $E(U\_{FRG,t+τ}|A\_{FRG,t+τ}^{\*})$. Moreover, $0<β<1$ represents the grapevine grower’s time preferences. The change in the share of land devoted to $FRG$, that is the desired minus the current (or last period) land share, is thus given by equation 1:

|  |  |
| --- | --- |
| (1) | $$∆A\_{FRG}=A\_{FRG,t+τ}^{\*}-A\_{FRG,t-τ}=β^{τ}E(U\_{FRG,t+τ})-U\_{FRG}$$ |

According to equation 1, grapevine growers will thus adjust their land share ($∆A\_{FRG}$) for fungus-resistant varieties by comparing (discounted) utility differences of the alternatives over time (Fernandez‐Cornejo 1998). Expected utility is a function of expected prices and costs, which define profits, and other features of $FRG$ that reward (dis)utility to the grower. Expected utility differentials and thus decisions across farms are driven by farmer- and farm characteristics, regional factors as well as perceptions, preferences, and personality traits of grapevine growers (Figure C1).

Farmer- and farm characteristics such as the degree of specialization, the size of the farm, structural factors such as the share of old grapevines, the production system, marketing channels and labelling as well as grapevine growers’ education and (self-assessed) knowledge about fungus-resistant varieties may all influence profits and costs including switching and adjustment costs (Gardebroek and Oude Lansink 2004). Grapevine growers’ risk preferences are crucial to explain economic decisions and especially time preferences are relevant to compare long-term utility levels across time (Foster and Rosenzweig 2010, Falk *et al.* 2018, Iyer *et al.* 2020). Moreover, grapevine growers’ perceptions about fungus-resistant varieties such as environmental and health benefits or marketing difficulties as well as the perceived willingness to pay from consumers may reward (dis)utility to grapevine growers (Piñeiro *et al.* 2020, Weersink and Fulton 2020, Finger and Möhring 2022). Additionally, personality traits such as grapevine growers’ ambition, locus of control and self-efficacy may matter for the uptake of preventive measures against pests (Knapp *et al.* 2021, Finger *et al.* 2022). Last, regional factors such as pest pressure or tradition may explain utility differentials across varieties and time.[[2]](#footnote-2)

Therefore, $∆A\_{FRG}>0$ in equation 1 means that the grapevine grower draws higher expected and discounted utility compared to current utility from $FRG$ by increasing their land share in the next period. Since fungus-resistant and traditional varieties are the sole planting alternatives, if expected utility of $FRG$ is lower compared to the current utility level, the grapevine grower reduces their land share for fungus-resistant varieties ($∆A\_{FRG}<0$), and consequently increases the land share devoted to traditional varieties ($∆A\_{TRAD}>0$).[[3]](#footnote-3)

1. **Derivation of expected effects**

Here we derive the expected effects, based on the limited knowledge available in the literature on adoption barriers and determinants of fungus-resistant varieties (i.e. Finger *et al.* 2022) and sustainable agricultural technology more general. Note that our dependent variable is the expected change of the land devoted to fungus-resistant varieties, thus including two factors i) the current share and ii) the future expected share of land under fungus-resistant varieties. Since the current share under fungus-resistant varieties is low, in Switzerland and elsewhere, we develop our argumentation from the view point that farms have not yet adopted these varieties unless stated in the literature on adoption barriers and determinants of fungus-resistant varieties (i.e. Finger *et al.* 2022). Thus, in the table below, + refers to an expected increase, - to an expected decrease and 0 to no expected change in the land share devoted to fungus-resistant varieties.

Table D1: Derivation of expected effects

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Variable name** | **Description**  | **Expectedeffect** | **Hypotheses** | **Sources** |
| **Farmer- and farm characteristics** | Labour | Standardized labour requirements for vineyard  | + | We expect labour-intensively managed farms to increase their land share under fungus-resistant varieties because the amount of labour can be reduced with fungus-resistant varieties. | Fernandez-Cornejo (1998) |
| Age  | Age (in years) | +/0/- | Younger grapevine growers devote currently more land to fungus-resistant varieties, older grapevine growers are less likely to replant and are more familiar with traditional varieties, resulting in an unclear expected effect.  | Polson and Spencer (1991) |
| Female | Gender | +/0/- | It is unclear how gender will affect the future development of fungus-resistant varieties. | Rola‐Rubzen et al. (2020) |
| Farm size | The size of the farm (in are) | + | Large farms are currently devoting a small share of land to fungus-resistant varieties (‘trying out’), we thus expect the land share to increase in the future.  | Fernandez-Cornejo (1998) |
| Farming specialization | Majority of income is from farming (>51%) | + | Similar as above. | Frick and Sauer (2021) |
| Viticulture specialization | Majority of income is from viticulture (>51%) | + | Similar as above. |
| Geographical denomination label | Farmer produces and markets their wine under AOC/DOC geographical denomination | + | Fungus-resistant varieties are less prominent in geographical denomination catalogues, this will likely change in the future thus increasing the land share. | Zachmann et al. (2022) |
| Organic label  | Farmer sells wine under organic label | +/0/- | Since particularly organic farms have currently adopted fungus-resistant varieties, it is unclear how they develop in the future. | Pedneault and Provost (2016) |
| Bio-dynamic label  | Farmer sells wine under bio-dynamic label | +/0/- | Similar as above |
| Integrated production label  | Farmer sells wine under integrated production label | + | Conventional growers have currently adopted less fungus-resistant varieties, thus we expect an increase in the land share.  |
| Direct marketing  | Farmer is specialized in direct marketing (share of sales that go directly to consumers is larger than 50%) | +/0/- | Current adopter are farms that mainly market directly to consumers, it is unclear how these will develop in the next 10 years | Finger et al. (2022) |
| Further education  | Farmer has further education in plant protection | +/0/- | Further education in plant protection can increase sensitivity to the negative effects of pesticide use or strengthen the conviction that pesticide use under best practice does not cause negative effects.  | Foster and Rosenzweig (2010) |
| Knowledge about fungus-resistant grapevines | Self-assessed knowledge about fungus-resistant grapevines (FRG) | +/0/- | It is unclear whether (self-assessed) knowledgeable growers will increase their land share under fungus-resistant varieties.  | Morris et al. (2017); Fernandez-Cornejo et al. (2007) |
| Replantation rate | Replantation rate in next 10 years | + | Growers who will replant (a large) part of the vineyard in the next 10 years will increase the land share under fungus-resistant varieties (more). | Carbone et al. (2019) |
| Farm successor | Does the farmer have a successor for the farm? | +/0/- | Farms with succession may increase, decrease or keep the land share under fungus-resistant varieties constant.  | Inwood and Sharp (2012) |
| **Regional characteristics** | Peronospora viticola infection risk | Average peronospora viticola infection risk index between 2012 and 2021 from the nearest weather station | + | Regions with higher fungal pest pressure are expected to increase their land share under fungus-resistant varieties, as they are particularly affected and thus can especially benefit from and increase in the land share. | Finger et al. (2022); Knapp et al. (2019); Masset and Weisskopf (2019); Dubuis et al. (2014) |
| Oidium infection risk | Average oidium infection risk index between 2012 and 2021 from the nearest weather station | + | Similar as above. |
| Wine region | Dummy variable identifying wine regions (Deutschschweiz, Valais, Ticino, Vaud, Geneva, and the Three Lakes Region) | +/0/- | Depending on the tradition of a wine region, we expected the future land shares to change differently. |
| **Farmer perceptions** | Fungal damage | Fungal Infections have the biggest negative impact on the grapevine yield (i.e. quality and quantity) | + | We expect that growers who perceive fungal damage to have the biggest negative effect on yield to increase their land share under fungus-resistant varieties. |  |
| Banned copper | Whether the farmer thinks copper will be a banned substance in Swiss viticulture in 10 years | + | Growers who expect that copper will be banned in 10 years will devote more land to fungus-resistant varieties because these require less plant protection including copper-based fungicides. |  |
| FRG have a positive impact on the human health of farmers and communities surrounding farms | FRG have a positive impact on the human health of farmers and communities surrounding farms | + | We expect grapevine growers who perceive fungus-resistant varieties to have human health benefits compared to traditional varieties in increase their land share in the future. | Finger and Möhring (2022); Dessart et al. (2019); Toma and Mathjis (2007); Becker (2013) |
| FRG varieties are better for the environment | FRG varieties are better for the environment | + | Similar as above. |
| FRG wine use will increase in the future | FRG wine use will increase in the future | + | Growers who perceive that the use of fungus-resistant varieties will increase in the future will themselves devoted more land to these varieties. |
| Wine from FRG is difficult to market | Wine from FRG is difficult to market | -/0 | We expect that growers who perceive difficulties in marketing wine from fungus-resistant varieties to keep the land share constant or decrease it. |
| Consumers are willing to pay less for wine from FRG | Consumers are willing to pay less for wine from FRG | -/0 | Similar as above. |
| Wine from FRG is of lower quality than traditional varieties | Wine from FRG is of lower quality than traditional varieties | -/0 | Similar as above. |
| **Farmer preferences** | Time preferences | How willing is the farmer to give up income that is beneficial for them today in order to benefit more from that in the future | + | We expect that grapevine growers who are willing to give up something today (e.g. traditional varieties under cultivation) to benefit more from it in the future will increase their land share under fungus-resistant varieties because the benefits of replanting will only materialized in some years.  | Mao et al. (2021); Falk et al. (2018) |
| Production risk preferences | Is the farmer willing to take risks or tries to mitigate risks in production | - | Since fungus-resistant varieties are more tolerant towards fungal infestations, thus reducing risks in production, we expect growers who are risk-averse in the production domain to increase their land share.  | Dohmen et al. (2011); Weber et al. (2002); Rommel et al. (2019) |
| Market risk preferences | Is the farmer willing to take risks or tries to mitigate risks with respect to market and prices | + | Fungus-resistant varieties are currently less know, thus subject to marketing uncertainties. We expect risk-loving farmers in the marketing domain to increase their land share.  |
| Plant protection risk preference | Is the farmer willing to take risks or tries to mitigate risks with respect to plant protection | - | We expect growers who are risk-averse regarding plant protection to increase their land share under fungus-resistant varieties, because these varieties require less plant protection.  |
| **Farmer personality traits** | Self-efficacy | I am confident that I can accomplish my production goals at the end of the harvest | + | We expect growers who are confident to reach their production goals to increase their land share under fungus-resistant varieties which is currently subject to a low level of experience regarding production (vinification, resistance, etc.)  | Abay et al. (2017); Knapp et al. (2021); Wuepper and Lybbert (2017)  |
| Locus of control | How successful my grape/wine production is, depends mostly on my skills as a farmer | + | Similar as above. |
| Ambition | I usually set myself quite ambitious production goals | +/0/- | It is unclear how ambition affects the future expected change under fungus-resistant varieties. |

1. **Calculation of pesticide treatment reductions**

Viret et al. (2019) estimate an average total number of sprays of 12 per year for Northern European vineyards for traditional grapevine varieties. This number, however, is rather a lower bound (e.g. Pertot *et al.* 2017). The number of pesticide treatments can be reduced to 0 or 3 treatments per year using fungus-resistant varieties (or around 80%, see Appendix B). We here assume 3 pesticide treatments per year for fungus-resistant varieties, thus calculating a lower bound of the pesticide treatment reduction.

Table J1: Calculation of pesticide treatment reduction

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Today** | **In 10 years** | **Change in number of pesticide treatments** |
| **Total area under grapevines** | 14’629 ha (100%) |  |
| **Area under traditional varieties** | 14’219 ha (97.2%) | 10’621 ha (72.6%) |  |
| **Treatments per hectare** | 12 x 14’219 = 170’633 | 12 x 10’621 = 127’448 | -43’185 |
| **Area under fungus-resistant varieties** | 410 ha (2.8%) | 4008 ha (27.4%) |  |
| **Treatments per hectare** | 3 x 410 = 1’229 | 3 x 4008 = 12’025 | +10’796 |
| **Total number of pesticide treatments** | 171’861 | 139’473 | **-32’389** |

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1. Our conceptual framework is inspired by French and Matthews (1971) and is adapted to grapevine growing. We extend their framework by considering utility (instead of profit) maximization (e.g. Weersink and Fulton 2020) as well as a farm-level (instead of an aggregative) perspective. To our knowledge, only a few studies look at supply responses in grapevines (Xu *et al.* 2012, e.g. Consoli *et al.* 2021). [↑](#footnote-ref-1)
2. A complete list of included variables, their description and expected effects are in Table 1. [↑](#footnote-ref-2)
3. Note that a decrease in the land share devoted to $FRG$ implies an increase in the land share devoted to the sole alternative, in this case the share of land devoted to $TRAD$ (since $A\_{FRG}$ + $A\_{TRAD}=1$). [↑](#footnote-ref-3)