D10.2 Report on incentives for, and barriers to, the adoption of PoshBee tools

Deliverable D10.2

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PoshBee

Pan-european assessment, monitoring, and mitigation of stressors on the health of bees

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Summary

Honey bee health is threatened by a number of stressors, including pests, diseases, agrochemical exposure and nutrient deficits, resulting in significant colony losses and increased costs to beekeepers. A number of tools are being developed to support beekeepers by improving detection and treatment of these stressors, however the barriers and incentives to adoption, as well as the impacts of mass adoption are relatively understudied.

In this deliverable, we develop a framework for assessing the barriers, incentives, costs and benefits of bee health tools, using the PoshBee Bee Health Card tool (WP9) as an illustrative case study. The Bee Health Card is a MALDI BioTyping tool that uses a sample of bees from within a hive to quickly and accurately determine the presence of stressors in the hive, allowing for quick health reports and recommendations to be made to the beekeeper. The framework consists of four components: 1) identifying the incentives and barriers towards using the tool, 2) quantifying the costs of using the tool, 3) quantifying the benefits of the tool to bee health and 4) quantifying the benefits of tool adoption to society (measured as increased output and increased pollination service capacity).

Using a survey of 474 beekeepers from 7 countries, most beekeepers expressed some interest in using the card with ~47% of respondents expressing a willingness to use the tool regardless of costs or economic incentives. However, costs were a substantial barrier to use, regardless of whether other economic incentives were provided. Economic incentives did not increase the stated willingness to use the tool but did increase the rate at which it was used. Use of the tool was incentivised mainly by its perceived effectiveness, however the perception of benefits to production or environmental benefits were also substantial drivers of uptake under different scenarios. As beekeepers associations are the primary source of information for most beekeepers, priority should be given to demonstrating the effectiveness and potential benefits of the tool to these organizations to encourage widespread uptake.

The estimated costs of the tool, per use were approximately €33-46, depending on the labour and postage costs of the country. If the tool was only partially subsidised, beekeepers could expect to pay €11-23, representing a significant proportion of the health management costs per hive. However, if the tool can result in even a small increase in overall honey production, these costs can still be recovered. Similarly, if the tool is effective at reducing colony losses, it can add value through avoiding colony replacement costs. Finally, the deliverable highlights key knowledge gaps that need to be addressed in order to operationalise the framework more effectively for assessment of tools aimed for widespread adoption, including data beyond experimental tests of the tool itself.

1. Introduction

Honey bees are key pollinators of many European crops (Klein et al., 2007; Kleijn et al., 2015) and represent a key component of European agricultural resilience when faced with declines in wild pollinators (Breeze et al., 2014). European honey bee populations are almost exclusively managed, with a wide range of locally adapted subspecies distributed and traded across Europe (de la Rua et al., 2009). These populations are under threat from a range of biotic and abiotic stressors, including chemical insecticides, diseases and nutritional deficits, which are key drivers of annual colony losses across Europe (Chauzat et al., 2013; Gray et al., 2020) and their management often represents a significant cost for European beekeepers (Breeze et al., 2017; Gray et al., 2019). This, coupled with declining prices for many beehive products, has resulted in beekeeping becoming increasingly unprofitable, resulting in a decline of beekeepers across the continent (Potts et al., 2010).

To address these challenges, several government organizations, both within the EU (EC, 2013) and beyond (DEFRA, 2020), have developed national apicultural programs that are designed to promote bee health through a range of health monitoring, treatment and training activities. However, lacking universal colony registration, it has proven challenging to fully monitor the prevalence and impacts of pressures on honey bee populations, as much of the information on management practices and impacts is decentralized, often relies on self-reporting and can vary between countries (Chauzat et al., 2013; Gray et al., 2020). To facilitate wider data collection, the EU has supported a range of international research projects designed to evaluate risks to bee health (e.g. MUST-B; More et al., 2020) and develop novel technologies for monitoring bee health (E.g. 'SmartBees' and 'Swarmonitor' - Chlebo et al., 2020).

Although there is significant interest in such technologies, there has been comparatively little work on the perceptions and attitudes of beekeepers to using these technologies, particularly compared to other farming sectors. For instance, numerous studies have demonstrated that perceived costs and complexity of using precision farming tools can affect farmer willingness to adopt, despite their purported benefits (Vecchio et al., 2020; Paustian and Theuvsen, 2017, Lencsés et al., 2014). As the rate of adoption can significantly influence the wider benefits of the technology (Jensen et al. 2012), understanding the factors that may incentivize or act as barriers to uptake is crucially important.

The PoshBee project is developing a range of bee health management tools that aim to improve beekeepers ability to detect and respond to bee health considerations. One such tool is the bee health card, developed from the MALDI BioTyping work of PoshBee Work Package 9 (Brown et al., 2021) that aims to measure a suite of different stressors from a small number of sampled honey bees within a colony. The tool aims, through widespread use, to reduce the risk of colony mortality, thereby contributing to the productivity of beehives and the availability of pollination services for crops.

Using the bee health card tool as an example, this deliverable develops a framework designed to identify incentives and barriers to adoption of honeybee health tools and examine the costs and benefits of such widespread adoption. A structured survey is used to collect information from beekeepers in seven countries on the incentives and barriers of the tool while other aspects of the framework are outlined and illustrated with a combination of real and hypothetical data.

2. Framework

2.1. Overview

We developed an analytical framework for estimating the uptake and potential costs and benefits of bee health tools that spans 4 steps, each with 2-3 sub-steps (Figure 1). Step 1 involves assessing the rate at which the tool could be used. Step 2 involves completing a comprehensive analysis of the costs of using the tool. Steps 3 and 4 look at the benefits of tool adoption to beekeepers and society at large. The framework is designed to be as generic as possible in order to be compatible with tools as they are developed.

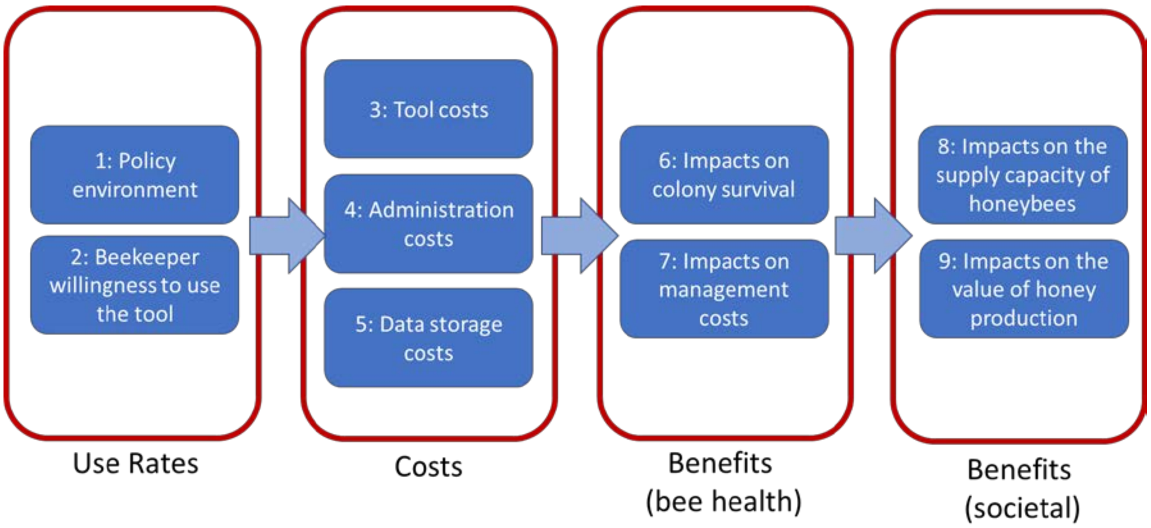

Figure 1: PoshBee framework for assessing tool costs and benefits**.**

For this study we use the PoshBee health card tool, developed in WP9, as an example.

2.1.1. Assessing Use Rates

<u>Policy Environment</u>

As an initial step, research should account for the available budget (e.g. under EU beekeeping funds) and regulations that may need to be accounted for before assessing later steps. This should, at a minimum, include compatibility with the European Commissions policies on bee health management (EC, 2013) and, where data specific to individuals is generated, appropriate data protection regulations (EC, 2016). Food labelling regulations (EC, 2011) should also be considered if the tool is to be integrated into the marketing of honey.

<u>Beekeeper willingness to use the tool</u>

This step will involve collecting information on beekeeper willingness to use the tool, typically using a survey of beekeepers in a region where the tool is to be deployed, disseminated through appropriate national and/or regional beekeeping organizations. This can include analysis of how this willingness to use changes with possible incentives and/or barriers. Ideally this should be accompanied with an informed demonstration of a working prototype and should be refined following dialogue with beekeeping organizations before dissemination. Large samples are ideal and obtaining fully representative samples can prove challenging in countries where beekeeper registration is not mandatory as the demographics of the community are unknown and it is unlikely that any organization will be able to reach all possible beekeepers.

2.1.2. Costs

Tool costs

These should account for all variable costs (materials and labour whose costs vary depending on the use frequency) involved in using the tool. Specialized machinery and lab materials (e.g. chemicals) should be included if the tool is to be part of a specific scheme. Where possible, these costs should disambiguate who will bear these costs (e.g. beekeepers, laboratories, farmers, buyers etc.) depending on the tool type. In the case of the bee health card tool, this will include the costs of sampling (to be paid for by the beekeepers in the scenario where the tool has costs to them).

Administration costs

These should account for the costs of suitably qualified administrators who will manage the data flowing from the tool, if applicable.

Data costs

Many tools can generate large amounts of data that will need to be analyzed, stored and made accessible. The total volume data per unit (e.g. per sample) to be stored and the processing requirements associated with any analysis should be accounted for and costed at this step. This should account for the long-term storage costs.

2.1.3. Benefits (Bee health)

Impact on colony survival

According to the annual COLOSS survey, colony health losses in Europe current stand at 14.5% in 2018-19, many of which are directly or indirectly caused by diseases and other stressors (Gray et al., 2020). Many health tools will ultimately aim to reduce the overall rate of colony losses by reducing the impact of pressures on the colony and facilitating effective health care. This can be tested empirically through controlled experiments with and without the tool or they can be estimated through modelling using agent-based models of colony performance that incorporate the impacts of pressures (e.g. BEEHAVE, ref). Following testing, the impact of the tool on colony survival (expressed as e.g. a change in the % probability that a colony survives the winter) should be estimated, ideally in relation to other environmental and demographic factors (e.g. colony age and size).

Impact on management costs

Managing bee health has been identified as a significant economic cost for both hobbyist and professional beekeepers. Many health tools could potentially reduce these costs by allowing beekeepers to shift from precautionary to reactive treatments, based on threshold levels of stressors, or allow for targeted treatment to specific problems. This can also be tested empirically using colonies with the tool to assess differences in treatment spending compared to control colonies which follow a standard, precautionary treatment regime.

2.1.4. Benefits (societal)

Impacts on the supply capacity of honey bees

Honey bee colonies can play a significant role in crop pollination, either as providers of pollination services or as insurance capacity in case of significant declines in wild pollinator populations. However, studies have demonstrated that newer, smaller colonies provide poorer pollination services than established colonies (Goodrich and Goodhue, 2020). By reducing colony losses, and the subsequent need to replace colonies with newer ones, bee health tools can maintain the availability and strength of honey bee colonies for pollination. This can be expressed as the difference in supply capacity (based on an adaptation of the formula from Breeze et al., 2014, detailed in section 3.4.2.) with and without the tool.

Impacts on Honey production

Across Europe, a majority of hives are owned by a small number of professional beekeepers, many of whom are producing honey for market. As newer colonies are unlikely to be able to produce full honey crops, a reduction in colony losses could therefore increase the production of honey in each country where the tool is employed. This increase is estimated as the % of total colonies that are not lost because of the use of the tool, multiplied by the price per kg of honey.

3. Methods (worked example)

The remainder of the deliverable focuses on establishing, applying and illustrating a basic version of the framework, using the Bee Health Card tool as a worked example. Many of these steps could not be tested during the lifespan of the deliverable and, where appropriate, hypothetical data are used.

The purpose of the analysis presented is to illustrate the methods for testing each step of the framework and to identify the broader incentives and barriers towards beekeeper adoption of new health tools. Furthermore, the analyses are accompanied by an interactive spreadsheet, which allows users to alter the parameters as they see fit and can, in future, use real data in place of the items of hypothetical data.

Throughout this example we use the rates of adoption for each country identified from the beekeeper survey (detailed in Section 3.1.) using two scenarios: 1) with economic incentives (subsidies etc.) and at no extra cost to the beekeeper and 2) without economic incentives and with additional costs. These represent the minimum and maximum rates of adoption in each country.

3.1. Beekeeper Incentives and Barriers Survey

3.1.1. Survey design

To investigate the incentives and barriers to adopt the PoshBee health card tool, we employed a survey of beekeepers across countries involved in PoshBee. The survey consisted of six sections with questions on: 1) their experience and reasons for practicing beekeeping, 2) their communications with growers, 3) their sources of information on bee health, 4) their perceptions of beekeepers regarding bee health and the decline of pollinators in general, 5) their perceptions of the possible benefits and barriers of the proposed PoshBee Health Card tool (henceforth: BHC) and 6) their willingness to adopt the BHC and frequency at which they would use the tool either with or without costs or economic incentives (described to respondents as “subsidies, grants, certified products, etc.”). As the BHC was still under development when the survey was distributed, the key details of the tool were communicated to respondents using a specially developed infographic (Figure 2). As it was not possible to estimate the costs of using the tool when the survey was deployed, an indicative cost of <€25 was provided to reduce the impact of “hypothetical bias”, whereby respondents are more inclined to indicate they will act in a certain way because they do not fully understand the impact of the proposals on their (economic) wellbeing (Henscher, 2010).

PoshBee: Bee Health Card infographic v2.0, Simon Potts

Bee Health Card

The Bee Health Card is a tool under development which will allow beekeepers and veterinarians to have a rapid insight into the health of their colonies. Beekeepers will send a sample of live bees to a laboratory which will assess the exposure of the bees to pesticides, diseases, parasites, and malnutrition. The laboratory will then send the beekeeper an electronic report with information on the health status of their bees, and what is likely to be affecting the colony; it will help inform beekeepers and veterinarians when choosing appropriate medicinal treatments for their colonies.

The expected time window between the shipment and the results is 4-6 days. A business plan to define the tool cost is currently under development, but it should be below 25 € (22 £).

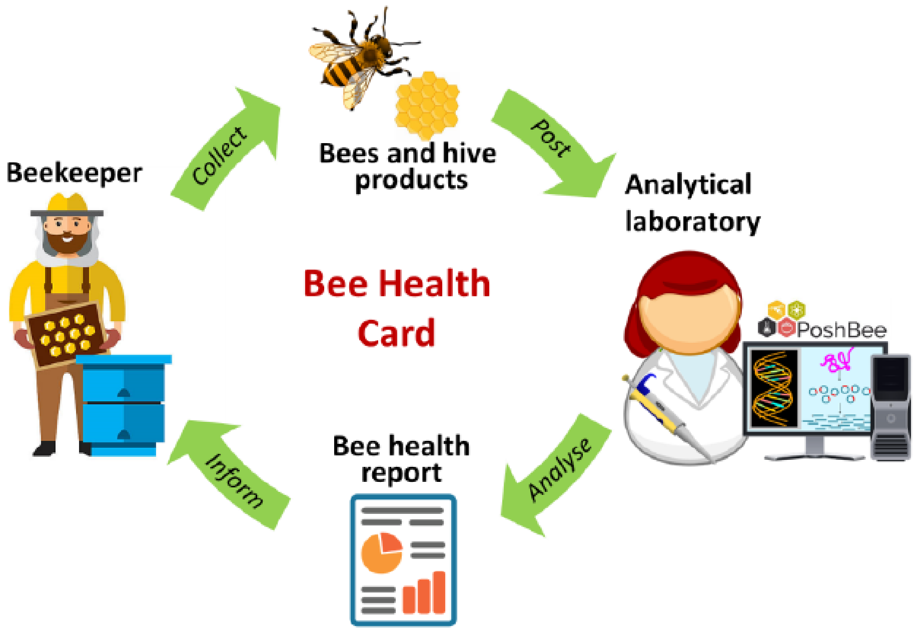

Figure 2: Bee health card infographic

The survey (Appendix 1) was developed in consultation with PoshBee partners representing beekeeper organizations in the eight countries involved to refine the questions and ensure clarity of language. The completed survey, including the infographic was translated into the native languages of each country (Table 1). All versions of the survey were hosted on the survey software Qualtrics, which allows for free switching between languages within a single survey. The survey was checked for ethical approval by the University of Reading (the lead organization handling the survey). The survey remained online for a period of 6 months, from July 31st, 2020, until February 2nd, 2021. The target was a minimum of 30 responses from each country, and this resulted in a final dataset from 7 countries.

Table 1: Countries and languages of distribution**.**

Country	Surveys language
Estonia	Estonian
Germany	German
Ireland	English
Italy	Italian
Spain	Spanish
Sweden	Swedish
Switzerland	German
United Kingdom	English

Surveys were disseminated via an open link, advertised through the POSHBEE social media channels (Twitter and Facebook) and webpage, and were promoted through various beekeeping and farming associations (official Facebook pages, Twitter accounts, webpages) and magazines (Appendix 2).

3.1.2. Survey analysis

The survey was analysed in stages. First, means were calculated for all variables. Correlations among all survey responses were explored using Kendall Rank Correlation Analysis in IBM SPSS Statistics 27.0.1 (Okagbue et al., 2021).

Multiple correspondence analysis

Since a high number of variables were correlated, to avoid significant collinearity issues in subsequent analyses, two Multiple Correspondence Analyses (MCA) were undertaken to identify groups of variables that could be clustered for later analysis. The first MCA (MCA 1) was performed with variables related to the willingness to use the tool and accept extra costs with and without planned incentives, and the second MCA (MCA 2) was conducted with variables related to the frequency of use of the tool with and without planned incentives. To further simplify analyses, some survey results with low occurrence were amalgamated (e.g. “strongly agree” and “agree” responses were grouped into a single “agree” category). The variables used in the MCAs and their respective codes are presented in Appendix 3.

The MCA resulted in two clusters in MCA 1, both of which amalgamate several perceived benefits that formed natural groupings: benefits to beekeeping (amalgamating the responses to “Improved crop pollination + improved bee health + better communication with growers”) and easy environmental benefits (amalgamating the responses to “Tool quick and easy to use + environment protection + pollinators protection”). MCA 2 produced only a single cluster amalgamating several non-cost barriers (“Tool is not important + not effective + difficult + time-consuming”).

Regression modelling

In order to statistically explore the influence of perceptions, incentives and barriers on willingness to use the tool, Bayesian Binary Logistic Regression (BBLR) analyses were performed in Minitab 19. These were used to explore the willingness to use the BHC a) with economic incentives and no extra costs, b) without economic incentives but with no extra costs, c) with economic incentives and with extra costs and d) without economic incentives and with extra costs. Two additional BBLR were performed to explore the relation between the frequency of using the health card tool a) with no extra costs and with incentives and b) with no extra costs and no economic incentives.

After creating the global models, terms with a Variance Inflation Factor (VIF) equal or higher than 5.0 were removed to avoid multicollinearity issues (Gareth et al., 2013). We then proceeded to remove terms with the highest p-value until only significant terms were left in the model. Final models were selected based on the Schwarz’s Bayesian Information Criterion (BIC) (Simon-grifé et al., 2013; Nikolaus et al., 2019; Farwell et al., 2020), reporting models with the lowest BIC and $\Delta BIC \leq 2$ from the lowest BIC model (Neath & Cavanaugh, 2012).

3.2. Estimating the costs of using and managing the health card

The costs of using and managing the health card tool were estimated using information on the material and labour requirements of the tool provided by relevant members of the project team. Costs of staff were drawn from a similar costing exercise in the EU Pollinator Monitoring Scheme (Potts et al., 2021), while material costs are drawn from Fisher scientific in the UK and converted to € (Appendix 4) using the 2020 annual average exchange rate from the European Central bank (EBC, 2022). Postage costs were taken from local carriers, using a 1kg parcel at 32 x 24 x 15cm as a guideline package with next-day delivery. ECB exchange rates were used to convert British Pounds and Swiss Francs into Euros as appropriate (ECB, 2022). These costs were then halved, assuming that special business rates would be negotiated for posting samples.

Administrators are assumed to be based in each country. Overheads are assumed to be 1.5x the cost of staff members. Only the variable costs involved in the BHC are estimated – fixed laboratory costs would depend on the structure of the health card scheme. However, a list of chemicals and items of laboratory equipment is provided in appendix 4). These costs are split into 1) collection costs, the costs of kit required to collect the samples, and 2) lab costs: the costs of analyzing the data.

The number of samples to be sent in is based on total number of beekeepers, multiplied by the willingness to adopt the tool. The number of beekeepers (Table 2) for EU countries were taken from each country's respective national Apicultural Programmes (EC, 2021a-e) as these are considered the most authoritative estimates of the number of beekeepers in the country. For non-EU countries, the number was estimated from Gray et al. (2020), based on the number of responses they received divided by the percentage representativeness of this response.

Table 2: Number of beekeepers per country

Country	Beekeepers	Source
CHE	18,150	Gray et al. (2020)
DEU	116,000	EC, 2021a
ESP	28,786	EC, 2021b
EST	5,215	EC, 2021c
GBR	39,475	Gray et al. (2020)
IRE	3,300	EC, 2021d
ITA	56059	EC, 2021e

The number of laboratory staff required to run the BHC is estimated as 1 technician per 51,000 samples (200 samples per day x 255 working days/year) and that each beekeeper will send 10 bees per sample round. This assumes each beekeeper uses the health card only once per year, although some beekeepers indicate that they may be willing to be use it more often.

3.3. Estimating the impacts on beekeeping

3.3.1. Estimating beekeeper health costs

As part of the framework, we establish a system for testing the hypothetical impacts of the bee health card tool on beekeeper costs. Although beekeeping costs are often cited as a driver behind falling numbers of beekeepers (Potts et al., 2010), there is little published material on the relative costs of beekeeping. To estimate the costs of health management the study used data collected from published literature and communications with the beekeeping organizations involved in PoshBee.

Using these cost estimates, cost savings were calculated assuming the proportion or respondents using the tool would directly inform the number of colonies affected and thus the savings would be equal to the adoption rate multiplied by the % shift in costs as a result of using the health card tool.

As the impact of the BHC on health management costs has not yet been tested, a dummy rate of 20% is applied.

3.3.2. Estimating colony survival impacts

The effect of the BHC on colony survival had not been empirically tested. As such a hypothetical 50% overall increase in colony survival is used for the purposes of illustrating the framework. However, many diseases and pests can be transmitted between colonies as a result of poor husbandry practices and, when considered at larger scales, the tool may be less effective than it otherwise would be. As such the actual effectiveness at a national scale will vary depending on the relationship between the rate of adoption and overall effectiveness. To explore this, three different "efficiency frontiers" were applied:

i. Linear – here the tool is equally effective regardless of how many beekeepers use it. Thus a 1% increase in use generates an E/100 % increase in effectiveness. Half the maximum efficiency is met at 50% adoption.

$$\sum_{f=1}^{F} E_f = U_f \times MaxE_f$$

(E = effectiveness, f = frequency of use, U = adoption rate, MaxE = maximum regional effectiveness at 100% adoption)

ii. Pessimistic – here, the tool is only effective at a large scale if it is widely adopted to prevent the spread of highly contagious pathogens. The relationship used to represent this here (where 50% of the maximum efficiency is only reached with ~70% adoption) is:

$$\sum_{f=1}^{F} E_f = {U_f}^2 \times MaxE_f$$

iii. Optimistic – here, the tool is very effective even at smaller adoption rates because of technical advances allowing for whole areas to be diagnosed from a few colonies. The relationship used to represent this here (where 50% of the maximum efficiency is reached with ~30% adoption) is:

$$\sum_{f=1}^{F} E_f = (U_f \times (2 - U_f)) \times MaxE_f$$

Using the rate of willingness to adopt from each country (see section 4.1.), and national colony winter loss rates from Gray et al (2020) and colony numbers from FAOSTAT, (2022), NBU (2022) and EC (2021d) (Table 3), each of these frontiers was applied to estimate the total number of colonies that survive winter in each of the seven countries studied.

Table 3: Rate of colony losses and colony numbers

	CHE	DEU	ESP	EST	GBR	IRE	ITA
Total colonies[1]	179,473	771,850	2,901,680	48,720	255,000[2]	22,278[3]	423,144
Winter loss %[3]	7.4%	11.6%	17.6%	8.3%	5.4%[4]	3.9%	8.8%

[1]Based on the average of 2016-2020 from FAOSTAT (2022), [2]as no FAO data were available for the UK in the selected time period the average number of hives from 2017-2020 estimated by the National bee Unit (NBU, 2022) are used instead, [3]As colony numbers are not reported to the FAO, we instead use the average of the last two years reported in Annex 3 of the Ireland National Apicultural program (EC, 2021) [4]Winter losses excludes the proportion due to queen failures and natural disasters. [4]Author calculation based on the data in Gray et al (2020) for each constituent country.

3.4. Estimating the benefits to society

3.4.1. Estimating the effect on honey and beeswax production

The effect of the BHC on the production of hive products (honey and beeswax) had not been empirically tested. To illustrate this aspect of the framework, it was assumed that colonies using the BHC tool would be 20% more productive than those without due to the reduction in current impacts of stressors. The impacts of this increase were quantified in economic terms using the current national production and value of honey and beeswax for each country (FAOSTAT, 2022).

3.4.2. Estimating the effect on honeybee supply capacity

Within each country, the capacity of honey bees to supply demands is a combination of 1) the number of hives within the country (supply), and 2) the total demand for pollination services, represented as the sum of the planted area and the recommended stocking density of colonies required to pollinate one hectare of crop. This can be expressed mathematically, adapting the formulae from Breeze et al (2014).

$$HBC_i = \frac{\sum_{c=1}^{ci} A_{ci} R_c}{H_i m}$$

Where HBC_i is the honey bee supply capacity of country i, *Ac* is the area of pollinated crop c (taken as the average area of the crop between 2016-2020 as reported in FAOSTAT, 2022; Appendix 5), R_c is the recommended stocking rate of honey bees per hectare of crop c (taken from Breeze et al., 2014), H_i is the number of hives in the country (taken as the average colony stocks between 2016-2020 as reported in FAOSTAT, 2022) and *m* is a factor representing the number of different hectares each colony is expected to provide pollination services to each year, representing the passive benefits of colonies supplying services to crops flowering at different times in the surrounding landscape and the active benefits of beekeepers moving their hives. In this study, following Breeze et al (2014), this is set as 2, however in reality many beekeepers do not move their hives often or at all (Breeze et al., 2019).

In order to estimate the effects of the reduced colony losses on the capacity of honeybees to supply pollination services, it is assumed that each colony lost is replaced but that each replacement colony, being smaller, is only 25% as effective as a full colony. This adjusts the formula to:

$$HBC_i = \frac{\sum_{c=1}^{ci} A_{ci} R_c}{(H_i - \left(L \times \frac{1}{f}\right))m}$$

Where L represents the number of colonies lost from the previous year that must be replaced and f represents the relative effectiveness of a new colony. L is multiplied by the inverse of this factor in order to give the correct proportionate equivalence of colony numbers. For this study, we assume that untreated colony loss rates are the same as those described in Gray et al., (2020). As the impact of the BHC has not been tested on colony survival, *f* is given a dummy value of 20%.

4. Results

4.1. Beekeeper Incentives and Barriers Survey

In total, 477 beekeepers gave useable responses to the survey (Table 4). The distribution of these responses was uneven with the UK and Ireland making >50% of the responses in total. As such, much of the subsequent analysis focuses on the sample as a whole. Insufficient responses from Swedish beekeepers resulted in them being removed from the analysis. The sample was mostly comprised of hobbyist beekeepers (74%) with a substantial proportion of professionals (24%) (see Appendix 6 for a national breakdown).

Table 4: Final usable response rate by country

Country	ISO Code	N respondents	% of respondents
Switzerland	CHE	52	10.9%
Germany	DEU	33	6.9%
Spain	ESP	40	8.4%
Estonia	EST	32	6.7%
United Kingdom	GBR	136	28.5%
Ireland	IRE	115	24.1%
Italy	ITA	66	13.8%
Sweden	SWE	3	0.6%
Total: 477			
Final total: 474			

Initial analysis of key questions relating to incentives and barriers around the health card tool (additional questions summarized in Appendix 7) identified that over 80% of respondents identified beekeeping associations as key sources of information on bee health (Figure 3,). This was consistent across countries. Other beekeepers, in person training and national beekeeping organizations were also important sources for many beekeepers.

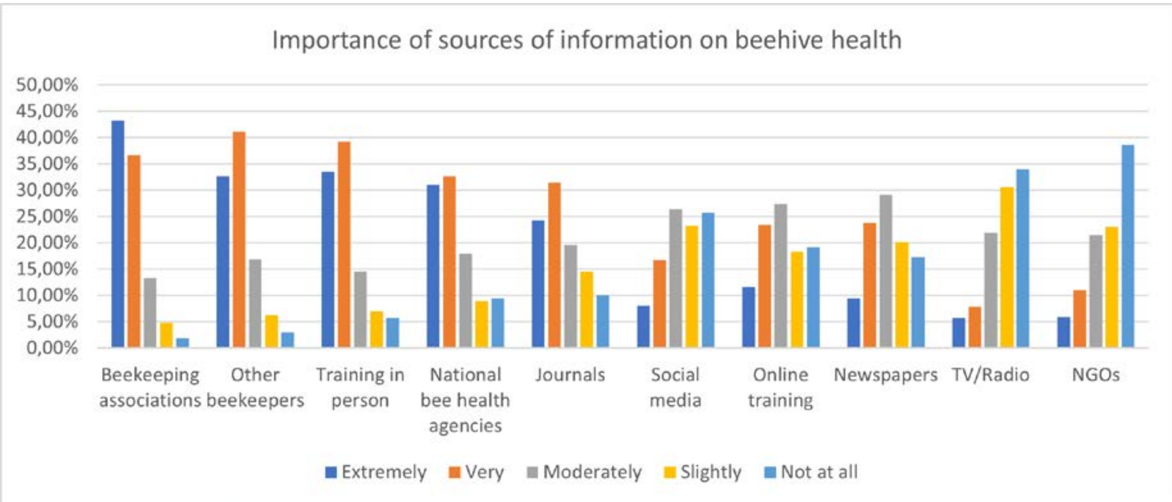

Figure 3: Importance of different information sources for beekeepers

Similarly, almost all beekeepers surveyed agreed that monitoring diseases, parasites, nutrition and agrochemical exposure were important measures to mitigate bee declines (Appendix 7). However, the survey also found that beekeepers check for disease and nutritional issues more often than they check for parasite and chemical stressors (Figure 4), despite being relatively equally concerned about these stressors. In particular, very few beekeepers checked for agrochemicals.

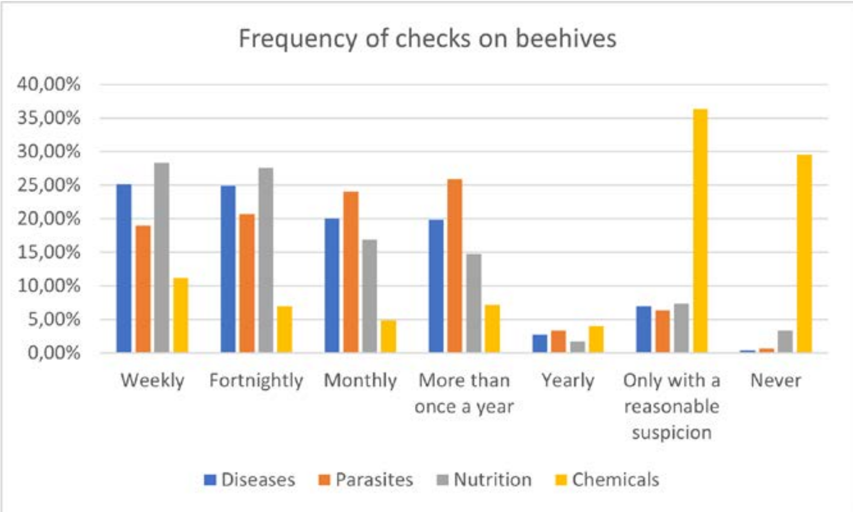

Figure 4: frequency of bee heath checks for different pressures

<u>Perceived effectiveness benefits and barriers in the BHC</u>

From the description provided, just under 40% of beekeepers were confident or very confident in the effectiveness of the proposed BHC in detecting health issues. However, ~43% were moderately confident in its effectiveness while nearly 27% were slightly or not at all confident.

Beekeepers identified a number of prospective benefits in using the health card tool, in particular that it could improve communication with growers, increase productivity and was seen as quick and easy to use (Figure 5). However, many gave "neutral" answers, neither agreeing of disagreeing with the possible benefit, likely because the technology was only described hypothetically rather than actively demonstrated to them.

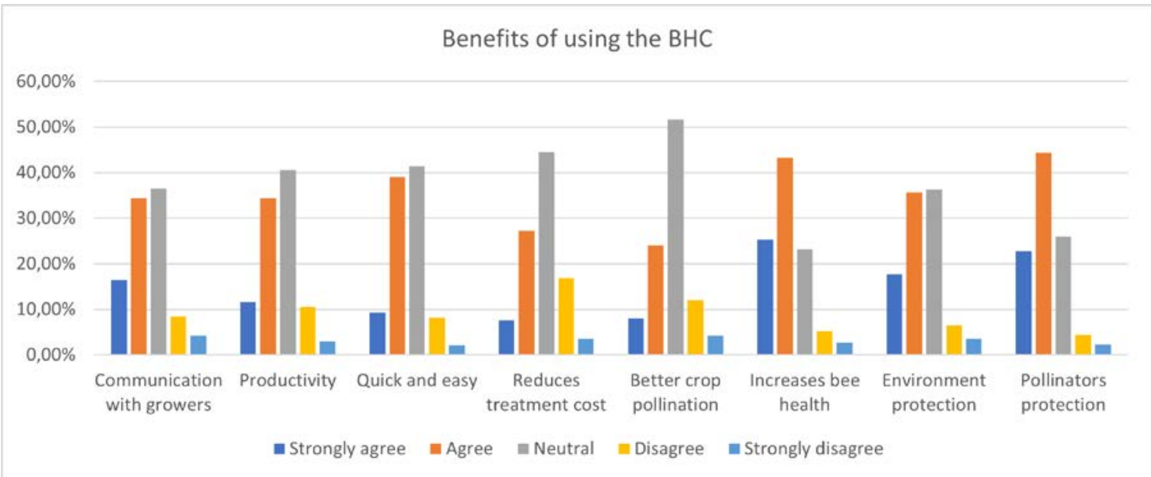

Figure 5: Percentages of respondents agreeing/disagreeing with factors being benefits of using the PoshBee health card tool.

In terms of barriers to using the BHC, a high proportion of respondents agreed or strongly agreed that a lack of communication with growers and costs would be barriers to their use of the tool (Figure 6). Perceived costs were a particularly widely perceived barrier for beekeepers from the UK, Ireland, Estonia, and Switzerland (Appendix 8), while 'lack of communication with growers' was perceived most by beekeepers from Italy and Spain. By contrast, respondents were largely neutral on barriers relating to non-cost barriers in using the tool (effectiveness, time consuming, difficulty and not important)

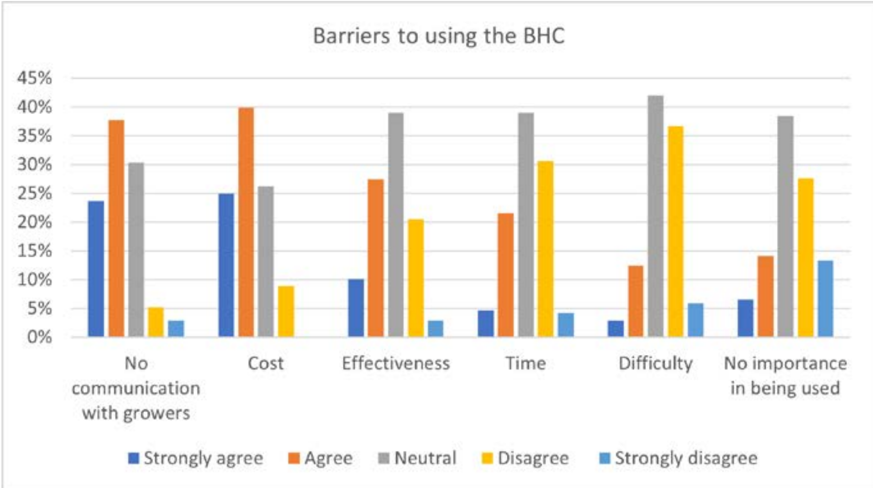

Figure 6: Percentages of total respondents agreeing/disagreeing with factors being barriers to using the PoshBee health card tool.

Willingness to use the tool

Economic incentives and the absence of costs both had substantial effects on the proportion of the sample that were willing to use the tool, with nearly 90% of the sample expressing a willingness to use the BHC, as described in the infographic, if economic incentives were available and no extra costs were involved (Table 5). Across all countries, the presence of extra costs had a substantially greater impact on willingness to adopt the BHC than the availability of economic incentives (described to participants as "subsidies, grants, certified products, etc.").

On a country-specific level, willingness to use the BHC was substantially lower in Germany and Switzerland compared with other countries, with as many as 33.3% of German respondents being unwilling to use the tool if no economic incentives were provided, regardless of the extra costs. By contrast, Estonian respondents were the most willing to use the tool overall without costs, with as many as 96.9% of respondents expressing willingness to the tool with economic incentives and no additional costs. However, they were also the most sensitive to costs and had the lowest willingness to use the tool if extra costs were involved and no economic incentives were to be provided.

Table 5: Country specific willingness to use the bee health card tool under different costs.

Use with economic incentives	**IRE**	**GBR**	**ESP**	**ITA**	**DEU**	**CHE**	**EST**	**Total**
Yes - even with extra costs	49.8%	47.78	55.0%	54.6%	48.5%	40.4%	40.6%	48.5%
Yes - only if there were no extra costs to me	43.8%	42.7%	35.0%	39.4%	24.2%	40.4%	56.2%	41.1%
No	7.0%	9.6%	10.0%	6.1%	27.3%	19.2%	3.1%	10.3%
Use without economic incentives	**IRE**	**GBR**	**ESP**	**ITA**	**DEU**	**CHE**	**EST**	**Total**
Yes - even with extra costs	49.6%	46.3%	55.0%	45.4%	45.4%	46.2%	34.4%	46.9%
Yes - only if there were no extra costs to me	40.9%	42.6%	35.0%	42.4%	21.2%	38.5%	56.2%	40.5%
No	9.6%	11.0%	10.0%	12.1%	33.3%	15.4%	9.4%	12.7%

If respondents were willing to use the tool, they were then asked how often they would use the tool. Most respondents indicated that they would only use the bee health card irregularly (a few times a year) (Table 6). However, the presence of economic incentives substantially increased the proportion of respondents that would use the BHC on a regular basis.

Table 6: Proportion of beekeepers who would use the PoshBee health card at different regularity with/without economic incentives.

Use frequency of the BHC		IRE	GBR	ESP	ITA	DEU	CHE	EST	Total
With incentives	Regularly	27.10%	19.67%	13.89%	40.98%	20.83%	23.81%	12.90%	24.11%
	Irregularly	50.47%	51.64%	69.44%	40.98%	54.17%	45.24%	41.94%	50.12%
	Suspicion only	22.43%	27.87%	13.89%	18.03%	25.00%	30.95%	41.94%	25.06%
	Never	0.00%	0.82%	2.78%	0.00%	0.00%	0.00%	3.23%	0.71%
Without incentives	Regularly	15.38%	7.50%	11.11%	15.79%	13.64%	18.18%	10.34%	12.62%
	Irregularly	45.19%	50.83%	50.00%	47.37%	54.55%	31.82%	27.59%	45.39%
	Suspicion only	37.50%	40.00%	33.33%	35.09%	31.82%	50.00%	58.62%	40.05%
	Never	1.92%	1.67%	5.56%	1.75%	0.00%	0.00%	3.45%	1.94%

Statistical analysis

Bayesian Binomial Logistic Regression analyses were used to determine the significance of factors affecting willingness to use the tool under different conditions (Tables 7-10, full models in Appendix 9). Regardless of incentives or costs, the willingness to use the tool consistently increased with greater confidence in the effectiveness of the tool and with perceiving fewer non-cost barriers (a cluster variable combining the responses to "Tool is not important + not effective + difficult to use + time-consuming"). The perception of costs as a barrier only had a significant impact on the willingness to use the BHC if additional costs were involved, and no incentives were to be provided (i.e. when beekeepers were expect to pay the costs themselves). If the tool was available without costs and economic incentives were provided, then the perception of benefits to honey production also significantly increased the willingness to use the tool. However, if no economic incentives were provided, willingness to use the tool was also significantly influenced by the perception of easy environmental benefits (a cluster variable combining the responses to "Tool quick and easy to use + environment protection + pollinators protection").

Table 7: Final model investigating the willingness to use the BHC with economic incentives.

Willingness to use the BHC tool with economic incentives and no extra costs			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	19.72	2	<0.001
Productivity as benefit	11.79	2	0.003
Non-Cost barriers	11.26	2	0.004
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	5.64	5	0.343
Model summary	**R^2**	**BIC**	**BIC global model**
	22.21	288.28	325.38

Table 8: Final model investigating the willingness to use the BHC without economic incentives.

Willingness to use the BHC tool without economic incentives and no extra costs			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	18.46	2	<0.001
Non-cost barriers	7.13	2	0.028
Easy environmental benefits	15.95	2	<0.001
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	0.59	2	0.965
Model summary	**R^2**	**BIC**	**BIC global model**
	24.80	313.92	373.76

Table 9: Final model investigating the willingness use the BHC with extra costs and economic incentives.

Willingness to use the BHC tool with additional costs and with economic incentives

Terms	**χ²**	**df**	**p-value**
Confidence level in effectiveness	19.47	2	**<0.001**
Non-cost barriers	25.81	2	**<0.001**
Goodness-of-fit	**χ²**	**df**	**p-value**
Hosmer-Lemeshow test	1.37	2	0.503
Model summary	**R^2**	**BIC**	**BIC global model**
	10.99	615.39	676.64

Table 10: Final model investigating the willingness to use the BHC with extra costs and without economic incentives**.**

Willingness to use the BHC tool with additional costs and without economic incentives

Terms	**χ²**	**df**	**p-value**
Confidence level in effectiveness	15.11	2	**0.001**
Cost as barrier	8.37	2	**0.015**
Non-cost barriers	14.03	2	**0.001**
Goodness-of-fit	**χ²**	**df**	**p-value**
Hosmer-Lemeshow test	3.39	5	0.640
Model summary	**R^2**	**BIC**	**BIC global model**
	10.33	630.62	678.82

When evaluating frequency of use, higher perceived effectiveness and not perceiving costs as a barrier to using the BHC were the only factors found to significantly increase the frequency at which beekeepers would use the tool (Tables 11 and 12), regardless of whether or not economic incentives were provided.

Table 11: Final model investigating the BHC use frequency with economic incentives.

Frequency of use of the BHC with economic incentives

Terms	**χ²**	**df**	**p-value**
Confidence level in effectiveness	20.81	2	**<0.001**
Cost as barrier	6.53	2	**0.038**
Goodness-of-fit	**χ²**	**df**	**p-value**
Hosmer-Lemeshow test	2.52	2	0.283
Model summary	**R^2**	**BIC**	**BIC global model**
	6.60	481.11	537.33

Table 12: Final model investigating the BHC use frequency without economic incentives.

Frequency of use of the BCH without economic incentives

Terms	**χ²**	**df**	**p-value**
Confidence level in effectiveness	23.42	2	**<0.001**
Cost as barrier	13.54	2	**0.001**
Goodness-of-fit	**χ²**	**df**	**p-value**
Hosmer-Lemeshow test	1.01	3	0.798
Model summary	**R^2**	**BIC**	**BIC global model**
	7.92	546.23	609.53

4.2. The costs of using and managing the tool

The costs of using the BHC ranged from €33.83 (Spain) to €45.66 (Germany) with much of the costs being associated with lab and staff costs (Table 13). However, in some countries, even assuming half the standard rate, postage was a significant expense. In addition to these costs per use, the re-usable materials amounted to €4.33/beekeeper and costs were between €29,419-€61,300/year for an administrator (assuming one administrator per country). In total, if beekeepers were only expected to pay for their sampling materials and postage, the costs would be approximately €11.05-22.59, which is in line with the estimated costs (<€25) stated in the survey infographic.

Table 13: Costs of using the BHC tool per use (assuming 10 samples/use)

Cost type	Cost/use
Beekeeper consumable costs per use	€2.24
Postage costs	€4.48-€16.02
Lab consumable costs per use	€15.54
Staff costs per use	€6.69-€14.97
Data storage per use (~2.5MB)	€0.001
Total costs/use	**€33.83 (ESP) – €45.66 (DEU)**

Extrapolating these costs to national scales, based on high (monetary incentives and no extra costs) and low (extra costs to the beekeeper and no economic incentives) adoption rates, total annual costs range from €4.2M (Germany, high adoption rates – Table 14) to €92,000 (Estonia, low adoption rates – Table 15). In the high adoption rates scenario, where the BHC is provided without additional costs to the growers, this cost will have to be entirely covered by national authorities, alongside any economic incentives. In the low adoption rates scenario, this cost would have to be paid by the users at ~€41-78 per user.

Table 14: Total national running costs of the BHC under high rates of adoption

Country	Beekeepers	Adoption rate	Samples /year	BK fixed costs (€,000)	BK variable costs (€,000)	Postage costs (€,000)	Analytical costs (€,000)	Admin costs (€,000)	Total costs (€,000)
CHE	18,150	81%	146,652	€ 36	€ 19	€ 91	€ 256	€ 41	€ 443
DEU	116,000	73%	843,320	€ 226	€ 118	€ 843	€ 1,443	€ 61	€ 2,692
ESP	28,786	90%	259,074	€ 68	€ 35	€ 148	€ 352	€ 49	€ 653
EST	5,215	97%	50,481	€ 8	€ 4	€ 23	€ 45	€ 29	€ 110
GBR	39,475	90%	357,173	€ 79	€ 41	€ 82	€ 558	€ 41	€ 799
IRE	3,300	94%	30,888	€ 7	€ 4	€ 21	€ 43	€ 53	€ 128
ITA	56,059	94%	526,955	€ 109	€ 57	€ 259	€ 685	€ 59	€ 1,169

Beekeepers = Number of beekeepers, Adoption rate = rate of adoption among beekeepers when the BHC is provided with economic incentives and with no extra costs. Samples/year = the number of samples to be process, assuming each user sends in 10 samples (figures rounded to the nearest 10). BK Fixed costs = the cost of reusable materials each beekeeper must use. BK variable costs = the costs of materials that are consumed with each use of the health card. Postage costs = the costs of postage using half standard international carrier rates. Analytical costs = the costs associated with lab work per sample analyzed. Admin costs = the salary of an administrator.

Table 15: Total national running costs of the BHC under low rates of adoption

Country	Beekeepers	Adoption rate	Samples/ year	BK fixed costs (€,000)	BK variable costs (€,000)	Postage costs (€,000)	Analytical costs (€,000)	Admin costs (€,000)	Total costs (€,000)
CHE	18,150	46%	146,650	€ 36	€ 19	€ 91	€ 130	€ 41	€ 317
DEU	116,000	45%	843,320	€ 226	€ 118	€ 843	€ 818	€ 61	€ 2,067
ESP	28,786	55%	259,070	€ 68	€ 35	€ 148	€ 246	€ 49	€ 547
EST	5,215	34%	50,480	€ 8	€ 4	€ 23	€ 28	€ 29	€ 92
GBR	39,475	46%	357,170	€ 79	€ 41	€ 82	€ 284	€ 41	€ 526
IRE	3,300	50%	30,890	€ 7	€ 4	€ 21	€ 25	€ 53	€ 110
ITA	56,059	45%	526,960	€ 109	€ 57	€ 259	€ 395	€ 59	€ 880

Beekeepers = Number of beekeepers, Adoption rate = rate of adoption among beekeepers when the BHC is provided with no economic incentives and with extra costs. Samples/year = the number of samples to be process, assuming each user sends in 10 samples (figures rounded to the nearest 10). BK Fixed costs = the cost of reusable materials each beekeeper must use. BK variable costs = the costs of materials that are consumed with each use of the health card. Postage costs = the costs of postage using half standard international carrier rates. Analytical costs = the costs associated with lab work per sample analyzed. Admin costs = the salary of an administrator.

4.3. Impacts on bee health

4.3.1. Impacts on the costs of bee health management

Estimated costs of managing for diseases and other stressors in colonies ranged from €17-€34, with an average cost of €23.81 (Table 16). These costs do not include the costs of replacing the entirety of a colony or of replacing frames due to notifiable diseases, which are considerably higher (Breeze et al., 2017; Eleanor Attridge pers. comm.; Peter Kosmus pers. comm.). Assuming a hypothetical 20% reduction in beekeeper health costs due to the health card tool, this would amount to a saving of ~€4.76 per colony.

Table 16: Costs of bee health management

Country	Costs/hive	Year	Source
GBR	€ 25.73	2014	Breeze et al., (2017)
ITA	€ 34.00	2015-2017	Mancuso et al (2020)
IRE	€ 18.50	2021	Eleanor Attridge, pers comm
SVN	€ 17.00	2021	Peter Kosmus, pers comm
Average	**€ 23.81**		

4.3.2. Impacts on national colony mortality

Using a hypothetical 50% increase in the survival of colonies using the BHC, the number of additional colonies surviving the winter at a national scale was assessed for both high and low levels of adoption using three different effectiveness frontiers: linear (where use is directly proportionate to the increase in survival), pessimistic (where the BHC is less effective if it is not widely taken up) and optimistic (where the BHC is highly effective, even at low use).

The projections highlight the importance of understanding the relationship between uptake and effectiveness, with additional colony survival from the BHC ranging from 6% in the pessimistic, low adoption, (Table 17) to near the maximum 50% in the optimistic, high adoption scenario (Table 19). Most notably, the shape of relationship between adoption rates and increased survival has a substantial impact in Germany and Switzerland, where high adoption rate is lower (73% and 81% respectively) than other countries (≥90%). Here, the shape of the relationship results in a 20% and 15% difference in survival increase respectively.

Table 17: Projected impacts on winter colony losses under a pessimistic efficiency frontier

						% Increase in survival		Extra colonies surviving	
Country	Total colonies	Winter loss %	Losses (status Quo)	Adoption (high)	Adoption (low)	High Ad	Low Ad	High Ad	Low Ad
CHE	179,473	7.40%	13,281	81%	46%	33%	11%	4335	1417
DEU	771,850	11.60%	89,535	73%	45%	26%	10%	23661	9227
ESP	2,901,680	17.60%	510,696	90%	55%	41%	15%	206832	77243
EST	48,720	8.30%	4,044	97%	34%	47%	6%	1895	239
GBR	255,000	5.40%	13,770	90%	46%	41%	11%	5636	1476
IRE	22278	3.90%	869	94%	50%	44%	12%	381	107
ITA	423,144	8.80%	37,237	94%	45%	44%	10%	16451	3838

Total colonies = Total estimated colony numbers from FAOSTAT, 2022, NBU, 2022 (GBR) and EC, 2021d (IRE). Winter losses = % winter colony losses as reported in Gray et al., 2020. Losses (status quo) = number of colonies projected to be lost with no intervention. Adoption (high) = the rate of adoption among beekeepers when the BHC is provided with economic incentives and with no extra costs, Adoption (low) = the rate of adoption among beekeepers when the BHC is provided with no economic incentives and with extra costs. % increase in survival = the % reduction in colony losses due to the BHC, based on a maximum 50% with total adoption. Extra colonies surviving = the number of colonies that survive due to the BHC.

Table 18: Projected impacts on winter colony losses under a linear efficiency frontier

						% Increase in survival		Extra colonies surviving	
Country	Total colonies	Winter loss %	Losses (status Quo)	Adoption (high)	Adoption (low)	High Ad	Low Ad	High Ad	Low Ad
CHE	179,473	7.40%	13,281	81%	46%	81%	46%	10731	6136
DEU	771,850	11.60%	89,535	73%	45%	73%	45%	65092	40649
ESP	2,901,680	17.60%	510,696	90%	55%	90%	55%	459626	280883
EST	48,720	8.30%	4,044	97%	34%	97%	34%	3914	1391
GBR	255,000	5.40%	13,770	90%	46%	90%	46%	12459	6376
IRE	22278	3.90%	869	94%	50%	94%	50%	813	431
ITA	423,144	8.80%	37,237	94%	45%	94%	45%	35002	16905

Total colonies = Total estimated colony numbers from FAOSTAT, 2022, NBU, 2022 (GBR) and EC, 2021d (IRE). Winter losses = % winter colony losses as reported in Gray et al., 2020. Losses (status quo) = number of colonies projected to be lost with no intervention. Adoption (high) = the rate of adoption among beekeepers when the BHC is provided with economic incentives and with no extra costs, Adoption (low) = the rate of adoption among beekeepers when the BHC is provided with no economic incentives and with extra costs. % increase in survival = the % reduction in colony losses due to the BHC, based on a maximum 50% with total adoption. Extra colonies surviving = the number of colonies that survive due to the BHC.

Table 19: Projected impacts on winter colony losses under an optimistic efficiency frontier

Country	Total colonies	Winter loss %	Losses (status Quo)	Adoption (high)	Adoption (low)	% Increase in survival: High Ad	% Increase in survival: Low Ad	Number of colonies surviving: High Ad	Number of colonies surviving: Low Ad
CHE	179,473	7.40%	13,281	81%	46%	48%	36%	6396	4718
DEU	771,850	11.60%	89,535	73%	45%	46%	35%	41431	31421
ESP	2,901,680	17.60%	510,696	90%	55%	50%	40%	252794	203640
EST	48,720	8.30%	4,044	97%	34%	50%	28%	2020	1152
GBR	255,000	5.40%	13,770	90%	46%	50%	36%	6823	4900
IRE	22278	3.90%	869	94%	50%	50%	37%	433	324
ITA	423,144	8.80%	37,237	94%	45%	50%	35%	18551	13068

Total colonies = Total estimated colony numbers from FAOSTAT, 2022, NBU, 2022 (GBR) and EC, 2021d (IRE). Winter losses = % winter colony losses as reported in Gray et al., 2020. Losses (status quo) = number of colonies projected to be lost with no intervention. Adoption (high) = the rate of adoption among beekeepers when the BHC is provided with economic incentives and with no extra costs, Adoption (low) = the rate of adoption among beekeepers when the BHC is provided with no economic incentives and with extra costs. % increase in survival = the % reduction in colony losses due to the BHC, based on a maximum 50% with total adoption. Extra colonies surviving = the number of colonies that survive due to the BHC

4.4. Impacts on wider societal benefits

4.4.1. Impact on honey and beeswax production

Assuming a hypothetical increase of 10% of honey output using the BHC, the total benefits to overall honey production range from ~€30,000 (Ireland, low adoption) to as high as €16M (Germany, high adoption) (Table 20). This equates to ~€5-56/colony, however these estimates assume that all colonies supply to the market whereas the true proportion is presently unknown.

Table 20: Projected impacts of BHC on honey production

Country	Colonies	Honey (Baseline): Value (1000 €)	Honey (Baseline): Qty (t)	Adoption: High	Adoption: Low	Honey gain (high): Value (1000 €)	Honey gain (high): Qty (t)	Honey gain (low): Value (1000 €)	Honey gain (low): Qty (t)	Honey gain/hive
CHE	179,473	€ 62,280	3761	81%	46%	€ 10,064	608	€ 2,877	174	€ 56.08
DEU	771,850	€ 232,870	21600	73%	45%	€ 33,859	3141	€ 10,572	490	€ 43.87
ESP	2,901,680	€ 126,039	31696	90%	55%	€ 22,687	5705	€ 6,932	872	€ 7.82
EST	48,720	€ 8,268	1184	97%	34%	€ 1,601	229	€ 284	20	€ 32.86
GBR	255,000	€ 72,517	8944	90%	46%	€ 13,123	1619	€ 3,358	207	€ 51.46
IRE	22,278	€ 605	267	94%	50%	€ 113	50	€ 30	7	€ 5.08
ITA	423,144	€ 25,095	9603	94%	45%	€ 4,718	1805	€ 1,139	218	€ 11.15

Colonies = number of colonies, honey (baseline) = the total value (€1000) and production volume (tonnes) from FAOSTAT (2022). Adoption (high) = the rate of adoption among beekeepers when the BHC is provided with economic incentives and with no extra costs, Adoption (low) = the rate of adoption among beekeepers when the BHC is provided with no economic incentives and with extra costs. % increase in survival = the % reduction in colony losses due to the BHC, based on a maximum 50% with total adoption. Honey gain = the total additional quantity of honey (in 1000 € and tonnes) assuming a 10% increase in hives using the BHC. Honey gain/hive = the value of additional production resulting from tool adoption.

4.4.2. Impact on honeybee supply capacity

The projected national scale reductions in colony mortality have, in most countries, only a minimal effect on the capacity of honey bees to supply pollination services (Table 21). The greatest difference would be in Switzerland where colonies already greatly exceed the demand for pollination services. However, in Spain this difference, under a high rate of adoption is equivalent to ~8% of the pollination service capacity of the country, one of Europe's largest producers of insect pollinated crops. It is important to note that, lacking a large US style market for honey bees (Breeze et al., 2019) and given the relatively minor role that honey bees play as pollinators in many (but not all) European crop systems, these benefits represent more of a contribution to the resilience of European farming systems rather than an annual contribution to pollination.

Table 21: Impacts of BHC adoption on honeybee pollination service supply capacity

	CHE	DEU	ESP	EST	GBR	IRE	ITA
Colonies	179,473	771,850	2,901,680	48,720	255,000	22,278	423,144
% winter losses	7.4%	11.6%	17.6%	8.3%	5.4%	3.9%	8.8%
Number of Losses	13,281	89,535	510,696	4,044	13,770	869	37,237
Losses prevented (High)	10,731	65,092	459,626	3,914	12,459	813	35,002
Losses prevented (Low)	6,136	40,649	280,883	1,391	6,376	431	16,905
Pollinated crop area	39,624	1,368,177	2,386,015	120,797	728,835	22,514	1,068,274
Honeybee demand	116,454	4,062,616	8,683,766	394,632	2,311,434	76,703	2,892,239
Maximum Capacity	308%	38%	67%	25%	22%	58%	29%
Capacity inc. Losses	291%	35%	58%	23%	21%	56%	27%
Difference (max -losses)	-17%	-3%	-9%	-2%	-1%	-2%	-2%
Capacity + Tool (High)	305%	37%	66%	25%	22%	58%	29%
Capacity + Tool (Low)	299%	36%	63%	24%	22%	57%	28%
Difference (High)	14%	2%	8%	1%	1%	2%	2%
Difference (Low)	8%	2%	5%	1%	0%	1%	1%

Colonies = number of colonies. % winter losses = the % of colonies lost each winter from Gray et al (2020). Number of losses = the number of colonies lost in the winter. Losses prevented = the number of colonies that survive the winter due to the BHC under High or Low rates of adoption, assuming a linear relationship between BHC use and colony survival, to a maximum 50% (table x). Pollinated crop area = the area of all animal pollinated crops in each country for which honeybees are suitable pollinators. Honeybee demand = the number of honeybee colonies required to pollinate the area of pollinated crops. Maximum capacity = the maximum capacity of honeybee populations to provide pollination services in each country, assuming all colonies are at full strength and are used to pollinated 2 ha of crops each throughout the year. Capacity inc. losses = the capacity of honeybees to supply pollination services assuming that new colonies to replace those lost in the winter are only 25% as effective as a full-strength colony. Difference (max – loss) = the difference in supply capacity between the maximum capacity and the capacity including losses. Capacity + Tool = the total supply capacity if the tool is used, under high and low adoption rates. Difference (high/low) = the difference between the capacity in. losses and the capacity + tool.

5. Discussion

This deliverable outlines a framework for assessing the incentives and barriers, as well as the costs and benefits of tools for improving bee health. This framework is tested using the PoshBee Bee Health Card (BHC) tool as an example.

5.1. Key barriers and incentives towards tool adoption

We undertook a survey of beekeepers across seven countries to examine barriers and incentives to the adoption of the BHC tool. In the surveys, beekeepers self-identified the costs of using the BHC and communication with growers as major barriers to using the tool. By contrast, while costs had a significant impact on uptake rates, the presence of incentives only effected the regularity of its use. The negative impact of costs is expected since beekeeping is an already costly activity for both hobbyists and professionals (Breeze et al., 2017; 2019; Gray et al., 2019) and aligns with similar cost-based barriers observed in wider literature on farmer adoption of novel farming tools (*e.g.* Barnes et al., 2019; Vecchio et al., 2020).

Communications with growers were also identified as a concern by beekeepers in a previous multi-national survey of beekeepers by Breeze et al (2019), with many expressing concerns about exposure to agrochemicals as a result of limited contact with local growers. Furthermore, this study also highlighted that many farmers wanted increased communication with beekeepers, in order to improve crop pollination supplies. However, although improving communication between these actors could help overcome this barrier, the use of the BHC tool may in turn result in potentially disruptive trust issues (Suryanarayanan et al., 2018), especially if agrochemical use cannot be tied to specific farmers. Furthermore, the barrier was not found to have a statistically significant impact on willingness to adopt the tool, indicating that it was more of a general concern among respondents than a factor that actually influenced their willingness to use the tool.

Other non-cost related barriers, related to the perception of the tool as being unimportant, ineffective, difficult and/or time consuming to use, collectively had a more significant effect on willingness to adopt the tool than communication issues with growers. By contrast, the most significant factor incentivizing use of the BHC was the strength of respondent perception in its effectiveness. This is consistent with wider research on farmer adoption of novel technologies where tools are more likely to be adopted if they are seen as easy and quick to use (*e.g.* Reichardt & Jürgens, 2009; Aubert et al., 2012; Vecchio et al., 2020). However, a large portion of the sample expressed only moderate confidence in the effectiveness of the tool, likely due to the limited available description and lack of working prototype. Collectively, these findings indicate that while there was a good baseline willingness to use the tool, that demonstrating and successfully communicating its effectiveness will be key to mass adoption. Based on the survey findings, beekeepers' organizations would be the most effective means to engage beekeepers with the BHC and other tools, e.g., by directly demonstrating the tool to organizations that can demonstrate its effectiveness to members (Caffaro et al., 2020).

Finally, the survey identified two perceived benefits as having significant influence on beekeeper willingness to adopt the tool. Perceived benefit to honey productivity was important when the tool was provided with no costs and with economic incentives, while easy environmental benefits (a cluster combining the benefits "Tool quick and easy to use + environment protection + pollinators protection") was an important benefit when the tool was provided at no costs but with no incentives. These results indicate a difference in the response of different beekeepers to economic incentives depending on whether they are more production focused or more environmentally conscious. Understanding the distribution of such motivational attitudes within the beekeeping community could therefore play a key role in tailoring engagement with the tool (Kahane et al., in press).

5.2. Impacts of tool adoption

The latter parts of the framework employ a range of different methods to quantify the effects of widespread adoption of the BHC. The results indicate that the costs of the tool are mainly driven by the staff costs in analysing the data and the costs of posting samples. The issue of postage costs could be resolved with specialist contracts and is likely to decrease in relative costs if more samples were posted each time. However, staff costs are likely to remain a substantial issue, due to the need for specialists to analyse the data. If adopted at the rates observed in the study, the total costs of the widespread adoption of the tool are potentially quite high for countries such as Italy and Germany with large beekeeping communities, running into several million € and costing €33-€78/hive. This is significantly in excess of most budgets for beekeeping (Majewski et al., 2017; EC, 2021a-e) and as such is likely to require beekeepers to pay for part of the costs themselves, reducing adoption rates. Furthermore, these costs are likely to be similar or greater than the current expenditure on bee health, meaning that even significant savings in these costs are unlikely to compensate for the costs of using the tool. It should be emphasized, however, that the cost estimates of bee health management are based on very limited available evidence and represent averages with wide variances to them.

The real value of the BHC is likely to be in its capacity to reduce colony mortality and improving honey productivity. The costs of replacing colonies are likely to greatly exceed the costs of using the tool (Breeze et al., 2017; Eleanor Attridge, pers comm), although, as with other aspects of bee health costs, this is poorly studied. Maximizing this benefit will require the BHC to be part of a comprehensive system that can support effective health management even at middling tool uptake, especially if the tool is to be provided at cost. Furthermore, although the analysis presented in this deliverable shows a high variance in the value of honey per hive, this is likely to be misleading as many beekeepers do not produce honey for commercial markets and in some countries, potentially deflating the estimated value of honey per hive, in line with the estimates in the National Apicultural Plans of the five EU member states in the survey (EC, 2021a-e). Finally, the impacts of the BHC tool on the pollination service capacity of national honeybee stocks are likely to be negligible in many countries where winter losses are relatively small (e.g. UK, Gray et al., 2020) and/or demand for pollination services is limited (e.g. Ireland). The only country where this may be a significant factor is Spain, which has both a high area of pollinated crops and large stocks of honeybees.

5.3. Refining the framework

The framework presented in this deliverable is an early guideline, designed to illustrate the potential scope of widespread adoption of health tools. Several steps of the framework can be improved through improved baseline data on the effectiveness of the tool and better input data.

Beekeepers' willingness to use the tool: A major challenge in testing the framework was the lack of a fully costed prototype during the survey. In reality, the total costs of using the tool are likely to be higher than the €25 stated in the survey (Table 13). However, if beekeepers were to be expected to pay just for the sampling kits and postage then the true costs would likely be lower than this (€11.1-€22.5). Similarly, incentives were not explicitly identified and it is possible that different beekeepers would react to different economic incentives (e.g. certification schemes are unlikely to be of interest to hobbyist beekeepers). Such information could be integrated into more standard economic survey methods such as choice experiments (e.g. Cosmina et al., 2016), in order to examine how changing costs and/or incentive levels directly affect respondent willingness to use the tool.

Costs of managing the tool: The costs used in this study are based on initial estimates rather than those of a properly scaled operation where better division of labor and economies of scale could greatly reduce the relative costs per use of the tool. In particular, the labor costs of using the tool could be greatly reduced with robotics which could increase sample processing by up to 50% per day. However, the study also does not estimate the initial set-up costs of any such facilities, such as buildings and equipment, nor on the maintenance of this equipment or the establishment and maintenance of companion apps and advertising. Cost estimates for future tools should therefore account for the scale at which the tool is to be used and budget accordingly.

Benefits to bee health: The impacts on beekeeping explored in this study are largely hypothetical, based on scattered data and unlikely to be comprehensive. Much of this is because of the lack of a tested prototype, which should ideally examine how management advice can affect beekeeper costs and colony mortality through structured experiments in a variety of countries and contexts. However, the study also highlights the impact that limited information on beekeeper costs and outputs can have on planning to support bee health and the urgent need for more detailed socio-economic research into beekeeping at a professional level and as a hobby that has potential environmental impacts (such as Breeze et al., 2017; 2019; Kahane et al., In Press).

Benefits to society: As with the impacts of the tool on beekeeping, field data are necessary to accurately quantify the impact that tool use could have on the production of honey and other hive products. Furthermore, the analysis presented here is limited to only one product (honey) and only the direct production per hive as opposed to the entire value chain associated with it, which can be highly varied between countries (e.g. Cosmina et al., 2016), may be subject to specialist marketing labels (Mădaş et al., 2020) and have a range of applications within the wider food system (Sarkar and Chandra, 2019; Yang et al., 2017) that are not widely explored. A full understanding of how any productivity or quality (including labels - e.g. Cosmina et al., 2016) benefits arising from the use of the tool are transmitted through the food system is crucial to fully capturing the extent of these benefits.

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8. Appendixes

8.1. Appendix 1: Beekeeper Survey

Table A1.1: List of Survey questions and answers

Question N.	Extended question
Q1	How many years have you been practicing beekeeping? • As hobby • As profession
Q2	How many hives have you kept in the last 3 years? Please indicate the average number per year (open answer)
Q3	Why do you practice beekeeping? Please tick all the options that apply. • Awareness of threats to pollinators • Environmental concerns • Personal hobby • Providing paid pollination services to growers • Selling honey, beeswax, pollen, other products • Others (please specify)
Q4_1	Are you a member of any beekeeping associations? • Yes • No
Q4_2	Please name the associations (open answer)
Q5	In a typical year, how often do you undertake a detailed check on your hives for each of the following health issues? • Diseases • Parasites • Nutrition • Chemical exposure
Q6	Please indicate what equipment and methods of hive inspection you use to monitor the issues below. If you do not use any, please skip this question. • Diseases • Parasites • Nutrition • Chemical exposure
Q7	Do you have any regular communication with growers? • Frequent (more than twice a year) • Infrequent (once or twice a year) • I am a grower myself and manage my own hives • I do not communicate with growers
Q8	How important to you are the following sources of information on beehive health? If you like, please also add the source names in the blank spaces below. • Scientific journals • Beekeeping • National bee health agencies • Newspapers • Television/radio • Social media • Online training courses • Training courses in person • Other beekeepers • NGOs • Other (please specify)
Q9	In your opinion, what are the reasons for the decline of bees? • The loss of natural habitats (floral and nesting resources) • The competition between managed and wild pollinators • Diseases • Parasites • Predators • Climate change • Agrochemicals

	• Genetic factors • Non-optimal beekeeping practices
Q10	In your opinion, what are the actions to take to reduce the decline of bees? • Collaborate and exchange information with growers • Choose hives location carefully • Create or manage natural habitats and flower areas • Monitor diseases • Monitor parasites • Monitor nutritional stress • Monitor exposure to agrochemicals • Optimal beekeeping practices
Q11	In your opinion, what are the reasons to protect the health of bees? • Economic (e.g. pollination contracts, income, etc.) • Legal (e.g. national requirements) • The perceptions of the public • The conservation of pollinators • The safety of consumers • The security of food supplies • The growth of different varieties of crops
Q12	If the Bee Health Card tool was commercially available, how confident would you be that it would be effective? • Extremely confident • Very confident • Moderately confident • Slightly confident • Not at all confident
Q13	In your opinion, what could be the barriers to using the Bee Health Card tool? • Poor communication with growers • The cost of it • I am not sure it is effective • It seems time-consuming • It seems difficult to use • I am not aware of the importance of using it
Q14	In your opinion, what could be the benefits to you to using the Bee Health Card tool? • Better communication with growers • It helps increase productivity • It seems quick and easy to use • It reduces treatment costs • It enhances crop pollination • It increases the health of bee colonies • It helps protect the environment • It helps protect pollinators
Q15	If the Bee Health Card tool was demonstrated to diagnose colony health issues efficiently and improve the colony performance, would you be interested in using it with economic incentives (e.g. subsidies, grants, certified products, etc.)? • Yes, even with extra costs to me • Yes, only if there were no extra costs to me • No
Q16	If the Bee Health Card tool was demonstrated to diagnose colony health issues efficiently and improve the colony performance, would you be interested in using it without economic incentives (i.e. no subsidies, grants, certified products, etc.)? • Yes, even with extra costs to me • Yes, only if there were no extra costs to me • No
Q17	Considering the expected benefits and cost, how many times in a typical year would you use the Bee Health Card tool with economic incentives (e.g. subsidies, grants, certified products, etc.)? • Regularly (at least once a month) • Irregularly (a few times a year) • Only with a reasonable suspicion • Never

Q18	Considering the expected benefits and cost, how many times in a typical year would you use the Bee Health Card tool without economic incentives (i.e. no subsidies, grants, certified products, etc.)? • Regularly (at least once a month) • Irregularly (a few times a year) • Only with a reasonable suspicion • Never
Q19	In your opinion, are there any specific health issues that you would like the Health Card tool to be able to detect in your colonies? (open answer)

8.2. Appendix 2: Survey distribution

Table A2.1: List of organizations that distributed the survey via social media

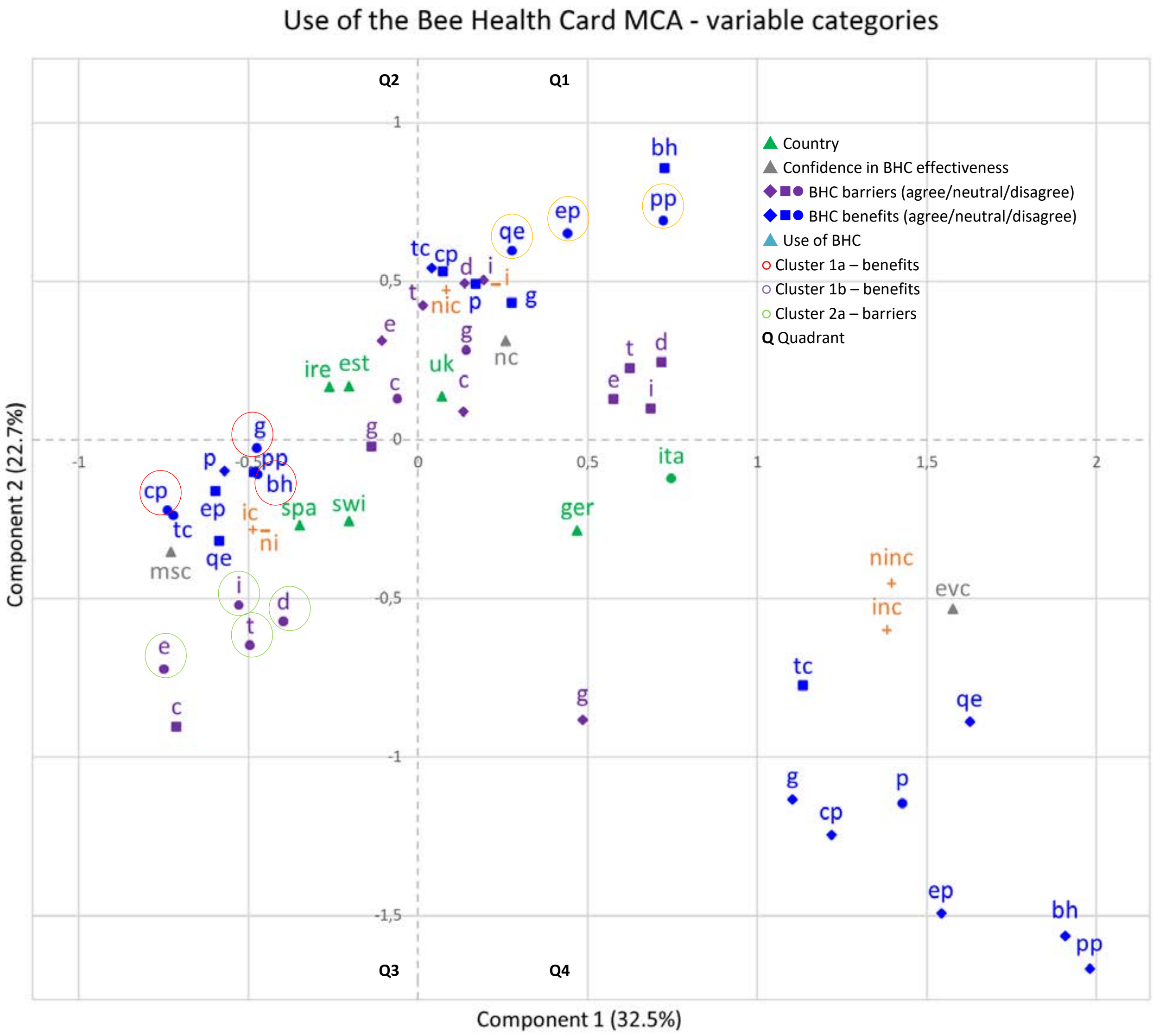
Country	Advertisement channels
Estonia	Local Estonian beekeepers associations
Germany	Local German beekeepers associations
Ireland	'FIBKA' Facebook page and Sept 2020 newsletter
	'NIHBS' Aug 2020 News Update
	'Beekeepers of Ireland' Facebook page
	'Cork Beekeepers' Facebook page
	Twitter account of WP1 leader for Ireland
Italy	'UNAAPI' Facebook page
Spain	Twitter and Facebook accounts of WP1 leader for Spain
	'ADEA-ASAJA' contact list and Twitter account
Switzerland	Local Swiss beekeeping associations
UK	'BBKA' Facebook and Twitter pages, website
	Kent beekeepers involved in WP1
	'Barnsley BKA', circulated to members
	'Mid Bucks BKA' Aug 2020 newsletter
	'Winchester BKA' Aug 2020 newsletter
	'Bee Craft Magazine' Sept 2020 issue
	'Rustley BKA', circulated to members
	Twitter and Facebook accounts of WP1 leader for the UK
Other sources	
Pensoft	PoshBee Twitter, Facebook, website

Reminder sent to WP1 leaders to re-advertise survey: 24.10.2020

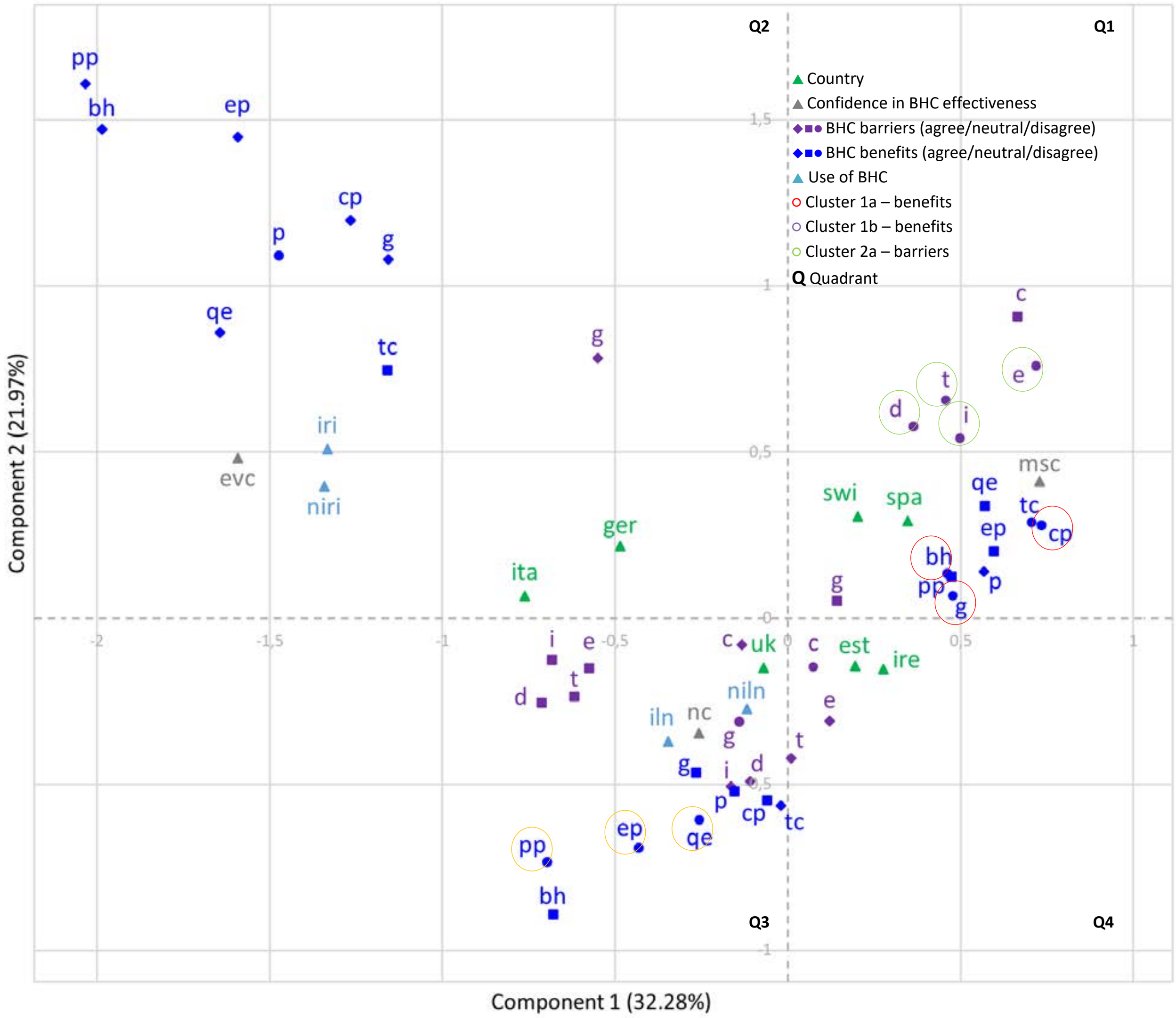
8.3. Appendix 3. MCA codes and maps

Table A3.1: List of Multiple Correspondence Analysis variables and their associated codes

Survey question	Variable	Code on MCA map
Country where respondent practices beekeeping	Estonia	**est**
	Germany	**ger**
	Ireland	**ire**
	Italy	**ita**
	Spain	**spa**
	Switzerland	**swi**
	United kingdom	**uk**
Benefits of the use of the Bee Health Card	Increased bee health	**bh**
	Pollinator protection	**pp**
	Environment protection	**ep**
	Toll is quick and easy to use	**qe**
	Enhanced crop production	**cp**
	Lower treatment cost	**tc**
	Higher productivity	**p**
	Better communication with growers	**g**
Barriers to the use of the Bee Health Card	Tool effectiveness	**e**
	Tool cost	**c**
	Tool is time consuming	**t**
	Tool is difficult to use	**d**
	Tool is not important to be used	**i**
	Lack of communication with growers	**g**
Confidence level in the effectiveness of the BHC	Extremely/very confident	**evc**
	Moderately/slightly confident	**msc**
	Not confident	**nc**
Willingness to use the tool and accept extra costs with and without incentives	Use with no incentives and no extra costs	**ninc**
	Use with incentives and no extra costs	**inc**
	Use with incentives and extra costs	**ic**
	Use with no incentives and extra costs	**nic**
	Use with incentives	**i**
	Use with no incentives	**ni**
Frequency of use of the tool with and without incentives	Regular to irregular use with incentives	**iri**
	Regular to irregular use without incentives	**niri**
	Limited to no use with incentives	**iln**
	Limited to no use without incentives	**niln**


Use of the Bee Health Card MCA - variable categories
Q2
Q1
Q3
Q4
Country
Confidence in BHC effectiveness
BHC barriers (agree/neutral/disagree)
BHC benefits (agree/neutral/disagree)
Use of BHC
Cluster 1a – benefits
Cluster 1b – benefits
Cluster 2a – barriers
Q Quadrant
Component 1 (32.5%)
Component 2 (22.7%)
ire
est
uk
ita
ger
spa
swi
nc
msc
evc
nic
ic
ni
ninc
inc

Use frequency of BHC MCA - variable categories



8.4. Appendix 4: Overview of materials required for the Bee Health Card

Table A4.1: Materials required for haemolymph collection and postage

Item	Quantity/sample	Cost	Cost/Sample	Source
Silicon collector tube	0.8	€ 1.80	€ 1.44	[1]
Filter tip 1000 µL	5	€ 0.15	€ 0.75	[2]
Capillary holder	1	€ 2.00	€ 2.00	[3]
Bee holder	0.06	€ 1.80	€ 0.11	[4]
Total reusable			€ 4.30	
Capilaries (80mm)	0.5	€ 0.08	€ 0.042	[5]
Coated microcentrifuge tubes 1.5 mL	10	€ 0.03	€ 0.293	[6]
Freezer Gel packs	2	€ 0.82	€ 1.64	[7]
Packaging	1	€ 0.27	€ 0.27	[8]
Total Per Use			€ 2.24	
Postage (CHE)	1	€ 21.79	€ 21.79	[9]
Postage (DEU)	1	€ 32.03	€ 32.03	[10]
Postage (ESP)	1	€ 18.74	€ 18.74	[11]
Postage (EST)	1	€ 26.00	€ 26.00	[12]
Postage (GBR)	1	€ 8.95	€ 8.95	[13]
Postage (IRE)	1	€ 25.69	€ 25.69	[14]
Postage (ITA)	1	€ 20.32	€ 20.32	[15]
Average			€ 16.02	

[1] https://www.fishersci.co.uk/shop/products/silicone-tubes-4/10430313#silicon%20tube
[2] https://www.fishersci.co.uk/shop/products/thermo-scientific-art-barrier-reload-insert-pipette-tips-10/12637696#200ul%20tip
[3] https://www.fishersci.co.uk/shop/products/adapter-quiksip-pvc-for-capillaries/10479862#?keyword=Capillary%20pipete
[4] https://www.fishersci.co.uk/shop/products/silicone-tubes-4/10430313#silicon%20tube
[5] https://www.fishersci.co.uk/shop/products/capillary-tube-2/10309901#Capillary
[6] https://www.fishersci.co.uk/shop/products/fisherbrand-premium-microcentrifuge-tubes-1-5ml/11926955#coated%20microcentrifuge%20tubes%201.5ml
[7] https://www.fishersci.co.uk/shop/products/sonoco-thermosafe-polarpack-gel-packs-18/13009342#freezer%20gel%20pack
[8] https://www.amazon.co.uk/Gold-Bubble-Padded-Envelopes-240x320mm/dp/B004K26SO6
[9] https://www.dhl.com/ch-en/home/get-a-quote.html
[10] https://mydhl.express.dhl/de/en/shipment.html#/rate-and-quote#address-details and https://www.tnt.com/express/de_de/site/home/applications/obt.html?respCountry=de&respLang=de&origincountry=DE&navigation=1&destcountry=DE
[11] https://www.tnt.com/express/es_es/site/obtener-presupuesto.html and https://mydhl.express.dhl/es/en/shipment.html#/rate-and-quote
[12] Potts et al (2021) – No international carrier is currently undertaking domestic deliveries
[13] https://direct.tnt.co.uk/quick-quote and https://www.dhl.com/gb-en/home/get-a-quote.html
[14] https://mydhl.express.dhl/ie/en/shipment.html#/rate-and-quote#delivery-options and https://www.tnt.com/express/en_ie/site/get-quote.html
[15] https://www.tnt.com/express/it_it/site/home/Spedisci-ora.html?source=legacy_obt and https://mydhl.express.dhl/it/en/shipment.html#/rate-and-quote#delivery-options

Table A4.2: Consumable materials, time and data required for Lab analysis

Item	Units/sample	Cost/1 unit (l, kg or day)	Unit/sample	Source
Eppendorf tubes (0.5ml)	1	€ 0.10	€ 0.104	[16]
Adapted pippete tips (10µL)	1	€ 0.10	€ 0.099	[17]
Adapted pippete tips (200µL)	1	€ 0.15	€ 0.153	[18]
Adapted pippete tips (1000 µL)	1	€ 0.15	€ 0.151	[19]
Kimwipes® disposable wipers	1	€ 0.04	€ 0.036	[20]
15 mL Falcon tubes	0.5	€ 0.32	€ 0.160	[21]
50 mL Falcon tubes	0.5	€ 0.35	€ 0.176	[22]
MALDI matrix	0.0078125	€ 86.51	€ 0.676	[23]
Total			**€ 1.554**	
Staff days (CHE)	0.005	€ 299.32	€ 1.50	[12]
Staff days (DEU)	0.005	€ 237.27	€ 1.19	[12]
Staff days (EST)	0.005	€ 133.72	€ 0.67	[12]
Staff days (ESP)	0.005	€ 195.65	€ 0.98	[12]
Staff days (GBR)	0.005	€ 299.32	€ 1.50	[12]
Staff days (IRE)	0.005	€ 212.14	€ 1.06	[12]
Staff days (ITA)	0.005	€ 227.51	€ 1.14	[12]
Data storage (1gb) - samples	0.0017	€ 0.02	<€ 0.001	[24]
Data storage (1gb) - calibaration	0.0006	€ 0.02	<€ 0.001	[24]

Additional Lab materials:

- MALDI equipment including the software (acquisition, post-processing), database of reference spectra, and all the devises required for the functionality of the mass spectrometer (Lab. Environment), a kit for sample traceability by barcoding
- General equipment: centrifuge for Eppendorf tubes (refrigerated is better but not mandatory), ice machine to keep sample sin the cold, a refrigerator and a freezer (-20°C being sufficient), a glass developing chamber for TLC adapted to the size of the reusable MALDI plates
- Chemicals: Ultrapure water, acetonitrile, ethanol, methanol, acetone, trifluoracetic acid, phenylmethanesulfonyl fluoride (PMSF, protease inhibitor), phenylthiourea (PTU, inhibitor of

[16] https://www.fishersci.co.uk/shop/products/eppendorf-0-5ml-pcr-tubes/10401203#?keyword=Eppendorf%200.5ml%20tube
[17] https://www.fishersci.co.uk/shop/products/axygen-10-l-microvolume-tips-19/12756749
[18] https://www.fishersci.co.uk/shop/products/art-softfit-l-barrier-hinged-rack-pipette-tips/11585454#200ul%20tip
[19] https://www.fishersci.co.uk/shop/products/thermo-scientific-art-barrier-reload-insert-pipette-tips-10/12637696#200ul%20tip
[20] https://www.fishersci.co.uk/shop/products/kimwipes-delicate-task-wipers-2/13258179#?keyword=Kimwipes%C2%AE
[21] https://www.fishersci.co.uk/shop/products/falcon-15ml-conical-centrifuge-tubes-5/10468502
[22] https://www.fishersci.co.uk/shop/products/falcon-50ml-conical-centrifuge-tubes-2/12716688#Falcon%2050%20mL%20Conical%20Centrifuge%20Tubes
[23] https://www.fishersci.co.uk/shop/products/alpha-cyano-4-hydroxycinnamic-acid-ultrapure-maldi-matrix-thermo-scientific/15410777#?keyword=A-Cyano-4-hydroxycinnamic%20acid
[24] https://cloud.google.com/storage/pricing#europe

melanization), MALDI matrix (4HCCA, A-Cyano-4-hydroxycinnamic acid preferentially), peptide/protein kits for equipment calibration. We developed a specific calibration kit for MALDI BeeTyping®

Table A4.3: Administration costs

Country	Admin cost/year	Notes
CHE	€ 40,642.73	Not included in Potts et al, so costs were assumed to be the same as GBR
DEU	€ 61,300.00	
ESP	€ 48,851.76	
EST	€ 29,419.20	
GBR	€ 40,642.73	
IRE	€ 53,337.00	
ITA	€ 59,263.35	

All costs taken from Potts et al., 2021

8.5. Area of pollinated crops

Table A5.1: Average area of pollinated crops (ha) 2016-2020 and average recommended stocking rates (RSR) from Breeze et al. (2014).

Crop	CHE	DEU	ESP	EST	GBR	IRE	ITA	RSR (av)
Almonds, with shell			656,155				55,540	6.9
Apples	3,767	33,437	30,096	1,359	16,211	704	54,742	3.6
Apricots	736	159	20,389				17,653	4.0
Avocados			13,073					4.5
Beans, dry			9,833	21,642			5,948	3.8
Beans, green	1,244	4,327	8,192		3,420	211	18,369	2.0
Berries nes	25	2,581	722	1,492	1,719	73	2,831	5.8
Blueberries	96	3,010	3,496				287	7.5
Broad beans, horse beans, dry	929	49,680	30,027	13,990	168,518	10,553	58,248	3.8
Buckwheat				4,182				3.5
Cherries	578	5,853	27,428	83	745		29,153	4.2
Cherries, sour		1,922	132				641	4.1
Chestnut			36,841				30,652	1.5
Chillies and peppers, green	21	101	20,776		86		10,434	5.5
Cucumbers and gherkins	96	2,388	7,519	163	104	9	2,060	5.5
Currants	6	2,236	20	458	2,560	34	144	4.5
Fruit, citrus nes			1,182				1,268	1.5
Fruit, fresh nes	1		21,272			632	13,599	3.3
Fruit, pome nes		90	3,253				60	3.3
Fruit, stone nes		565	447				306	3.3
Gooseberries	46	12,596	19	140	270			4.0
Grapefruit (inc. pomelos)			2,232				282	1.5
Kiwi fruit	19		1,599				25,092	8.0
Lemons and limes			45,101				24,284	1.5
Lupins	153	24,860	3,002				1,625	0.7
Melons, other (inc.cantaloupes)	4		19,680				24,173	4.4
Mustard seed		6,101						2.8
Oilseeds nes	117	6,067	23,473	4,387			23	2.8
Oranges			140,749				83,962	1.5
Peaches and nectarines	10	90	79,936				62,600	1.8
Pears	762	2,096	21,321		1,520		29,870	3.4
Persimmons			18,180				2,416	3.3
Plums and sloes	319	4,507	14,875	141	620		11,960	3.3
Poppy seed		5,284	10,900					2.8
Pumpkins, squash and gourds	689	5,471	14,973			43	18,983	3.8
Quinces	10		1,413				53	1.0
Rapeseed	22,290	1,134,680	81,504	71,982	526,800	10,038	14,912	2.9
Raspberries	197	1,033	2,467	155	1,463	22	352	2.0
Safflower seed			6,290					2.8
Seed cotton			63,766					5.0
Sesame seed							183	2.8

Soybeans	1,805	24,360	1,437				293,305	1.4
Strawberries	515	13,703	7,065	626	4,797	186	4,763	8.6
Sunflower seed	5,190	20,980	697,080			10	114,064	2.1
Tangerines, mandarins, clementines, satsumas			107,066				32,555	1.5
Vetches			110,503				7,807	0.7
Watermelons			20,532				13,073	4.5
Grand Total	**1,427**	**43,441**	**54,019**	**3,451**	**47,140**	**1,167**	**29,831**	

As with Breeze et al (2014), tomatoes, eggplants (aubergines), groundnuts (peanuts) and linseed were excluded from analysis. Peppers were used as a proxy for chilies and vetches as a proxy for lupins.

8.6. Appendix 6. National breakdown of professional vs hobbyist beekeepers

Table A6.1: National breakdown of professional vs hobbyist beekeepers (highest % per country: in bold)

Respondents	Estonia	Germany	Ireland	Italy	Spain	Switzerland	UK	Total
Hobbyists	43.75%	**87.88%**	**89.57%**	37.88%	**55.00%**	**82.69%**	**85.29%**	**74.26%**
Professionals	**50.00%**	9.09%	10.43%	**60.61%**	45.00%	11.54%	13.97%	24.05%

8.7. Appendix 7. Data from additional questions

Table A7.1: Number of beehives per year (average of last 3 years) by country

Average number per year	Respondents															
	Estonia		Germany		Ireland		Italy		Spain		Switzerland		UK		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0	0	0.00	1	3.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
1	1	3.13	1	3.03	12	10.43	1	1.52	0	0.00	0	0.00	5	3.68	20	4.22
1.5	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
2	0	0.00	2	6.06	19	16.52	0	0.00	0	0.00	0	0.00	18	13.24	39	8.23
2.5	0	0.00	1	3.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
3	1	3.13	1	3.03	22	19.13	3	4.55	0	0.00	1	1.92	29	21.32	57	12.03
3.5	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
4	1	3.13	1	3.03	9	7.83	2	3.03	0	0.00	2	3.85	17	12.50	32	6.75
5	2	6.25	4	12.12	7	6.09	3	4.55	1	2.50	1	1.92	12	8.82	30	6.33
6	0	0.00	5	15.15	5	4.35	3	4.55	0	0.00	2	3.85	12	8.82	27	5.70
7	0	0.00	1	3.03	5	4.35	1	1.52	1	2.50	1	1.92	2	1.47	11	2.32
8	1	3.13	0	0.00	1	0.87	0	0.00	1	2.50	1	1.92	6	4.41	10	2.11
8,5	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
9	0	0.00	0	0.00	0	0.00	1	1.52	1	2.50	0	0.00	0	0.00	2	0.42
10	4	12.50	2	6.06	9	7.83	3	4.55	3	7.50	7	13.46	9	6.62	37	7.81
11	0	0.00	0	0.00	1	0.87	1	1.52	0	0.00	0	0.00	0	0.00	2	0.42
12	0	0.00	3	9.09	3	2.61	1	1.52	1	2.50	3	5.77	1	0.74	12	2.53
13	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
14	1	3.13	1	3.03	2	1.74	0	0.00	1	2.50	1	1.92	0	0.00	6	1.27
15	0	0.00	3	9.09	3	2.61	3	4.55	5	12.50	1	1.92	1	0.74	16	3.38
16	0	0.00	2	6.06	0	0.00	1	1.52	0	0.00	1	1.92	2	1.47	6	1.27
16.5	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
17	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
17.5	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	1	0.21
18	0	0.00	0	0.00	0	0.00	2	3.03	0	0.00	3	5.77	1	0.74	6	1.27
19	0	0.00	0	0.00	2	1.74	0	0.00	0	0.00	0	0.00	0	0.00	2	0.42
20	0	0.00	1	3.03	3	2.61	3	4.55	1	2.50	7	13.46	4	2.94	19	4.01
22	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	0	0.00	1	0.21
24	0	0.00	1	3.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
25	2	6.25	0	0.00	0	0.00	4	6.06	1	2.50	4	7.69	4	2.94	15	3.16
30	1	3.13	0	0.00	2	1.74	0	0.00	5	12.50	7	13.46	3	2.21	18	3.80
32	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	0	0.00	2	0.42
35	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	3.85	1	0.74	3	0.63
40	0	0.00	1	3.03	2	1.74	1	1.52	2	5.00	2	3.85	1	0.74	9	1.90
45	2	6.25	0	0.00	0	0.00	1	1.52	1	2.50	0	0.00	0	0.00	4	0.84
50	1	3.13	1	3.03	0	0.00	7	10.61	2	5.00	3	5.77	1	0.74	15	3.16
54	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
60	0	0.00	0	0.00	1	0.87	1	1.52	0	0.00	0	0.00	0	0.00	2	0.42
65	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
70	1	3.13	0	0.00	0	0.00	0	0.00	2	5.00	0	0.00	0	0.00	3	0.63
75	0	0.00	0	0.00	0	0.00	2	3.03	0	0.00	0	0.00	1	0.74	3	0.63
80	1	3.13	0	0.00	0	0.00	0	0.00	1	2.50	1	1.92	1	0.74	4	0.84
85	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
100	2	6.25	1	3.03	1	0.87	3	4.55	6	15.00	0	0.00	3	2.21	16	3.38
119	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
120	1	3.13	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	2	0.42
149	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	1	0.21
150	1	3.13	0	0.00	0	0.00	5	7.58	0	0.00	0	0.00	0	0.00	6	1.27
155	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
160	2	6.25	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.42
170	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
180	0	0.00	0	0.00	1	0.87	1	1.52	0	0.00	0	0.00	0	0.00	2	0.42
200	2	6.25	0	0.00	0	0.00	1	1.52	2	5.00	0	0.00	0	0.00	5	1.05
230	0	0.00	0	0.00	0	0.00	2	3.03	0	0.00	0	0.00	0	0.00	2	0.42

250	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
280	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
350	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
500	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
600	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	1	0.21
1000	0	0.00	0	0.00	0	0.00	2	3.03	0	0.00	0	0.00	0	0.00	2	0.42
1500	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
N/A	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
Total	**32**		**33**		**115**		**66**		**40**		**52**		**136**		**474**	

Table A7.2: Number of Years of beekeeping by country

Years of beekeeping as hobby	**Estonia**		**Germany**		**Ireland**		**Italy**		**Spain**		**Switzerland**		**UK**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
0	5	15.63	1	3.13	1	0.87	7	10.61	1	2.50	0	0.00	0	0.00	15	3.18
0.3	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
0.5	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	1	0.74	2	0.42
1	1	3.13	1	3.13	12	10.43	6	9.09	2	5.00	0	0.00	10	7.41	32	6.78
1.5	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
2	4	12.50	1	3.13	12	10.43	8	12.12	3	7.50	0	0.00	16	11.85	44	9.32
3	0	0.00	5	15.62	11	9.57	6	9.09	2	5.00	2	3.85	8	5.93	34	7.20
4	1	3.13	2	6.25	20	17.39	8	12.12	1	2.50	2	3.85	14	10.37	48	10.1
5	4	12.50	0	0.00	6	5.22	13	19.70	5	12.50	4	7.69	12	8.89	44	9.32
6	4	12.50	3	9.38	4	3.48	4	6.06	2	5.00	2	3.85	10	7.41	29	6.14
7	1	3.13	1	3.13	5	4.35	2	3.03	4	10.00	2	3.85	6	4.44	21	4.45
8	2	6.25	2	6.25	6	5.22	1	1.52	1	2.50	3	5.77	3	2.22	18	3.81
9	0	0.00	1	3.13	4	3.48	1	1.52	0	0.00	3	5.77	3	2.22	12	2.54
10	2	6.25	1	3.13	11	9.57	0	0.00	0	0.00	5	9.62	11	8.15	30	6.36
11	0	0.00	2	6.25	0	0.00	0	0.00	0	0.00	1	1.92	3	2.22	6	1.27
12	0	0.00	0	0.00	2	1.74	1	1.52	1	2.50	2	3.85	4	2.96	10	2.12
13	1	3.13	2	6.25	2	1.74	1	1.52	0	0.00	2	3.85	1	0.74	9	1.91
14	0	0.00	1	3.13	2	1.74	0	0.00	0	0.00	2	3.85	1	0.74	6	1.27
15	1	3.13	1	3.13	4	3.48	3	4.55	4	10.00	7	13.46	3	2.22	23	4.87
16	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	1	0.74	2	0.42
17	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	0	0.00	1	0.21
18	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	1	1.92	0	0.00	2	0.42
19	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	1	0.74	2	0.42
20	0	0.00	0	0.00	2	1.74	2	3.03	4	10.00	1	1.92	4	2.96	13	2.75
21	0	0.00	2	6.25	1	0.87	0	0.00	0	0.00	0	0.00	0	0.00	3	0.64
22	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
24	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
25	0	0.00	0	0.00	1	0.87	0	0.00	2	5.00	2	3.85	2	1.48	7	1.48
26	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00	1	0.74	2	0.42
28	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	2	0.42
30	1	3.13	1	3.13	1	0.87	0	0.00	6	15.00	0	0.00	3	2.22	12	2.54
31	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	2	0.42
32	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
35	0	0.00	0	0.00	1	0.87	0	0.00	0	0.00	0	0.00	3	2.22	4	0.85
38	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
40	0	0.00	0	0.00	2	1.74	1	1.52	1	2.50	1	1.92	2	1.48	7	1.48
42	0	0.00	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
43	0	0.00	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
45	1	3.13	1	3.13	1	0.87	0	0.00	0	0.00	3	5.77	0	0.00	6	1.27
47	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
48	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	1.48	2	0.42
50	0	0.00	1	3.13	1	0.87	0	0.00	0	0.00	0	0.00	2	1.48	4	0.85
59	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
60	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	1	0.74	2	0.42

65	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.92	0	0.00	1	0.21
N/A	1	3.13	1	3.13	0	0.00	0	0.00	0	0.00	2	3.85	0	0.00	4	0.85
Total	**32**		**32**		**115**		**66**		**40**		**52**		**135**		**472**	

Table A7.3: Years as a professional beekeeper by country

Years of beekeeping as profession	**Estonia**		**Germany**		**Ireland**		**Italy**		**Spain**		**Switzerland**		**UK**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
0	14	43.75	29	87.88	103	89.57	25	37.88	22	55.00	43	82.69	116	85.29	352	74.26
1	0	0.00	1	3.03	2	1.74	5	7.58	4	10.00	0	0.00	4	2.94	17	3.59
2	1	3.13	1	3.03	2	1.74	1	1.52	2	5.00	1	1.92	3	2.21	11	2.32
3	1	3.13	0	0.00	1	0.87	6	0.09	4	10.00	2	3.85	5	3.68	19	4.01
4	1	3.13	0	0.00	0	0.00	2	3.03	1	2.50	0	0.00	0	0.00	4	0.84
5	4	12.50	0	0.00	3	2.61	3	4.55	0	0.00	1	1.92	1	0.74	12	2.53
6	1	3.13	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	2	0.42
7	1	3.13	0	0.00	0	0.00	4	6.06	0	0.00	0	0.00	0	0.00	5	1.05
8	0	0.00	0	0.00	1	0.87	1	1.52	0	0.00	1	1.92	1	0.74	4	0.84
9	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	1	1.92	0	0.00	2	0.42
10	1	3.13	0	0.00	1	0.87	5	7.58	1	2.50	0	0.00	1	0.74	9	1.90
11	1	3.13	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	2	0.42
12	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	1	0.21
13	0	0.00	1	3.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
15	1	3.13	0	0.00	1	0.87	0	0.00	1	2.50	0	0.00	0	0.00	3	0.63
17	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	1	0.21
18	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
21	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
22	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
25	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
30	1	3.13	0	0.00	1	0.87	3	4.55	0	0.00	0	0.00	3	2.21	8	1.69
35	1	3.13	0	0.00	0	0.00	2	3.03	0	0.00	0	0.00	0	0.00	3	0.63
36	1	3.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.21
37	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	1	0.21
42	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	0	0.00	1	0.21
45	1	3.13	0	0.00	0	0.00	1	1.52	1	2.50	0	0.00	0	0.00	3	0.63
50	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.74	1	0.21
N/A	2	6.25	1	3.03	0	0.00	1	1.52	0	0.00	3	5.77	1	0.74	8	1.69
Total	**32**		**33**		**115**		**66**		**40**		**52**		**136**		**474**	

Table A7.4: Reasons to practice beekeepers (highest % per country: in bold)

Why practice beekeeping	Estonia	Germany	Ireland	Italy	Spain	Switzerland	UK	Total
Other	21.88%	18.18%	8.33%	12.86%	12.50%	19.23%	16.22%	14.07%
Providing paid pollination services to growers	6.25%	12.12%	2.78%	4.29%	0.00%	9.62%	2.70%	4.24%
Personal hobby	**71.88%**	**93.94%**	**71.53%**	47.14%	**82.50%**	**90.38%**	**87.84%**	**77.07%**
Environmental concerns	12.50%	30.30%	45.83%	27.14%	40.00%	40.38%	41.89%	38.15%
Awareness of threats to pollinators	18.75%	51.52%	35.42%	42.86%	22.50%	32.69%	40.54%	36.61%
Selling honey, beeswax, pollen, other products	**71.88%**	57.58%	27.78%	**67.14%**	47.50%	57.69%	37.16%	44.89%

Table A7.5 Communication with growers (highest % per country: in bold)

Communication with growers	Country							
	Estonia	Germany	Ireland	Italy	Spain	Switzerland	UK	Total
Frequent communication (more than twice a year)	21.88%	27.27%	17.39%	**40.91%**	**47.50%**	**57.69%**	12.50%	27.22%
I am a grower myself and manage my own hives on my lands	15.63%	0.00%	7.83%	19.70%	20.00%	3.85%	11.76%	11.18%
I do not communicate with growers	21.88%	**39.39%**	**62.61%**	18.18%	22.50%	3.85%	**67.65%**	**43.67%**
Infrequent communication (once or twice a year)	**40.63%**	33.33%	12.17%	21.21%	10.00%	32.69%	8.09%	17.72%
Only when taking payments for professional pollination services	0.00%	0.00%	0.00%	0.00%	0.00%	1.92%	0.00%	0.21%

Table A7.6: Source of information on beehive health (highest % per country: in bold)

Country	Source of information	Importance of sources of information				
		Extremely important	Very important	Moderately important	Slightly important	Not at all important
Estonia	Beekeeping associations	15.63%	**43.75%**	31.25%	9.38%	0.00%
	Other beekeepers	18.75%	**37.50%**	**37.50%**	6.25%	0.00%
	Training in person	6.25%	**34.38%**	31.25%	21.88%	6.25%
	National bee health agencies	3.13%	21.88%	**31.25%**	12.50%	31.25%
	Journals	**28.13%**	18.75%	25.00%	21.88%	6.25%
	Social media	0.00%	15.63%	28.13%	**37.50%**	18.75%
	Online training	3.13%	15.63%	28.13%	**37.50%**	15.63%
	Newspapers	6.25%	28.13%	**37.50%**	21.88%	6.25%
	TV/Radio	3.13%	6.25%	31.25%	**34.38%**	25.00%
	NGOs	3.13%	3.13%	**31.25%**	25.00%	37.50%
Germany	Beekeeping associations	27.27%	**39.39%**	18.18%	12.12%	3.03%
	Other beekeepers	**39.39%**	**39.39%**	12.12%	3.03%	6.06%
	Training in person	15.15%	**51.52%**	12.12%	9.09%	12.12%
	National bee health agencies	12.12%	21.21%	15.15%	18.18%	**33.33%**
	Journals	15.15%	**48.48%**	9.09%	15.15%	12.12%
	Social media	3.03%	9.09%	15.15%	24.24%	**48.48%**
	Online training	6.06%	9.09%	18.18%	24.24%	**42.42%**
	Newspapers	6.06%	24.24%	27.27%	**30.30%**	12.12%
	TV/Radio	0.00%	6.06%	15.15%	**39.39%**	**39.39%**
	NGOs	3.03%	9.09%	9.09%	18.18%	**60.61%**
Ireland	Beekeeping associations	**54.78%**	34.78%	6.09%	3.48%	0.87%
	Other beekeepers	41.74%	**42.61%**	11.30%	2.61%	1.74%
	Training in person	33.91%	**38.26%**	14.78%	6.09%	6.96%
	National bee health agencies	31.30%	**35.65%**	13.91%	10.43%	8.70%
	Journals	19.13%	**27.83%**	23.48%	16.52%	13.04%
	Social media	13.91%	20.87%	**21.74%**	**21.74%**	**21.74%**
	Online training	10.43%	22.61%	21.74%	17.39%	**27.83%**
	Newspapers	7.83%	23.48%	**26.96%**	20.00%	21.74%

	TV/Radio	8.70%	6.96%	21.74%	30.43%	**32.17%**
	NGOs	6.96%	12.17%	20.00%	26.96%	**33.91%**
Italy	Beekeeping associations	**45.45%**	33.33%	15.15%	4.55%	1.52%
	Other beekeepers	**40.91%**	33.33%	18.18%	6.06%	1.52%
	Training in person	**42.42%**	39.39%	13.64%	4.55%	0.00%
	National bee health agencies	21.21%	**31.82%**	25.76%	12.12%	9.09%
	Journals	30.30%	**50.00%**	15.15%	4.55%	0.00%
	Social media	7.58%	21.21%	**40.91%**	21.21%	9.09%
	Online training	22.73%	**33.33%**	28.79%	10.61%	4.55%
	Newspapers	13.64%	**37.88%**	28.79%	13.64%	6.06%
	TV/Radio	6.06%	16.67%	18.18%	**36.36%**	22.73%
	NGOs	12.12%	9.09%	**28.79%**	**28.79%**	21.21%
Spain	Beekeeping associations	35.00%	**47.50%**	12.50%	5.00%	0.00%
	Other beekeepers	27.50%	**42.50%**	15.00%	12.50%	2.50%
	Training in person	32.50%	**47.50%**	15.00%	5.00%	0.00%
	National bee health agencies	10.00%	**37.50%**	32.50%	12.50%	7.50%
	Journals	17.50%	**37.50%**	20.00%	17.50%	7.50%
	Social media	7.50%	25.00%	**40.00%**	17.50%	10.00%
	Online training	17.50%	**37.50%**	35.00%	10.00%	0.00%
	Newspapers	0.00%	25.00%	27.50%	**35.00%**	12.50%
	TV/Radio	2.50%	12.50%	30.00%	**32.50%**	22.50%
	NGOs	2.50%	5.00%	12.50%	**37.50%**	42.50%
Switzerland	Beekeeping associations	**50.00%**	38.46%	7.69%	3.85%	0.00%
	Other beekeepers	28.85%	**53.85%**	5.77%	9.62%	1.92%
	Training in person	**63.46%**	32.69%	1.92%	0.00%	1.92%
	National bee health agencies	**46.15%**	42.31%	9.62%	0.00%	1.92%
	Journals	**28.13%**	18.75%	25.00%	21.88%	6.25%
	Social media	0.00%	23.08%	23.08%	**30.77%**	23.08%
	Online training	11.54%	**30.77%**	**30.77%**	15.38%	11.54%
	Newspapers	17.31%	**30.77%**	26.92%	15.38%	9.62%
	TV/Radio	1.92%	15.38%	**30.77%**	28.85%	23.08%
	NGOs	3.85%	19.23%	28.85%	11.54%	**36.54%**
UK	Beekeeping associations	**47.06%**	30.88%	13.97%	5.15%	2.94%
	Other beekeepers	**42.65%**	33.82%	15.44%	3.68%	4.41%
	Training in person	28.68%	**38.24%**	16.18%	8.09%	8.82%
	National bee health agencies	25.74%	**39.71%**	22.06%	7.35%	5.15%
	Journals	18.38%	19.85%	**25.00%**	17.50%	17.65%
	Social media	9.56%	8.09%	22.79%	20.59%	**38.97%**
	Online training	8.82%	17.65%	**30.15%**	20.59%	22.79%
	Newspapers	5.15%	11.76%	19.85%	17.65%	**45.59%**
	TV/Radio	7.35%	0.74%	17.65%	25.00%	**49.26%**
	NGOs	10.29%	13.24%	**30.88%**	18.38%	27.21%

Table A7.7. Reasons for bee decline (highest % per country: in bold)

Country	**Reasons for bee decline**	**Agreement**				
		Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
Estonia	Loss of natural habitats	25.00%	**40.63%**	21.88%	9.38%	3.13%
	Competition wild/managed	3.13%	15.63%	25.00%	**37.50%**	18.75%
	Diseases	40.63%	**53.13%**	3.13%	3.13%	0.00%
	Parasites	**56.25%**	34.38%	6.25%	3.13%	0.00%
	Predators	12.50%	21.88%	**34.38%**	31.25%	0.00%
	Climate change	6.25%	34.38%	**40.63%**	12.50%	6.25%
	Genetics	3.13%	34.38%	**46.88%**	15.63%	0.00%
	Non-optimal beekeeping	31.25%	**50.00%**	9.38%	9.38%	0.00%
	Agrochemicals	34.38%	**50.00%**	12.50%	3.13%	0.00%
Germany	Loss of natural habitats	**48.48%**	42.42%	3.03%	3.03%	3.03%
	Competition wild/managed	3.03%	15.15%	30.30%	**42.42%**	9.09%
	Diseases	18.18%	**33.33%**	30.30%	15.15%	3.03%

	Parasites	30.30%	30.30%	**33.33%**	3.03%	3.03%
	Predators	0.00%	3.03%	21.21%	**51.52%**	24.24%
	Climate change	12.12%	21.21%	**33.33%**	27.27%	6.06%
	Genetics	0.00%	15.15%	**39.39%**	27.27%	18.18%
	Non-optimal beekeeping	6.06%	36.36%	**30.30%**	18.18%	9.09%
	Agrochemicals	40.63%	**50.00%**	6.25%	3.13%	0.00%
Ireland	Loss of natural habitats	**66.09%**	28.79%	3.48%	0.87%	0.87
	Competition wild/managed	3.48%	11.30%	**52.17%**	22.61%	10.43%
	Diseases	22.61%	**53.04%**	22.61%	0.87%	0.87%
	Parasites	32.17%	**47.83%**	17.39%	2.61%	0.00%
	Predators	1.74%	13.04%	**44.35%**	33.91%	6.96%
	Climate change	15.65%	**43.48%**	33.04%	7.83%	0.00%
	Genetics	4.35%	20.87%	**56.52%**	18.26%	0.00%
	Non-optimal beekeeping	9.57%	30.43%	**46.96%**	11.30%	1.74%
	Agrochemicals	**65.22%**	30.43%	2.61%	1.74%	0.00%
Italy	Loss of natural habitats	**62.12%**	36.36%	0.00%	1.52%	0.00%
	Competition wild/managed	12.12%	10.61%	**36.36%**	30.30%	10.61%
	Diseases	**40.91%**	37.88%	16.67%	4.55%	0.00%
	Parasites	**50.00%**	39.39%	7.58%	3.03%	0.00%
	Predators	13.64%	**33.33%**	24.24%	21.21%	7.58%
	Climate change	**63.64%**	25.76%	7.58%	3.03%	0.00%
	Genetics	4.55%	16.67%	**43.94%**	30.30%	4.55%
	Non-optimal beekeeping	15.15%	**39.39%**	25.76%	12.12%	7.58%
	Agrochemicals	**75.76%**	18.18%	6.06%	0.00%	0.00%
Spain	Loss of natural habitats	40.00%	**45.00**%	7.50%	5.00%	2.5%
	Competition wild/managed	7.50%	17.50%	15.00%	**35.00%**	25.00%
	Diseases	**57.50%**	27.50%	12.50%	2.50%	0.00%
	Parasites	**57.50%**	30.00%	12.50%	0.00%	0.00%
	Predators	12.50%	**30.00%**	27.50%	25.00%	5.00%
	Climate change	**47.50%**	35.00%	10.00%	5.00%	2.50%
	Genetics	10.00%	22.50%	**30.00%**	**30.30%**	7.50%
	Non-optimal beekeeping	22.50%	**35.00%**	22.50%	12.50%	7.50%
	Agrochemicals	**57.50%**	32.50%	7.50%	2.50%	0.00%
Switzerland	Loss of natural habitats	**61.54%**	28.85%	3.85%	3.85%	1.92%
	Competition wild/managed	3.85%	9.62%	30.77%	**40.38%**	15.38%
	Diseases	17.31%	**42.31%**	19.23%	19.23%	1.92%
	Parasites	**36.54%**	28.85	15.38%	17.31%	4.01%
	Predators	1.92%	3.85%	25.00%	**42.31%**	26.92%
	Climate change	9.62%	**30.77%**	21.15%	26.92%	11.54%
	Genetics	7.69%	21.15%	**30.77%**	28.85%	11.54%
	Non-optimal beekeeping	23.08%	**42.31%**	26.92%	7.69%	0.00%
	Agrochemicals	32.00%	**48.00%**	14.00%	6.00%	0.00%
UK	Loss of natural habitats	**67.65%**	22.06%	7.35%	1.47%	1.47%
	Competition wild/managed	5.88%	21.32%	**40.44%**	23.53%	8.82%
	Diseases	26.47%	**51.47%**	18.38%	2.94%	0.74%
	Parasites	38.24%	**44.85%**	13.97%	2.21%	0.74%
	Predators	4.41%	30.88%	**35.29%**	19.85%	9.56%
	Climate change	22.06%	**40.44%**	22.79%	11.76%	2.94%
	Genetics	8.09%	25.74%	**49.26%**	14.71%	2.21%
	Non-optimal beekeeping	17.65%	**38.24%**	35.29%	6.62%	2.21%
	Agrochemicals	**53.33%**	35.56%	8.89%	2.22%	0.00%

Table A7.8: Reasons to reduce bee decline (highest % per country: in bold)

Country	Reasons to reduce bee decline	Agreement				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Estonia	Collab with growers	41.94%	**48.39%**	9.68%	0.00%	0.00%
	Hive position	40.63%	**59.38%**	0.00%	0.00%	0.00%
	Natural habitats/flower areas	**53.13%**	40.63%	6.25%	0.00%	0.00%
	Monitor diseases	**59.38%**	37.50%	3.13%	0.00%	0.00%
	Monitor parasites	**68.75%**	25.00%	6.25%	0.00%	0.00%
	Monitor nutrition	28.13%	**46.88%**	21.88%	3.13%	0.00%
	Monitor agrochemicals	37.50%	**46.88%**	15.63%	0.00%	0.00%
	Optimal beekeeping	40.63%	**53.13%**	6.25%	0.00%	0.00%
Germany	Collab with growers	**54.55%**	39.39%	3.03%	0.00%	3.03%
	Hive position	32.26%	**45.16%**	16.13%	6.45%	0.00%
	Natural habitats/flower areas	**65.63%**	31.25%	3.13%	0.00%	0.00%
	Monitor diseases	37.50%	**40.63%**	21.88%	0.00%	0.00%
	Monitor parasites	**46.88%**	28.13%	25.00%	0.00%	0.00%
	Monitor nutrition	15.15%	**54.55%**	27.27%	0.00%	3.03%
	Monitor agrochemicals	**53.13%**	34.38%	12.50%	53.13%	0.00%
	Optimal beekeeping	35.48%	**51.61%**	12.90%	0.00%	0.00%
Ireland	Collab with growers	**46.09%**	**46.09%**	7.83%	0.00%	0.00%
	Hive position	26.96%	**55.65%**	14.78%	2.61%	0.00%
	Natural habitats/flower areas	**62.61%**	33.91%	1.74%	1.74%	0.00%
	Monitor diseases	43.48%	**53.04%**	3.48%	0.00%	0.00%
	Monitor parasites	44.35%	**51.30%**	4.35%	0.00%	0.00%
	Monitor nutrition	39.13%	**43.48%**	15.65%	0.87%	0.87%
	Monitor agrochemicals	**68.70%**	26.09%	4.35%	0.87%	0.00%
	Optimal beekeeping	**42.61%**	41.74%	15.65%	0.00%	0.00%
Italy	Collab with growers	**60.94%**	31.25%	7.81%	0.00%	0.00%
	Hive position	39.06%	**46.88%**	14.06%	0.00%	0.00%
	Natural habitats/flower areas	**74.24%**	24.24%	0.00%	1.52%	0.00%
	Monitor diseases	**45.31%**	42.19%	12.50%	0.00%	0.00%
	Monitor parasites	**48.44%**	45.31%	6.25%	0.00%	0.00%
	Monitor nutrition	34.85%	**40.91%**	19.70%	4.55%	0.00%
	Monitor agrochemicals	**66.67%**	30.30%	3.03%	0.00%	0.00%
	Optimal beekeeping	**51.52%**	33.33%	15.15%	0.00%	0.00%
Spain	Collab with growers	45.00%	**52.50%**	2.50%	0.00%	0.00%
	Hive position	35.00%	**42.50%**	17.50%	5.00%	0.00%
	Natural habitats/flower areas	35.00%	**45.00%**	20.00%	0.00%	0.00%
	Monitor diseases	**60.00%**	32.50%	7.50%	0.00%	0.00%
	Monitor parasites	**57.50%**	32.50%	10.00%	0.00%	0.00%
	Monitor nutrition	**37.50%**	**37.50%**	17.50%	7.50%	0.00%
	Monitor agrochemicals	**55.00%**	37.50%	7.50%	0.00%	0.00%
	Optimal beekeeping	**56.41%**	33.33%	10.26%	0.00%	0.00%
Switzerland	Collab with growers	**50.00%**	48.08%	1.92%	0.00%	0.00%
	Hive position	**48.08%**	36.54%	7.69%	7.69%	0.00%
	Natural habitats/flower areas	**63.46%**	30.77%	5.77%	0.00%	0.00%
	Monitor diseases	**48.08%**	40.38%	11.54%	0.00%	0.00%
	Monitor parasites	**46.15%**	42.31%	11.54%	0.00%	0.00%
	Monitor nutrition	**42.31%**	34.62%	19.23%	3.85%	0.00%
	Monitor agrochemicals	**50.00%**	36.54%	9.62%	3.85%	0.00%
	Optimal beekeeping	**52.94%**	45.10%	1.96%	0.00%	0.00%
UK	Collab with growers	29.85%	**46.27%**	22.39%	0.00%	1.49%
	Hive position	27.21%	**51.47%**	19.12%	2.21%	0.00%
	Natural habitats/flower areas	**71.32%**	24.26%	4.41%	0.00%	0.00%
	Monitor diseases	**54.07%**	41.48%	4.44%	0.00%	0.00%
	Monitor parasites	**53.68%**	41.18%	5.15%	0.00%	0.00%
	Monitor nutrition	**41.91%**	40.44%	17.65%	0.00%	0.00%
	Monitor agrochemicals	**57.04%**	33.33%	8.89%	0.74%	0.00%
	Optimal beekeeping	**54.07%**	31.11%	14.81%	0.00%	0.00%

Table A7.9: Reasons to protect bee health (highest % per country: in bold)

Country	Reasons to protect bee health	Agreement				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Estonia	Economic reasons	28.13%	**43.75%**	25.00%	3.13%	0.00%
	Legal reasons	18.75%	**40.63%**	31.25%	9.38%	0.00%
	Public perception	15.63%	21.88%	**43.75%**	12.50%	6.25%
	Pollinators conservation	**65.63%**	28.13%	6.25%	0.00%	0.00%
	Consumer safety	**43.75%**	40.63%	15.63%	0.00%	0.00%
	Food security	37.50%	**56.25%**	6.25%	0.00%	0.00%
	Crop varieties	34.38%	**43.75%**	18.75%	3.13%	0.00%
Germany	Economic reasons	12.12%	**33.33%**	**33.33%**	15.15%	6.06%
	Legal reasons	12.12%	30.30%	**36.36%**	12.12%	9.09%
	Public perception	18.18%	30.30%	**36.36%**	6.06%	9.09%
	Pollinators conservation	**59.38%**	37.50%	3.13%	0.00%	0.00%
	Consumer safety	9.09%	30.30%	**33.33%**	18.18%	9.09%
	Food security	24.24%	**33.33%**	27.27%	12.12%	3.03%
	Crop varieties	**51.52%**	36.36%	9.09%	3.03%	0.00%
Ireland	Economic reasons	25.22%	**40.87%**	26.09%	6.09%	1.74%
	Legal reasons	13.91%	31.30%	**36.52%**	13.91%	4.35%
	Public perception	18.26%	**33.04%**	32.17%	13.91%	2.61%
	Pollinators conservation	**77.39%**	20.00%	1.74%	0.87%	0.00%
	Consumer safety	30.43%	**44.35%**	16.52%	7.83%	0.87%
	Food security	**56.52%**	33.04%	7.83%	1.74%	0.87%
	Crop varieties	42.61%	**43.48%**	12.17%	1.74%	0.00%
Italy	Economic reasons	25.76%	**43.94%**	25.76%	3.03%	1.52%
	Legal reasons	18.18%	31.82%	**42.42%**	6.06%	1.52%
	Public perception	21.21%	30.30%	**31.82%**	9.09%	7.58%
	Pollinators conservation	**81.82%**	13.64%	3.03%	1.52%	0.00%
	Consumer safety	**39.39%**	37.88%	15.15%	6.06%	1.52%
	Food security	**57.58%**	28.79%	9.09%	4.55%	0.00%
	Crop varieties	39.39%	**43.94%**	13.64%	3.03%	0.00%
Spain	Economic reasons	27.50%	**35.00%**	22.50%	15.00%	0.00%
	Legal reasons	10.00%	32.50%	**40.00%**	12.50%	5.00%
	Public perception	10.00%	**37.50%**	35.00%	15.00%	2.50%
	Pollinators conservation	**60.00%**	35.00%	5.00%	0.00%	0.00%
	Consumer safety	**40.00%**	**40.00%**	17.50%	2.50%	0.00%
	Food security	**42.50%**	40.00%	15.00%	2.50%	0.00%
	Crop varieties	30.00%	**50.00%**	17.50%	2.50%	0.00%
Switzerland	Economic reasons	9.62%	**30.77%**	26.92%	25.00%	7.69%
	Legal reasons	13.46%	**48.08%**	26.92%	11.54%	0.00%
	Public perception	21.15%	**48.08%**	23.08%	7.69%	0.00%
	Pollinators conservation	**57.69%**	36.54%	5.77%	0.00%	0.00%
	Consumer safety	17.31%	28.85%	**44.23%**	7.69%	1.92%
	Food security	23.08%	**38.46%**	30.77%	7.69%	0.00%
	Crop varieties	34.62%	**42.31%**	19.23%	3.85%	0.00%
UK	Economic reasons	**38.24%**	33.09%	20.59%	6.62%	1.47%
	Legal reasons	12.50%	28.68%	**47.06%**	9.56%	2.21%
	Public perception	16.18%	34.56%	**38.97%**	9.56%	0.74%
	Pollinators conservation	**78.68%**	16.91%	4.41%	0.00%	0.00%
	Consumer safety	24.26%	**36.03%**	32.35%	5.88%	1.47%
	Food security	**52.21%**	33.09%	11.03%	2.21%	1.47%
	Crop varieties	**40.44%**	39.71%	16.18%	2.21%	1.47%

Table A7.10: Health checks on beehives (highest % per country: in bold)

Country	Frequency	Checks			
		Diseases	Parasites	Nutrition	Chemicals
Estonia	Weekly	**31.25%**	25.00%	28.13%	18.75%
	Fortnightly	9.38%	12.50%	15.63%	6.25%
	Monthly	18.75%	18.75%	15.63%	9.38%
	More than once a year	21.88%	**34.38%**	**31.25%**	15.63%
	Yearly	3.13%	3.13%	3.13%	6.25%
	Only with a reasonable suspicion	15.63%	6.25%	6.25%	**43.75%**
	Never	0.00%	0.00%	0.00%	0.00%
Germany	Weekly	12.12%	6.06%	9.09%	0.00%
	Fortnightly	15.15%	15.15%	18.18%	3.03%
	Monthly	9.09%	9.09%	15.15%	3.03%
	More than once a year	**27.27%**	**45.45%**	**33.33%**	6.06%
	Yearly	12.12%	12.12%	6.06%	9.09%
	Only with a reasonable suspicion	21.21%	9.09%	9.09%	**48.48%**
	Never	3.03%	3.03%	9.09%	30.30%
Ireland	Weekly	20.87%	14.78%	32.17%	10.43%
	Fortnightly	**32.17%**	26.09%	**34.78%**	8.70%
	Monthly	19.13%	20.00%	17.39%	3.48%
	More than once a year	20.87%	**30.43%**	4.35%	2.61%
	Yearly	0.87%	1.74%	0.87%	2.61%
	Only with a reasonable suspicion	6.09%	6.09%	5.22%	28.70%
	Never	0.00%	0.87%	5.22%	**43.48%**
Italy	Weekly	**37.88%**	**27.27%**	24.24%	21.21%
	Fortnightly	27.27%	25.76%	**31.82%**	15.15%
	Monthly	21.21%	19.70%	6.06%	12.12%
	More than once a year	9.09%	22.73%	18.18%	10.61%
	Yearly	0.00%	0.00%	1.52%	7.58%
	Only with a reasonable suspicion	4.55%	4.55%	15.15%	**24.24%**
	Never	0.00%	0.00%	3.03%	9.09%
Spain	Weekly	7.50%	5.00%	10.00%	10.00%
	Fortnightly	20.00%	12.50%	17.50%	5.00%
	Monthly	**30.00%**	**40.00%**	22.50%	7.50%
	More than once a year	25.00%	20.00%	**27.50%**	10.00%
	Yearly	12.50%	17.50%	5.00%	2.50%
	Only with a reasonable suspicion	5.00%	2.50%	10.00%	20.00%
	Never	0.00%	2.50%	7.50%	**45.00%**
Switzerland	Weekly	19.23%	19.23%	19.23%	5.77%
	Fortnightly	**34.62%**	25.00%	**30.77%**	9.62%
	Monthly	25.00%	**32.69%**	25.00%	1.92%
	More than once a year	15.38%	13.46%	21.15%	13.46%
	Yearly	0.00%	0.00%	0.00%	3.85%
	Only with a reasonable suspicion	5.77%	9.62%	3.85%	**46.15%**
	Never	0.00%	0.00%	0.00%	10.29%
UK	Weekly	**31.62%**	**24.26%**	**40.44%**	2.21%
	Fortnightly	21.32%	17.65%	26.47%	2.21%
	Monthly	18.38%	26.47%	17.65%	4.41%
	More than once a year	22.06%	23.53%	7.35%	2.21%
	Yearly	1.47%	1.47%	0.74%	**44.85%**
	Only with a reasonable suspicion	4.41%	6.62%	5.88%	33.82%
	Never	0.74%	0.00%	1.47%	10.29%

Table A7.11: List of health issues that beekeepers want to be detected by the Bee Health Card (open question)

Health issues	**Respondents**	
	n	**%**
Acarine	4	1.82%
Bacterial infections	2	0.91%
Bee health improvements	1	0.45%
Black Queen Cell Virus	1	0.45%
Brood diseases	2	0.91%
Chalkbrood	5	2.27%
Chilled brood	1	0.45%
Chronic Bee Paralysis Virus	22	10.00%
Colony Collapse Disorder	3	1.36%
Deformed Wing Virus	16	7.27%
Diseases	31	14.09%
Fat body	1	0.45%
Foulbroods	**52**	**23.64%**
Fungal infections	2	0.91%
Gut diseases	1	0.45%
Issues that cannot be detected by visual inspections	2	0.91%
Mated queen fertility	1	0.45%
Nosema	41	18.64%
Nutritional issues	17	7.73%
Parasites	18	8.18%
Parasitic Mite Syndrome	1	0.45%
Pathogens	4	1.82%
Pesticides	**47**	**21.36%**
Pollution	5	2.27%
Queen health	1	0.45%
Resilience index	1	0.45%
Sac brood	6	2.73%
Sour brood	2	0.91%
Spiroplasma	1	0.45%
Stress	2	0.91%
Tracheal mites	2	0.91%
Varroa and viruses linked to it	**57**	**25.91%**
Viruses	41	18.64%

8.8. Appendix 8. Distribution of perceived barriers and benefits by country

Table A8.1: Summary of perceived barriers by country (highest % per country: in bold)

Country	Barriers	Agreement				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Estonia	No communication with growers	18.75%	**46.88%**	25.00%	9.38%	0.00%
	Cost	25.81%	**38.71%**	22.58%	12.90%	0.00%
	Effectiveness	6.25%	12.50%	**50.00%**	28.13%	3.13%
	Time	6.25%	15.63%	**40.63%**	34.38%	3.13%
	Difficulty	3.13%	12.50%	**40.63%**	31.25%	12.50%
	No importance in being used	3.13%	3.13%	**40.63%**	31.25%	21.88%
Germany	No communication with growers	9.09%	**42.42%**	36.36%	3.03%	9.09%
	Cost	15.63%	**43.75%**	34.38%	6.25%	0.00%
	Effectiveness	21.21%	18.18%	**33.33%**	27.27%	0.00%
	Time	3.03%	21.21%	**45.45%**	27.27%	3.03%
	Difficulty	0.00%	12.12%	**51.52%**	33.33%	3.03%
	No importance in being used	18.18%	15.15%	**39.39%**	18.18%	9.09%
Ireland	No communication with growers	21.74%	**39.13%**	31.30%	6.96%	0.87%
	Cost	25.44%	**40.35%**	26.32%	7.89%	0.00%
	Effectiveness	2.61%	32.17%	**42.61%**	19.13%	3.48%
	Time	2.61%	20.00%	**41.74%**	29.57%	6.09%
	Difficulty	0.87%	11.30%	**42.61%**	39.13%	6.09%
	No importance in being used	3.48%	12.17%	**43.48%**	26.96%	13.91%
Italy	No communication with growers	**42.42%**	34.85%	15.15%	6.06%	1.52%
	Cost	18.46%	**33.85%**	32.31%	15.38%	0.00%
	Effectiveness	10.61%	28.79%	**33.33%**	22.73%	4.55%
	Time	7.58%	24.24%	**36.36%**	31.82%	0.00%
	Difficulty	6.06%	18.18%	34.85%	**39.39%**	1.52%
	No importance in being used	4.55%	9.09%	28.79%	**37.88%**	19.70%
Spain	No communication with growers	30.00%	**40.00%**	20.00%	5.00%	5.00%
	Cost	20.00%	**32.50%**	**32.50%**	15.00%	0.00%
	Effectiveness	12.50%	17.50%	**35.00%**	32.50%	2.50%
	Time	0.00%	12.50%	**45.00%**	27.50%	15.00%
	Difficulty	0.00%	7.50%	**50.00%**	35.00%	7.50%
	No importance in being used	10.00%	7.50%	**37.50%**	27.50%	17.50%
Switzerland	No communication with growers	7.69%	**48.08%**	30.77%	7.69%	5.77%
	Cost	17.65%	**52.94%**	27.45%	1.96%	0.00%
	Effectiveness	15.38%	**40.38%**	28.85%	11.54%	3.85%
	Time	9.62%	**34.62%**	**34.62%**	19.23%	1.92%
	Difficulty	9.62%	23.08%	**36.54%**	23.08%	7.69%
	No importance in being used	15.38%	19.23%	**44.23%**	11.54%	9.62%
UK	No communication with growers	25.00%	30.15%	**39.71%**	2.21%	2.94%
	Cost	33.82%	**38.97%**	19.85%	7.35%	0.00%
	Effectiveness	11.76%	26.47%	**42.65%**	16.91%	2.21%
	Time	4.41%	20.59%	**36.03%**	**36.03%**	2.94%
	Difficulty	2.21%	8.09%	**42.65%**	41.18%	5.88%
	No importance in being used	3.68%	20.59%	**36.03%**	30.88%	8.82%

Table A8.2: Summary of perceived benefits by country

Country	Benefits	Agreement				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Estonia	Communication with growers	9.38%	**50.00%**	31.25%	6.25%	3.13%
	Productivity	6.25%	**43.75%**	40.63%	6.25%	3.13%
	Quick and easy	3.13%	40.63%	**50.00%**	3.13%	3.13%
	Lower treatment cost	3.13%	40.63%	**43.75%**	9.38%	3.13%
	Better crop pollination	3.13%	31.25%	**59.38%**	3.13%	3.13%
	Increases bee health	9.38%	**65.63%**	21.88%	0.00%	3.13%
	Environment protection	3.13%	**43.75%**	40.63%	9.38%	3.13%
	Pollinators protection	3.13%	**65.63%**	25.00%	3.13%	3.13%
Germany	Communication with growers	9.09%	**36.36%**	33.33%	6.06%	15.15%
	Productivity	3.03%	15.15%	**51.52%**	21.21%	9.09%
	Quick and easy	0.00%	**42.42%**	39.39%	9.09%	9.09%
	Lower treatment cost	0.00%	15.15%	**60.61%**	18.18%	6.06%
	Better crop pollination	0.00%	27.27%	**42.42%**	21.21%	9.09%
	Increases bee health	9.09%	**54.55%**	21.21%	9.09%	6.06%
	Environment protection	6.06%	**42.42%**	33.33%	15.15%	3.03%
	Pollinators protection	9.09%	**45.45%**	33.33%	9.09%	3.03%
Ireland	Communication with growers	14.78%	35.65%	**37.39%**	9.57%	2.61%
	Productivity	14.78%	**45.22%**	33.04%	5.22%	1.74%
	Quick and easy	9.57%	**43.48%**	41.74%	4.35%	0.87%
	Lower treatment cost	9.57%	33.04%	**46.09%**	10.43%	0.87%
	Better crop pollination	10.43%	32.17%	**48.70%**	7.83%	0.87%
	Increases bee health	33.91%	**42.61%**	21.74%	0.87%	0.87%
	Environment protection	26.09%	31.30%	**39.13%**	2.61%	0.87%
	Pollinators protection	29.57%	**46.96%**	20.87%	1.74%	0.87%
Italy	Communication with growers	21.21%	**43.94%**	25.76%	6.06%	3.03%
	Productivity	15.15%	**39.39%**	33.33%	12.12%	0.00%
	Quick and easy	7.58%	33.33%	**48.48%**	10.61%	0.00%
	Lower treatment cost	4.55%	30.30%	**40.91%**	19.70%	4.55%
	Better crop pollination	6.06%	22.73%	**50.00%**	18.18%	3.03%
	Increases bee health	21.21%	**48.48%**	19.70%	7.58%	3.03%
	Environment protection	19.70%	**45.45%**	25.76%	4.55%	4.55%
	Pollinators protection	22.73%	**59.09%**	15.15%	1.52%	1.52%
Spain	Communication with growers	25.00%	**35.00%**	30.00%	7.50%	2.50%
	Productivity	25.00%	**50.00%**	15.00%	7.50%	2.50%
	Quick and easy	22.50%	**40.00%**	32.50%	2.50%	2.50%
	Lower treatment cost	20.00%	**35.00%**	25.00%	15.00%	5.00%
	Better crop pollination	17.50%	22.50%	**47.50%**	7.50%	5.00%
	Increases bee health	35.00%	**37.50%**	20.00%	5.00%	2.50%
	Environment protection	22.50%	**42.50%**	27.50%	5.00%	2.50%
	Pollinators protection	**30.00%**	40.00%	22.50%	5.00%	2.50%
Switzerland	Communication with growers	19.23%	26.92%	**36.54%**	13.46%	3.85%
	Productivity	3.85%	13.46%	**46.15%**	30.77%	5.77%
	Quick and easy	5.77%	34.62%	**38.46%**	17.31%	3.85%
	Lower treatment cost	5.77%	11.54%	**42.31%**	32.69%	7.69%
	Better crop pollination	3.85%	17.31%	**48.08%**	17.31%	13.46%
	Increases bee health	13.46%	28.85%	**38.46%**	13.46%	5.77%
	Environment protection	7.69%	25.00%	**42.31%**	11.54%	13.46%
	Pollinators protection	15.38%	28.85%	**42.31%**	7.69%	5.77%
UK	Communication with growers	15.44%	27.21%	**44.85%**	8.09%	4.41%
	Productivity	9.56%	28.68%	**52.94%**	5.88%	2.94%
	Quick and easy	11.03%	38.24%	**39.71%**	9.56%	1.47%
	Lower treatment cost	7.35%	24.26%	**48.53%**	16.91%	2.94%
	Better crop pollination	8.82%	18.38%	**58.09%**	11.76%	2.94%
	Increases bee health	29.41%	**40.44%**	22.79%	5.15%	2.21%
	Environment protection	18.38%	33.09%	**39.71%**	6.62%	2.21%
	Pollinators protection	25.74%	**36.76%**	29.41%	5.88%	2.21%

8.9. Appendix 9: Full Statistical modelling outputs

Table A9.1. Full statistical models

Response variable	Full model before removing terms with VIF ≥5	Full model after removing terms with VIF ≥5
Willingness to use the BHC with incentives	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp	bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp
Willingness to use the BHC without incentives	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp
Willingness to accept BHC extra costs with incentives	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i
Willingness to accept BHC extra costs without incentives	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i
Frequency of BHC use with incentives	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i
Frequency of BHC use without incentives	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i bhc.be.pp.ep.qe bhc.be.g.bh.cp	Country bhc.e bhc.be.p bhc.be.tc bhc.ba.c bhc.ba.t.e.d.i

Table A9.2: BIC model selection (selected models in bold)

Willingness to use the BHC with economic incentives		
Terms	**BIC**	**ΔBIC**
bhc.e + bhc.be.p + bhc.ba.t.e.d.i	**288.28**	**0**
bhc.e + bhc.be.p + bhc.ba.c + bhc.ba.t.e.d.i	295.14	6.86
bhc.e + bhc.be.p + bhc.ba.c + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe	303.77	15.49
bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.c + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe	313.11	24.83
bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.c + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe + bhc.be.g.bh.cp	325.38	37.1
Willingness to use the BHC without economic incentives		
Terms	**BIC**	**ΔBIC**
bhc.e + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe	**313.92**	**0**
Country + bhc.e + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe	339.15	25.23
Country + bhc.e + bhc.be.tc + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe	349.79	35.87
Country + bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe	361.51	47.59
Country + bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.t.e.d.i + bhc.be.pp.ep.qe + bhc.be.g.bh.cp	373.76	59.84
Willingness to accept BHC extra costs with economic incentives		
Terms	**BIC**	**ΔBIC**
bhc.e + bhc.ba.t.e.d.i	**615.39**	**0**
bhc.e + bhc.be.p + bhc.ba.t.e.d.i	623.91	8.52
bhc.e + bhc.be.p + bhc.ba.c + bhc.ba.t.e.d.i	632.36	16.97
bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.c + bhc.ba.t.e.d.i	643.44	28.05
Country + bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.c + bhc.ba.t.e.d.i	676.64	61.25
Frequency of BHC use with economic incentives		
Terms	**BIC**	**ΔBIC**
bhc.e + bhc.ba.c	**481.11**	**0**
bhc.e + bhc.be.p + bhc.ba.c	488.02	6.91
bhc.e + bhc.be.p + bhc.ba.c + bhc.ba.t.e.d.i	497.26	16.15
Country + bhc.e + bhc.be.p + bhc.ba.c + bhc.ba.t.e.d.i	526.07	44.96
Country + bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.c + bhc.ba.t.e.d.i	537.33	56.22
Frequency of BHC use without economic incentives		
Terms	**BIC**	**ΔBIC**
bhc.e + bhc.ba.c	**546.23**	**0**
Country + bhc.e + bhc.ba.c	574.27	28.04
Country + bhc.e + bhc.be.p + bhc.ba.c	585.79	39.52
Country + bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.c	597.62	51.39
Country + bhc.e + bhc.be.p + bhc.be.tc + bhc.ba.c + bhc.ba.t.e.d.i	609.53	63.30

Table A9.3: Statistical model output - Willingness to use the tool with economic incentives

Regression analysis			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	19.72	2	**<0.001**
Productivity as benefit	11.79	2	**0.003**
Time, effectiveness, difficulty, and importance as barriers	11.26	2	**0.004**
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	5.64	5	0.343
Model summary	**R^2**	**BIC**	**BIC global model**
	22.21	288.28	325.38

Coefficient values					
Terms	**Coeff**	**SE**	**Z-Value**	**P-Value**	**VIF**
Confidence level in effectiveness					
High confidence	0.706	0.536	1.32	0.188	1.19
No confidence	-1.630	0.418	-3.90	**<0.001**	1.09
Productivity as benefit					
Disagree	-0.791	0.391	-2.03	**0.043**	1.14
Agree	0.963	0.468	2.06	**0.040**	1.17
Time, effectiveness, difficulty, and importance as barriers					
Disagree	0.065	0.563	0.11	0.908	1.19
Agree	-1.163	0.366	-3.18	**0.001**	1.16

Table A9.4: Statistical Model outputs - Willingness to use the tool without economic incentives

Regression analysis			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	18.46	2	**<0.001**
Time, effectiveness, difficulty, and importance as barriers	7.13	2	**0.028**
Pollinator protection, environment protection, and easy to use as benefits	15.95	2	**<0.001**
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	0.59	2	0.965
Model summary	**R^2**	**BIC**	**BIC global model**
	24.80	313.92	373.76

Coefficient values					
Terms	**Coeff**	**SE**	**Z-Value**	**P-Value**	**VIF**
Confidence level in effectiveness					
High confidence	1.535	0.651	2.36	**0.018**	1.15
No confidence	-1.366	0.413	-3.31	**0.001**	1.07
Time, effectiveness, difficulty, and importance as barriers					
Disagree	-0.313	0.492	-0.64	0.524	1.18
Agree	-0.918	0.345	-2.66	**0.008**	1.16
Pollinator protection, environment protection, and easy to use the tool as benefits					
Disagree	-1.097	0.466	-2.36	**0.018**	1.11
Agree	1.058	0.393	2.69	**0.007**	1.17

Table A9.5: Statistical Model outputs - Willingness to accept extra costs with economic incentives

Regression analysis			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	19.47	2	**<0.001**
Time, effectiveness, difficulty, and importance as barriers	25.81	2	**<0.001**
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	1.37	2	0.503
Model summary	**R^2**	**BIC**	**BIC global model**
	10.99	615.39	676.64

Coefficient values					
Terms	**Coeff**	**SE**	**Z-Value**	**P-Value**	**VIF**
Confidence level in effectiveness					
High confidence	0.475	0.215	2.21	**0.027**	
No confidence	-1.902	0.552	-3.45	**0.001**	1.02
Time, effectiveness, difficulty, and importance as barriers					
Disagree	0.778	0.255	3.05	**0.002**	1.10
Agree	-0.894	0.268	-3.34	**0.001**	1.09

Table A9.6: Statistical Model outputs - Willingness to accept extra costs without economic incentives

Regression analysis			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	15.11	2	**0.001**
Cost as barrier	8.37	2	**0.015**
Time, effectiveness, difficulty, and importance as barriers	14.03	2	**0.001**
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	3.39	5	0.640
Model summary	**R^2**	**BIC**	**BIC global model**
	10.33	630.62	678.82

Coefficient values					
Terms	**Coeff**	**SE**	**Z-Value**	**P-Value**	**VIF**
Confidence level in effectiveness					
High confidence	0.306	0.216	1.42	0.156	1.12
No confidence	-1.866	0.555	-3.36	**0.001**	1.02
Cost as barrier					
Disagree	0.624	0.403	1.55	0.122	1.23
Agree	-0.381	0.227	-1.68	**0.094**	1.21
Time, effectiveness, difficulty, and importance as barriers					
Disagree	0.655	0.257	2.54	**0.011**	1.15
Agree	-0.593	0.267	-2.22	**0.026**	1.13

Table A9.7: Statistical Model outputs - Frequency of use with economic incentives

Regression analysis			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	20.81	2	**<0.001**
Cost as barrier	6.53	2	**0.038**
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	2.52	2	0.283
Model summary	**R^2**	**BIC**	**BIC global model**
	6.60	481.11	537.33

Coefficient values					
Terms	**Coeff**	**SE**	**Z-Value**	**P-Value**	**VIF**
Confidence level in effectiveness					
High confidence	0.837	0.260	3.22	**0.001**	1.04
No confidence	-1.262	0.476	-2.65	**0.008**	1.03
Cost as barrier					
Disagree	-0.310	0.482	-0.64	0.520	1.33
Agree	-0.734	0.296	-2.48	**0.013**	1.31

Table A9.8: Statistical Model outputs -Frequency of use without economic incentives

Regression analysis			
Terms	**χ^2**	**df**	**p-value**
Confidence level in effectiveness	23.42	2	**<0.001**
Cost as barrier	13.54	2	**0.001**
Goodness-of-fit	**χ^2**	**df**	**p-value**
Hosmer-Lemeshow test	1.01	3	0.798
Model summary	**R^2**	**BIC**	**BIC global model**
	7.92	546.23	609.53

Coefficient values					
Terms	**Coeff**	**SE**	**Z-Value**	**P-Value**	**VIF**
Confidence level in effectiveness					
High confidence	0.877	0.221	3.96	**<0.001**	1.03
No confidence	-1.273	0.586	-2.17	**0.030**	1.02
Cost as barrier					
Disagree	0.287	0.428	0.67	0.503	1.23
Agree	-0.742	0.249	-2.98	**0.003**	1.23