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Economic evaluation of the eradication program for bovine viral diarrhea in the Swiss dairy sector

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Abstract

Since 2008, the Swiss veterinary service has been running a mandatory eradication program for Bovine Viral Diarrhea (BVD) that is focused on detecting and eliminating persistently infected (PI) animals. Detection was initially based on antigen testing from ear tag samples of the entire cattle population, followed by antigen testing of all newborn calves until 2012. Since then, bulk milk serology (dairy herds) and blood sample serology (beef herds) have been used for the surveillance of disease-free herds. From 2008 to 2012, the proportion of newborn PI calves decreased from 1.4% to less than 0.02%. However, this success was associated with substantial expenditures.

The aim of this study was to conduct an economic evaluation of the BVD eradication program in the Swiss dairy sector. The situation before the start of the program (herd-level prevalence: 20%) served as a baseline scenario. Production models for three dairy farm types were used to estimate gross margins as well as net production losses and expenditures caused by BVD. The total economic benefit was estimated as the difference in disease costs between the baseline scenario and the implemented eradication program and was compared to the total eradication costs in a benefit-cost analysis. Data on the impact of BVD virus (BVDV) infection on animal health, fertility and production parameters were obtained empirically in a retrospective epidemiological case-control study in Swiss dairy herds and complemented by literature. Economic and additional production parameters were based on benchmarking data and published agricultural statistics. The eradication costs comprised the cumulative expenses for sampling and diagnostics. The economic model consisted of a stochastic simulation in @Risk for Excel with 20,000 iterations and was conducted for a time period of 14 years (2008 to 2021).

The estimated annual financial losses in BVDV infected herds were CHF 85–89 per dairy cow and CHF 1,337–2,535 for an average farm, depending on the production type. The median net present value (NPV) was estimated at CHF 44.9 million (90% central range: CHF

13.4 million – 69.4 million) and the break-even point to have been reached in 2015. Overall, the outcomes demonstrate that the Swiss BVD eradication program results in a net benefit for the dairy sector. These findings are relevant for planning similar BVD control programs in other countries.

Keywords:

Dairy cattle; Cost-benefit analysis; Gross margin; Control programme

1. Introduction

Bovine viral diarrhea virus (BVDV), a *Pestivirus*, is endemic in cattle populations worldwide, including various European countries, and causes substantial economic losses. These losses result from decreased outputs due to reduced milk production, lower reproductive performance, reduced weight gain, increased mortality, premature culling as well as increased expenditures for veterinary services (Houe, 2003). Different studies show herd-level economic losses between €21–135 per cow (Fourichon et al., 2005; Heuer et al., 2007; Houe, 2003; Lindberg et al., 2006; Valle et al., 2005). Infections with BVDV may either lead to transiently infected or persistently infected (PI) animals, depending on the time of infection (Lanyon et al., 2014). Persistently infected animals are generated from intrauterine infections in an early stage of gestation, are immunotolerant against BVDV, and shed large quantities of virus throughout their lives. Therefore PI animals represent the main source for spreading the virus to naïve animals.

Several European countries implemented either mandatory or voluntary BVD surveillance and control programs (Pinior et al., 2017). The Swiss BVD eradication program has been running since 2008 and is mandatory for the entire cattle population (Presi and Heim, 2010). It is focused on detecting and eliminating PI animals and is divided into three different phases: (i) the initial phase in 2008 when the entire cattle population was earnotched and antigen tested, (ii) the calf phase with antigen testing of all newborn calves from October 2008 to December 2012, and (iii) the surveillance phase with serological testing of disease-free herds via bulk milk (dairy herds) and blood sample (beef herds) analyses since 2012. The results from the census in the initial phase showed that 0.8% of animals and 20.0% of farms were virus positive (Presi et al., 2011). From 2008 to 2012, the proportion of newborn PI calves decreased from 1.4% to less than 0.02% (FSVO, 2016a). However, complete eradication of BVDV in Switzerland has not yet been achieved. In 2015, a total of 111 farms (0.2%) newly infected through PI animals have been reported (FSVO, 2016b). This resulted in an adaptation of the eradication program and the implementation of intensive investigations in newly infected farms, including tracing of all contacts with other herds.

Häsler et al. (2012) conducted an economic analysis of the Swiss BVD eradication program and reported baseline disease costs for the entire cattle sector of CHF 16 million in 2008 and that the break-even point would be reached five years after the start of the program. However, their estimations of the benefits relied largely on data from scientific literature and epidemiological models. Furthermore, the authors predicted that complete eradication would have been achieved in 2012. Hence, as new cases of PI animals continue to occur and eradication costs have surpassed initial predictions, the question was raised whether the program is still economically beneficial.

The aim of this study was to perform a benefit-cost analysis (BCA) of the BVD eradication program for the Swiss dairy cattle sector for the time period of 2008 to 2021. Specifically, the aims were (i) to estimate the benefits and costs of the eradication program in the dairy sector from 2008 to 2021, (ii) to determine the break-even point of the program, and (iii) to assess the net economic value of the BVD eradication program. The analysis took into account the most recent data and adjustments of the eradication program and was supported with empirical data from a recent epidemiological case-control study in Swiss dairy cattle herds.

2. Materials and methods

2.1. General overview and baseline scenario

The benefit of eliminating BVD from the Swiss dairy sector was compared with the total eradication expenditures in a BCA. The analysis included four main components: (i) production models combined with (ii) gross margin (GM) analyses for the benefit estimation; (iii) surveillance and control costs, and (iv) epidemiological case investigations (ECI) expenditures for the overall cost estimation.

The BCA was a combination of *ex post* and *ex ante* analysis. It was conducted for a time period of 14 years: from the start of the eradication campaign in 2008 until the expected end of the campaign in 2021, when complete elimination of BVDV infections was assumed to be reached. This assumption was based on discussions with senior officials responsible for the implementation of the program. The models were developed in MS Excel (Microsoft Corp., Redmond, WA) and the BCA was conducted as a stochastic simulation with the add-on @Risk 7 (Palisade Corp., Ithaca, NY), which allowed for variation of uncertain input variables, and was performed with 20,000 iterations. The built-in @Risk sensitivity analysis tool was used to assess the impact of uncertain input values on the outputs.

All monetary values were expressed in Swiss Francs, CHF (CHF 1 = US$0.99 at the time of analysis). The start of the program in 2008 was set as reference point and all future benefits and costs were converted into present values and discounted at a rate of 2%. The discount rate was estimated using the mean yield on Swiss Confederation long term (20 years) bond issues from 2008 to 2015 (SNB, 2016) subtracted by the mean change in consumer prices (SNB, 2016b) for the same time period. Economic key figures, namely net present value (NPV), benefit-cost ration (BCR) and internal rate of return (IRR), were then calculated as described by Rushton et al. (1999).

The situation at the start of the BVD eradication program was chosen as a baseline scenario and compared with the intervention. For the baseline scenario, the estimated BVDV herd-level prevalence of 20% and a calculated within-herd prevalence of 7% (mean number of virus positive animals per herd: 1.6) derived from the census in the initial phase were used (Presi et al., 2011). As the reported animal-level virus prevalence (0.81%) was similar to the situation in 2000 (0.64%; Rüfenacht et al., 2000), a situation of endemic disease equilibrium was assumed. For the prevalence during the eradication program, the number of case farms with PI animals was obtained from the information system for cases of notifiable diseases (FSVO, 2016c). The future number of cases was predicted using expert opinion. The experts were two specialists (E. Di Labio, H. Schwermer; Federal Food Safety and Veterinary Office, FSVO) with long standing experience and senior roles in the Swiss BVD eradication program. Poisson distributions were fitted to the mean number of cases per year predicted by the experts to account for uncertainty of these values. Demographic characteristics of the Swiss dairy sector were obtained from the annual reports on dairy production published by the Federal Office for Agriculture (FOAG) for the years 2008 to 2015. At the start of the eradication program in 2008, there were 28,014 registered dairy farms in Switzerland, with an average herd size of 20 dairy cows, accounting for an average annual milk production of 114,000 kg/farm (FOAG, 2009). Further input variables on production and disease impact are described in detail below.

2.2. Production models and gross margin analyses

The production models were developed for three main production types based on Swiss benchmarking data (AGRIDEA, 2012; FOAG, 2009): (i) 50% extensive, (ii) 30% medium, and (iii) 20% intensive farms, respectively. Key differentiating variables between the production types were the milk yield and the general farming type: organic dairy production, dairy production for raw milk cheese making with silage-free feeding and standard dairy production with silage feeding. These criteria were also used to define the number of farms per production type and validated with published statistics (SBV, 2012). This approach allowed taking into account the heterogeneity of Swiss dairy farms and production types with regards to production intensity, feed rations, topography, breeds and other associated economic input and output variables. An overview of the three production types is listed in Table 1. Production models were built at the individual animal-level and the assumption to be BVDV negative. The models contained different sections: general production variables (e.g. milk yield, mortality rate, culling rate), economic values (e.g. milk price, value of slaughtered animals), feeding (e.g. amount of concentrates, cost of forage), reproduction and health (e.g. number of artificial inseminations, veterinary costs) and miscellaneous (e.g. hoof trimming, ear tags). The production models are available as supplementary material (see Supplementary Table S1 in the online version at DOI: http://dx.doi.org/10.1016/j.prevetmed.20XX.XXXXX). In a subsequent step, the impact of disease on production was included in the models by adapting respective variables for production, fertility and animal health. Variables on disease impact (Table 2) were obtained empirically in a retrospective epidemiological case-control study in Swiss dairy herds (Tschopp et al., submitted) and from scientific literature. Production and economic variables were based on relevant benchmarking data and published agricultural statistics (AGRIDEA, 2012; SBV, 2012; SMP, 2015).

The production models were used to assess the annual GM for the different production types. The GM was defined as the total revenue from dairy farming minus the variable costs for the same operation. The revenue was the amount of money a farm receives for selling of milk and animals, namely calves for fattening, calves for breeding, slaughtered heifers and slaughtered cows. The variable costs comprised replacement, feed, veterinary and miscellaneous costs. Replacement costs contained the expenditures for restocking with own heifers. The feed costs consisted of costs for concentrates and forages and were calculated considering dry matter intake and milk yield. For each of the three production types GM were estimated for both BVDV free and BVDV infected farms. The annual economic loss of a BVDV infected farm was defined as the difference in GM between a BVDV free and a BVDV infected farm.

2.3. Estimation of total disease cost and benefit for the dairy sector

The economic benefit was estimated as the difference in disease costs between the baseline scenario and the implemented eradication program, i.e. the avoided production losses and disease expenditures. First, the annual economic losses for the dairy sector were estimated by multiplying farm-level losses with the number of BVDV infected farms. Consequently, the baseline scenario contained 20% (n = 5,608) BVDV infected dairy farms, and the years after the start of the eradication program the corresponding number obtained from the annual prevalence. The number of infected farms was distributed proportionally to the number of farms per production type. To estimate the total loss for the dairy sector for both the baseline scenario and the intervention, the number of BVDV infected farms per production type was multiplied with the corresponding median farm-level losses. Then, the annual benefit was estimated as the difference between the annual disease costs with the intervention and the baseline scenario. Finally, the total cumulative benefit of the BVD eradication program was calculated by summing up all annual economic benefits for the years 2008 to 2021.

2.4. Estimation of total eradication costs

The total cumulative eradication costs consisted of two components: estimations of surveillance and control costs and expenditures for ECI. The assessment of the surveillance and control costs consisted of separate estimations for three time periods. For 2008 to 2011, cost estimates were based on Häsler et al. (2012). As their estimates did not distinguish between dairy and beef sector, the costs were proportionally distributed by 2:1, according to the reported dairy-beef ratio in number of animals (FSVO). For 2012 to 2017, costs data were based on annual budgeting reports from the FSVO (Antrag Nationales Überwachungsprogramm, 2012–2017). Finally, for 2018 to 2021, costs were assessed by combining 2017 budgeting estimates with predictions on future development of the control program by the means of expert opinion.

In addition to the regular surveillance and control activities, extended ECI are performed since 2016. Every time a new PI animal is detected, epidemiological investigations are conducted to identify the source of infection and describe potential spread. Data on 22 performed investigations served as reference and were analyzed to define variables to estimate the average costs of an ECI. These consisted of expenditures for farm visits (CHF 28.00 per farm), blood sampling (CHF 8.50 per animal) and median costs for diagnostics (CHF 71.70 per animal). Labor costs were defined as fixed cost and not considered. The average costs per ECI (taking into account the median number of animals and farms) was then multiplied by the detected or predicted PI cases for the time period 2016 to 2021 to calculate the total ECI expenditure.

3. Results

3.1. Financial impact of BVD and benefit estimations

In general, stochastic model outputs were not normally distributed and estimates are, unless stated otherwise, reported as medians. The annual financial losses of BVDV infected Swiss dairy herds, expressed as the difference in GM between a BVDV free and a BVDV infected herd, were estimated to be CHF 1,337 (90% central range, CR: CHF 914–1,665) for extensive, CHF 1,755 (90% CR: CHF 1,220–2,170) for medium and CHF 2,535 (90% CR: CHF 1,775–3,138) for intensive production types, respectively. Annual animal-level losses were found to be CHF 85–89 (90% CR: CHF 59–111) per dairy cow in a BVDV infected herd (Table 3). The baseline disease costs for the Swiss dairy sector prior the start of the eradication program were estimated to be CHF 9.5 million (90% CR: CHF 6.6 million – 11.8 million). The cumulative discounted benefit in the dairy sector from 2008 to 2021 was estimated to be CHF 102 million (95% CR: 71 million – 127 million).

3.2. BVD eradication program costs

The cumulative discounted eradication costs for the dairy sector from 2008 to 2021 were estimated to be CHF 60.9 million (90% CR: 60.6 million – 61.2 million). The initial phase accrued expenditures of CHF 22.7 million. The calf phase incurred annual costs of CHF 6.3 million – 8.6 million. The ongoing surveillance phase accrues annual costs between CHF 0.5 million – 1.7 million, also including expenditures for ECI for the period 2016 to 2021. An overview of annual surveillance and control costs is shown in Figure 1. Epidemiological case investigations varied considerably with respect to the number of farms and animals involved. In the event of a newly discovered PI animal, 20 farms (min = 2, max = 202) and 137 animals (min = 12, max = 634) were tested for BVDV. The average cost of an ECI was CHF 13,828 and in total ECI accounted for expenditures of CHF 2.2 million (90% CR: CHF 1.9 million – 2.5 million) in the years 2016 to 2021.

3.3. Benefit-cost analysis

The comparison of the cumulative benefit and eradication costs of the BVD eradication program resulted in a NPV of CHF 44.9 million (90% CR: CHF 13.4 million – 69.4 million), a BCR of 1.78 (90% CR: 1.23–2.21) and an IRR of 16.7% (90% CR: 6.7%–24.0%). The break-even point (when the cumulative benefit surpasses the cumulative expenditures), was estimated to have been reached seven years after the start of the eradication program, namely in 2015. The sensitivity analysis showed that the outcome was most sensitive to changes in the variables describing disease impact. In particular, reduced milk yield and veterinary costs had a strong association with the NPV and had the highest regression coefficients of 0.85 and 0.49, respectively. The regression coefficients of the calf mortality rate and the calving interval were 0.12 and 0.07, respectively. All other variables had regression coefficients of < 0.05.

4. Discussion

This study presents an economic evaluation of the Swiss BVD eradication program for the dairy sector and reports estimates at the animal, farm and national level. The total benefits of BVDV eradication exceed the total costs induced by the control program for the dairy sector thereby demonstrating that the eradication program is beneficial. The break-even point has been reached after 7 years and the program will generate a net benefit for the sector over the 14-year time span considered in the study.

When comparing our findings with results from other studies, differences in study design as well as differences in BVD control program and farm demographics have to be considered. In general, animal-level estimates for financial losses attributable to infection with BVDV lie in the range of published literature values (Fourichon et al., 2005; Heuer et al., 2007; Houe, 2003; Lindberg et al., 2006; Pinior et al., 2017; Valle et al., 2005). Slightly higher monetary values compared to estimates from other European countries might be explained with the generally higher production costs in Switzerland. The higher price level has an effect on various input variables such as milk price, veterinary costs, slaughter value or feed costs. When comparing national- and farm-level estimates with other studies, it has to be considered that these estimates highly depend on the number of farms and animals per farm, respectively.

The previous Swiss study by Häsler et al. (2012) reported cumulative discounted benefits of CHF 131 million over a 10 year time span. However, the analysis was conducted for the entire cattle sector and the predictions were based on the assumption that complete elimination of PI animals would have been achieved after four years. Our analyses benefitted from experience and data that were gained over the recent years, as it was conducted at a later stage during the ongoing eradication program. The results from our study considered adjustments made to the eradication program and were supported with empirical data on disease impact variables. Furthermore, our estimates were obtained from production models and GM analyses, and reflect average values for three typical production types in Switzerland.

These models allowed accounting for differences in management practices between production types and facilitated capturing cascade effects of disease variables, which would be difficult to assess otherwise. In addition, results expressed as GM permit comparison with published values and consequently validation with existing benchmarking data. Furthermore, the results allow Swiss dairy farmers and their veterinarians or technical advisors to determine approximately BVDV induced losses on their farms and show how profitability changes.

The economic evaluation was performed for the dairy sector, which is the largest cattle sector in Switzerland. Benefits for the beef sector were not assessed, because detailed production and disease effect data were lacking. Currently, the beef sector surveillance and control costs are larger than those for the dairy sector, as blood sampling is more expensive than the bulk milk testing of the dairy farms (FSVO, 2016d). To assess the beef sector benefits required to maintain a positive NPV for the entire program, we compared dairy sector benefits with the estimated discounted overall costs of the eradication program, including the beef sector (data not shown). Even when assuming no financial benefits in the beef sector, the break-even point was predicted to be reached in 2019 and thus the eradication program would still result in a financial net benefit after 11 years. It has to be noted that the findings from the BCA depend on future BVDV incidences as well as the eradication program and its associated costs. However, current annual benefits exceed current costs and the program generates a net benefit every year. This implies that even if complete eradication will not be achieved in 2021, but the number of cases and control costs stay similar to the current level, the program will still result in a net benefit. Furthermore, the results from the BCA depend on the applied discount rate, which is needed to convert future values of benefits and costs into present values. The 2% used in our analysis was estimated using a standard procedure and is based on current market values. Discount rates used in several previous economic evaluations for BVD range from 2%–4% (Häsler et al., 2012; Houe, 2003; Santman-Berends et al., 2015; Valle et al., 2005). The IRR estimated in this study (16.7%; 5% percentile: 6.7%) implies that discounting with a rate up to these values would still result in a positive NPV, as the IRR is reflecting the discount rate that would make the NPV equal to zero (Rushton et al., 1999).

One of the main limitations of this study was the nature of the disease effect variables that were obtained from the case-control study (Tschopp et al., submitted). Due to the case definition, these estimates reflect the situation of farms that are chronically infected with BVDV. Transiently infected farms and infection of naïve herds, which often experience more severe effects, were excluded from the analyses, which might have led to an underestimation of the disease effects. Furthermore, for effects that were significant only at a liberal significance level ($p > 0.05$), zero effect was used as the minimum value of the fitted probability distributions applied in our study, which led to larger ranges of possible input values. As a result, CR of benefit estimates were relatively large and the disease impact variables were found to be the most sensitive input variables. The sensitivity analysis showed that the reduction in milk yield was that most sensitive input variable. As milk is the main output of dairy farms, large effects on the farm revenue and GM were expectable. The wide input range of the increased veterinary costs per cow, multiplied with the number of cows per farm, explains the considerable sensitivity of this variable. In contrast, the surveillance and control costs were found to be less correlated with the outcome, which is due to the fact that the uncertainty of these input values was relatively small. Estimations on future number of cases as well as on the development of the control program and associated costs are subject to inherent limitations of predictions that are based on expert opinion. Furthermore, the assessment of average ECI costs was based on a sample size of 22 cases only, and thus values used in the model are subject to some uncertainty. However, the reported overall cost estimates of this study still show relatively small CR. This is due to the fact that the analysis relies predominantly on retrospective and accurate official records collected since the start of the program.

Overall, the outcomes demonstrate that the Swiss BVD eradication program results in a net benefit for the dairy sector. The findings from this study are a significant contribution to the growing body of evidence on the economic value of BVD control programs, and might be indicative for similar BVD control programs under comparable production and market environments.

5. Conclusions

The Swiss BVD eradication program was shown to result in an estimated net benefit of CHF 44.9 million in the dairy sector. Prior to the start of the eradication program, BVDV infections caused annual losses of CHF 85–89 per cow. At the farm level, annual losses of CHF 1,337–2,535 were estimated, for the production types and farm sizes considered in our model. The eradication program was associated with substantial expenditures, especially during the initial phase when all animals were sampled and tested for virus antigen. However, the break-even point was reached in 2015; the program has been generating a net benefit since that time. Even though complete elimination of BVDV infections is not yet reached, annual benefits surpass current expenses for the surveillance and control of BVD. In conclusion, the results from this study indicate that the BVD eradication program is beneficial and justify its implementation.

Conflicts of interest

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Figure 1

Annual costs of the Bovine Viral Diarrhea (BVD) eradication program in the Swiss dairy sector.

Figure 2

Median cumulative discounted costs and benefits (including 90% central range; dotted lines) of the Bovine Viral Diarrhea (BVD) eradication program in the Swiss dairy sector.

Figure.1

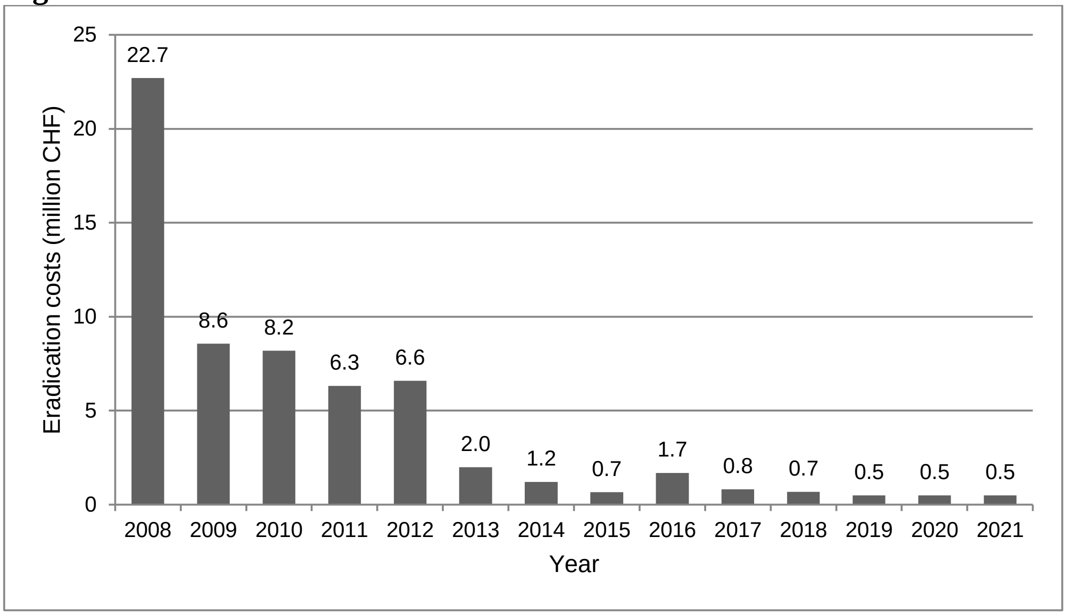

Figure 2

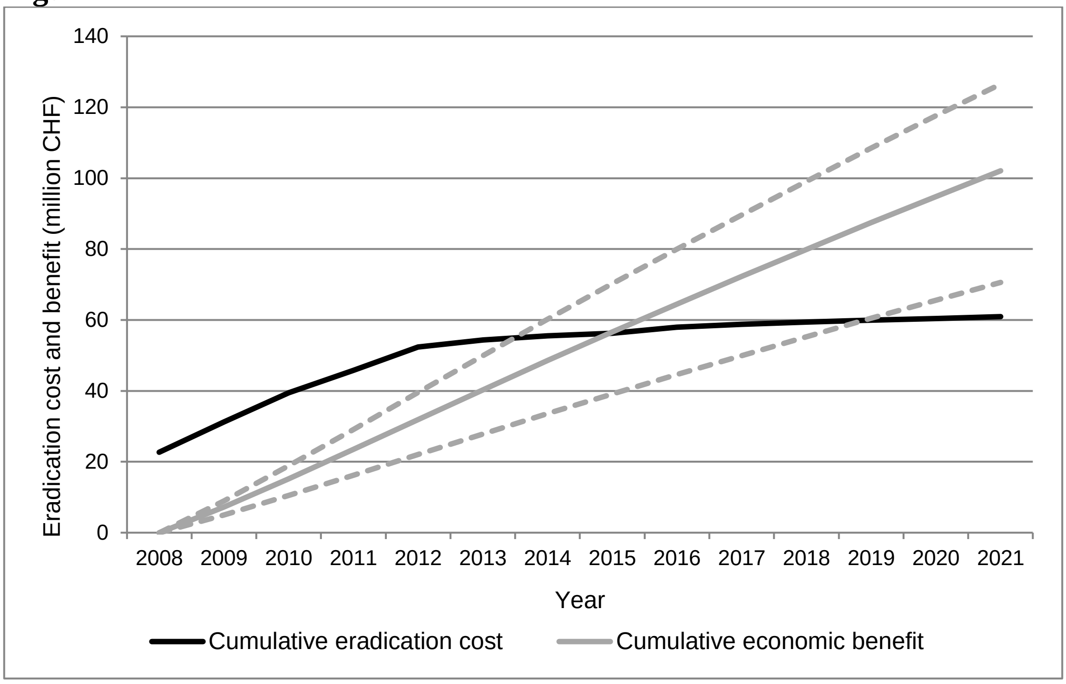

Table 1
Farm characteristics of the 3 production types and input data used to estimate Bovine Viral Diarrhea (BVD) disease costs.

Production type	Extensive	Medium	Intensive
Milk yield (kg/305d)	6,000	7,000	8,000
Milk specification	organic	raw milk cheese	standard
Milk price (CHF/kg)	0.78	0.69	0.58
Herd size (n)	15	20	30
Forages			
Grass (%)	52	55	53
Hay (%)	18	45	17
Grass silage (%)	15	-	15
Corn silage (%)	15	-	15
Concentrates (kg/d)	0.8	2.9	2.5

Table 2
Disease input variables used to assess the economic impact for Bovine Viral Diarrhea Virus (BVDV) infected farms.

Variable	Value or distribution	Description/source
Milk yield reduction (%)	Pert (0, -1.87, -2.29)	Average milk reduction per cow in a BVDV infected herd. Calculated based on Tschopp et al. (submitted)
Veterinary costs (CHF)	Pert (0, 15.43, 38.41)	Average annual costs per cow in a BVDV infected herd. Calculated based on Tschopp et al. (submitted)
Calf mortality (%)	Pert (1, 2.39, 3.78)	In addition to normal calf mortality. Calculated based on Viet et al. (2004), Presi et al. (2011) and Häsler et al. (2012). Considering PI animal within-herd prevalence of 7% and a corresponding mortality rate of 50%.
Cow mortality (%)	Pert (1.0, 1.1, 2.0)	In addition to normal cow mortality. Derived from Duffell and Harkness (1985)
Calving interval (%)	Pert (0.2, 1.1, 1.9)	In addition to normal calving interval. Calculated based on Tschopp et al. (submitted) and Burgstaller et al. (2016)

Table 3
Median differences in Gross Margins (in CHF, including 90% central range; CR) of Bovine Viral Diarrhea Virus (BVDV) free dairy farms compared to BVDV infected dairy farms.

Production type	Extensive	Medium	Intensive
Animal level	89	88	85
(90% CR)	(61–111)	(61–108)	(59–105)
Farm level	1,337	1,755	2,535
(90% CR)	(914–1,665)	(1,220–2,170)	(1,775–3,138)