Wageningen University – Department of Social Sciences

MSc Thesis Business Economics

Cost effectiveness of longevity traits in breeding of dairy cows

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ABSTRACT

As new phosphate regulation is introduced in the Netherlands and replacement costs are considerate, longevity is an attribute that becomes more interesting. The objective of this research is to evaluate the economic impact of breeding with longevity traits in Dutch dairy cows. A bio-economic stochastic simulation model was developed to compare longevity bred cows to base cows. In the base scenario cows have a conception rate of 0.5 and an average milk yield of 8,310 kg. In the longevity scenario cows have a conception rate of 0.58 and an average milk yield of 8,000 kg. The net present value (NPV) estimates the economic impact of each of the breeding scenarios. Net cash flow per year was determined based on milk production, feed costs, insemination costs, veterinary costs, calf management costs and replacement costs from the returns on milk and calf sales. Results showed that 3 years after the first cow of the new breeding decision enters the herd, the longevity scenario is more profitable than the base scenario, increasing to a difference of 10 euros per cow place in year 5. The NPV of the base and longevity scenario differ by 7 euros per 5 years with an advantage to the base scenario. The sensitivity analysis revealed that the results are sensitive for milk price. The sensitivity analysis showed that at low milk prices, the longevity scenario is favorable (with a difference of 75 euros per cow place) and at high milk prices the base scenario (with a difference of 74 euros per cow place). With an expected future milk price of 29 cents/ kg milk farmers should consider breeding for longevity.

CONTENT

1. INTRODUCTION

Considerable replacement costs of €1,567 on average per heifer makes lowering the replacement rate interesting (Mohd Nor et al., 2012). As Mohd Nor et al. (2015) already examined a decrease of 6.5% in rearing costs is possible with a different replacement strategy. For the cost of replacement rate to decrease further the replacement rate (30% on average in the Netherlands ((Mohd Nor et al., 2012)) must be reduced and therefore the longevity of dairy cows must be higher. Longevity can be defined as the capability of a dairy cow to not become prematurely culled (Vollema, 1998). Cows with an improved longevity thus have a longer productive lifetime compared to individuals that have not (Pritchard et al., 2013). The current longevity of Dutch dairy cows is 1,128 productive days with average calving interval 417 days.

In addition to the economic motives, increasing longevity is also encouraged from a social perspective. Society considers animal welfare as an important aspect of animal husbandry. An example of society affecting farming methods is the rapid-growth broilers. Because the largest supermarkets in the Netherlands stopped selling the rapid-growth broiler due to societal pressure, farmers were forced to produce in a way that considered animal welfare more (Pijpker, 2015). Since longevity has become more and more an indicator of animal welfare in dairy farming (Bruijnis et al., 2012; Thomsen and Houe, 2006), it might be important for farmers to improve longevity.

Another factor which makes increasing longevity interesting is the change in the production restricting regulation for the dairy industry in the Netherlands. The milk quota system was abolished and new regulation now limits the phosphate emissions on farms in the Netherlands (Dijksma, 2015). This means that famers are limited in the amount of animals they can keep. In dairy farming a part of the 'phosphate rights' needs to be used for young stock, which implies that when less heifers need to be reared for replacement, less young stock has to be kept and more of the 'phosphate rights' are available for the milk producing dairy cows. This makes it interesting to create a situation in which the replacement rate is lowered.

One way to improve longevity in dairy cows is via breeding (Zijlstra et al., 2014). Traditionally dairy breeding programs have, however, been focusing on an increased milk yield per cow (Atsbeha et al., 2014). This has led to a steady increase in yield per cow (van Arendonk and Liinamo, 2003). For the Netherlands Cooperatie RundveeVerbetering (2014) reports an average production per lactation of 4,010 kg in 1950 to an average production of 8,867 kg in 2005. This production focus has a negative effect on animal welfare including health, longevity and fertility (Oltenacu and Broom, 2010). Oltenacu and Algers (2005) reported a decreased percentage of dairy cows that reached the age of 48 months decreased, from 80% to 60% from 1957 to 2002 in the US. In the Netherlands the lifespan of dairy cows decreased from 2006 to 2012 to an average of 5.9 years (Boer and Zijlstra, 2013). Similarly, fertility decreased in 1980 2.0 inseminations were, on average, needed for conception in the US, this has increased to 3,5 in 2000 (Oltenacu and Algers, 2005). Likewise in the UK the pregnancy rate to first service decreased from 56% in 1975 to 40% in 1995 (Royal et al., 2000). To deal with these negative effects on the longevity of dairy cows, longevity has been added to the Dutch breeding evaluation model for the first time in 1999 and has been a part of the evaluation ever since (Linde et al., 2004a). This shows that the decreasing longevity in dairy cows is acknowledged as a problem and is considered important.

The economic effect of longevity can be measured as the increase of the Net Present Value (NPV) that arises when involuntary replacement is removed (Stott 1994). In a dynamic programming model developed by Stott (Stott, 1994) it was found that an increased longevity has a worth of 20 pounds per lactation per year for UK dairy cows. Steinwidder and Greimel (1999) found that the profit per cow per year and the profit per farm per year increased with longevity, based on data from Austrian Simmental cows. Horn et al. (2012) found that extending longevity in Austrian organic Simmental cows allows lower milk yields without decreasing profitability. Although these studies establish an economic impact for longevity, it is not yet proven what the economic impact of breeding for longevity is, by taking the possible improvements, breeding trade-offs and breeding delay into account.

Longevity is found to be an important aspect in dairy farming and has an impact on farm economics. Multiple biological factors, such as conception rate, milk yield and calving interval, have effect on the lifespan of a cow, but also on each other (Pritchard et al., 2012). Furthermore, each of the factors is subject to variance and uncertainty, which is why a stochastic modelling approach is used in this study. Economic quantification of improved longevity via a breeding programme has, up to the author's knowledge, not been performed and is vital to give farmers and animal breeding organisations insights in the economic consequences of their breeding decisions towards longevity. This study therefore aims to investigate the economic impact of increasing the longevity of Dutch dairy cows by breeding for a longer productive life.

In the following chapters the research objective and questions are stated, literature is discussed, the materials and methods are described, the results are given and discussed. The report will end by giving a conclusion of the research.

2. RESEARCH

2.1. Research objective. The objective in this research is to determine the economic effects of breeding dairy cows with longevity trait. We will use a stochastic dynamic biological model to estimate the economic effects of breeding incentives that lead to increased longevity.

2.2. Research question. The main question resulting from the problem statement is:

What is the economic impact of breeding with longevity traits in Dutch dairy farms?

To answer this question some sub-questions need to be answered.

What is the possible improvement concerning longevity in Dutch dairy cows?

What is the correlation/relation/trade-off of longevity with other breading traits?

Which cost factors need to be taken into account and what are the corresponding values?

3. LITERATURE REVIEW

3.1. Longevity. This paragraph will discuss the definition of longevity and previous researches that attempted to define the value of longevity

Longevity in dairy cows is usually defined as the capability of a dairy cow to survive (Vollema, 1998). In this case by survival, the cow's ability to not getting a disease, lameness or other reasons for 'involuntary culling' is meant. Measurement of longevity is usually done in days of life or days of productive life (Pritchard et al., 2013).

The value of longevity has been researched before in different ways. Stott (1994) for example has defined the value of longevity as the decreased NPV that arises when involuntary culling is removed. Stott claims that involuntary culling is the reason cows do not have a larger lifespan. He uses a stochastic model in which the value of longevity is determined as the Net Present Value of the replacement heifers needed. He compared two situations in his model, with and without involuntary culling. The difference would be the value of longevity according to Stott. He used data on involuntary culling to create the difference. He stated that longevity has a worth of 20 pounds per extra lactation per year in the U.K. being corrected for the made investment potential.

Steinwidder and Greimel (1999) used data of Austrian Simmental cows to see the effects of a longer lifespan to the economics of a farm. He grouped the cows into different groups based on performance on either longevity or milk production. He found that based on his data that profits per cow increased linearly with milk yield. Profits increased digressive with longevity.

Also Horn et al. (2012) used available data to investigate the value of longevity. They used data on Austrian organic Simmental cows, which was used as input for a bio-economic model. The results are compared by taking the results of the best 50 animals and the average performance of each lactation group. Horn et al. used a target profit of €4,000. The model calculated the needed lifespan and milk yield in organic Simmental cows with a short lifespan and high milk yields and the needed lifespan and milk yield in cows with higher lifespan and lower milk yield. 7,300 kg of milk were needed per cow in a herd with an average lifespan of two lactations to reach target profit. 6,650 kg where needed for a herd with an average lifespan of three lactations, 6,400 for four lactations and 6,150 for five lactations. He concluded that long-living animals need substantially lower milk-yields than short-living animals to reach the same profit outputs.

Previous research shows that it is interesting to increase longevity in dairy cows. One of the ways to do this is by breeding. The next paragraph describes the Dutch breeding situation.

3.2. Breeding. This research focusses specifically on what breeding can do for longevity. This paragraph therefore explains the history and specifics on breeding in dairy farming.

Nowadays in breeding different aspects are taken into account. Whereas in history breeding mainly focussed on milk yield. Before the 1960's breeding focussed mainly on production-related traits (Atsbeha et al., 2014). This lead to a steady increase in milk production (van Arendonk and Liinamo, 2003), but also had negative effects on animal welfare, longevity, health and fertility (Oltenacu and Broom, 2010; Oltenacu and Algers, 2005; Royal et al., 2000). From the 1960's to the 1990's a shift occurred, and more other traits, such as fertility, mastitis resistance and conformation where added to the breeding programmes (Atsbeha et al., 2014). In 1999 longevity was added to the genetic evaluation in the Netherlands (Linde et al., 2004b). This lead to an increase in lifespan in the Netherlands, however from 2008 to 2012 the lifespan decreased to an average of 5.9 years (Boer and Zijlstra, 2013).

In the Netherlands genetic improvement of dairy cows is organized in a few official organisations. These organisations are CRV, GES (Genetische Evaluatie Stieren) and FHRS (Fries-Hollands Rundvee Stamboek). The purpose of these organisations is to evaluate breeding traits, ensure the herd diversity and registration. Furthermore the NVO (Nederlandse Veeverbeterings Organisatie) critically reviews the genetic evaluation of dairy cows (Remmelink et al., 2015).

CRV, GES, NVO and FHRS are using breeding values to estimate expected performance of the offspring. Concerning the durability of dairy cows the following statistical model is used to estimate the breeding value (GES, 2015):

$$Y_{ijklmnopqrstu} = BHJ_i + PARSTAD_j + PARJ2M_k + BGV_l + LEA_m + HETER_p + RECOM_q + V_r + MV_s + GG_t + rest_u$$

In which:

$Y_{ijklmnopqrstu}$	: Chance of replacement of a cow
BHJ_i	: Farm half-year class I,
$PARSTAD_j$	: Parity-lactationstage class j
$PARJ2M_k$	: Parity-year-2-monthly class k
BGV_l	: Farm-size-change class l
LEA_m	: Age at first calving m
$HETER_p$	: heterosiseffect p
$RECOM_q$	: recombination-effect q
V_r	: father-effect r
MV_s	: Mother-father-effect s
GG_t	: Genetic Group t of maternal grandmother
$rest_u$	: rest-term u

3.3. Replacement. As explained in the introduction of this research the costs of replacement of dairy cows is the main cost factor which is impacted by longevity. In this paragraph the current replacement rate, the estimated costs for replacement and the perception of farmers towards replacement are discussed.

Culling is defining the eventual replacement rate. The chance for a cow to be culled is not equally divided throughout the year. It is dependent on the parity the cow is in and the lactation stage within a parity. In Figure 1 the dynamics between parity, lactation stage and survival and chance of culling (risk) is shown (Heise et al., 2015).

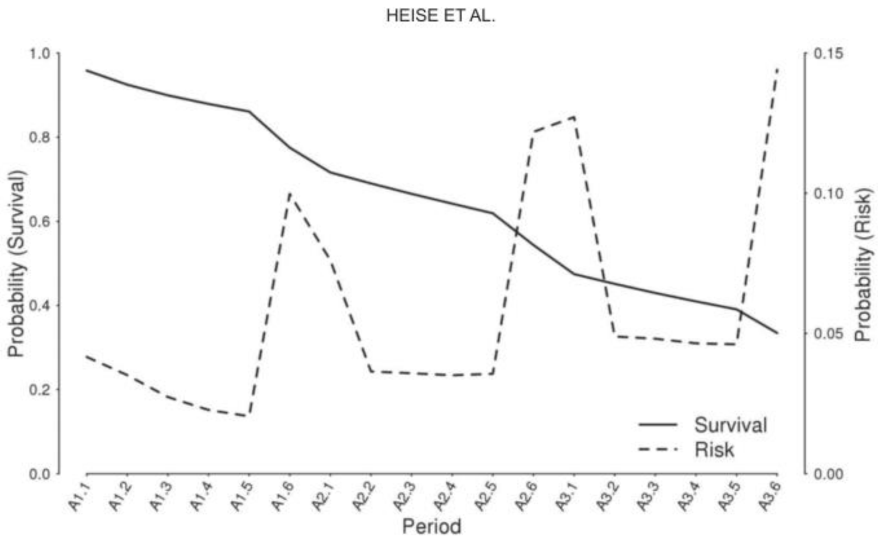

Figure 1: Dynamic risk vs survival of dairy cows

The replacement rate is mostly expressed as the percentage of cows that needs to be replaced in the dairy herd per year. The replacement rate varies between countries and between farmers within a country. In the U.S. the average replacement rate in dairy herds is 35% (Smith et al., 2000). This percentage is an average over different regions within the U.S. between North and south the replacement rate varies between 34 and 36 percent. Apart from regions the replacement rate also varies between farmers. Especially the size of the farm seems to have impact in the U.S. Smith et al. (2000) grouped small, medium and large farms into groups. The average replacement rate for small farms appeared to be 31% while in large farms this was 37%. In the Netherlands the replacement rate is lower than in the U.S. In 2010 this rate was on average 29.6% (Mohd Nor et al., 2014). Also in the Netherlands there is a spread with regard to the replacement rate. The standard deviation was 6.5. The wide of the spread implies that improvements are possible.

When the replacement rate changes, also the age distribution within the herd changes (table1). Although it is an old source, the distribution rules of Mandersloot and Meulen (1991) are still applicable to modern dairy farming.

Table 1: Parity distribution given a certain replacement rate

	20%	25%	30%	35%
1	20	25	30	35
2	17.5	20	22.1	23.6
3	15.6	16.4	16.7	16.4
4	13.5	13	12.1	10.9
5	11.2	9.9	8.4	6.9
5 +	22.2	15.7	10.7	7.2
	100.00	100.00	100.00	100.00

The costs of replacement are based on the rearing of heifers to replace dairy cows. In the Netherlands these costs are estimated on €1567,- (Mohd Nor et al., 2012). These costs contain feed costs, labour costs, barn costs, prevention, veterinary treatment, calf price and breeding costs. Since not all calves make it to heifer, also the costs of those losses are accounted for in the average costs for a successfully reared heifer. Feed and labour are the largest cost elements, being 44.5% and 31.8% respectively.

Farmers do not always see the correct amount of costs for rearing. Costs for feed are usually made in a few periods a year (harvesting) and the harvested feed is used for the dairy herd and for young stock. Of this big pile of feed costs it is not always clear which part is used for young stock and which part for the dairy herd. Farmers do not really keep track of the costs for rearing. Research showed that it gives a big difference between the actual costs for rearing and the perceived costs for rearing (Mohd Nor et al., 2015a). This research used the tool JONKOS to compare the perceived costs for rearing and the actual estimated costs. On average farmers perceived the costs of rearing €760 lower than the actual on farm rearing costs. This would explain why the replacement rate and longevity used to get relatively low attention from farmers and breeders.

3.4. Cow specifics/biological change/trade-offs. In this research the effects of breeding for longevity to fertility, milk yield and replacement are important. In the UK research found the genetic correlation between breading traits that recently have been found important (Pritchard et al., 2012). Among these breading traits is longevity. The genetic correlation between milk yield and longevity is found to be -0.34 (Pritchard et al., 2012). This means that when breeding for longevity the performances of milk yield decrease. Likewise the correlation between longevity and the number of inseminations is -0.42. Which means that when longevity increases, less inseminations are needed for conception. Also the calving interval has a negative correlation with longevity being -0.54, which means that the calving interval is expected to decrease when breeding for longevity.

4. MATERIALS & METHODS

4.1. Model functionality. A stochastic Monte Carlo simulation model developed by Rutten et al. (2014) was used and adapted for the aim of this study. Excel (Microsoft Corporation, Redmond, WA, USA) with @Risk add-in software (Palisade Corporation, Ithaca, NY, USA) was used to develop and simulate the model. For the purpose of this study two scenarios were modelled. The first scenario focusses on the subject of this research, longevity. In this scenario cows bred for longevity traits (L) could enter the herd when the decision was made to breed for longevity and after the model ran stable (7 model years). In this research we were interested in the development of the cow place over multiple years to see the effect of breeding. Therefore (L) cows could only enter the herd as a consequence of natural replacement. The second scenario does not involve genetic improvement by breeding and is assumed representative for the current Dutch dairy farming situation where breeding incentives are mostly focused on milk yield. (L) Cows have an assumed increased lifespan of 250 days a trade-off on milk yield of approximately 300 kg and a conception rate of 0.08 (personal communication, M. van Pelt) compared to the second scenario cows. In the second scenario the cows (base cows) represent the average Dutch dairy cow. The simulation continued until 5 years after the first (L) cow had entered the herd. For both scenarios technical model output was aggregated and collected and used for economic calculations. In this chapter the functionality of the model by Rutten et al. (2014) is shortly described. Furthermore, the model adaptations are elaborated. Also the inputs and assumptions of the model are stated.

Table 2: Input parity distribution (Mandersloot and Meulen, 1991)

Parity	Frequency
1	32%
2	25%
3	18%
4	11%
5	9%
5+	5%

The model developed by Rutten et al. (2014) simulates an individual cow place in which the dynamics of a dairy cow on that specific cow place were simulated in weekly time steps. Each simulation begins with a cow in a cow place with an assigned parity and production level. The assigned parity was drawn from the average herd distribution given in Table 2. The model consists of the reproductive cycle, the lactation stage and milk production. These processes run parallel and are affected by each other. The reproductive cycle starts at calving and ends when the cow calves and moves on to the next reproductive cycle or when a cow gets culled and replaced. In the reproductive cycle, the ovulation, heat detection, insemination and conception were modelled. Detection rate was based on the average herd detection rate, the lactation value and milk yield. If heat was detected and the moment is past the voluntary waiting period a cow gets inseminated. The conception was determined by the average herd conception rate, lactation value, parity and postpartum disorders such as metritis. The cow proceeds to the next parity after being dried of and after calving.

During the whole lactation the cow has a chance of getting culled for general reasons. Furthermore a cow can get culled for fertility reasons. This is when no conception is established. Directly after calving the cow starts giving milk. The milk production is based on the cow’s lactation stage, age, pregnancy and farm-level milk production. Weekly feed requirements were based on the milk production level at each specific week.

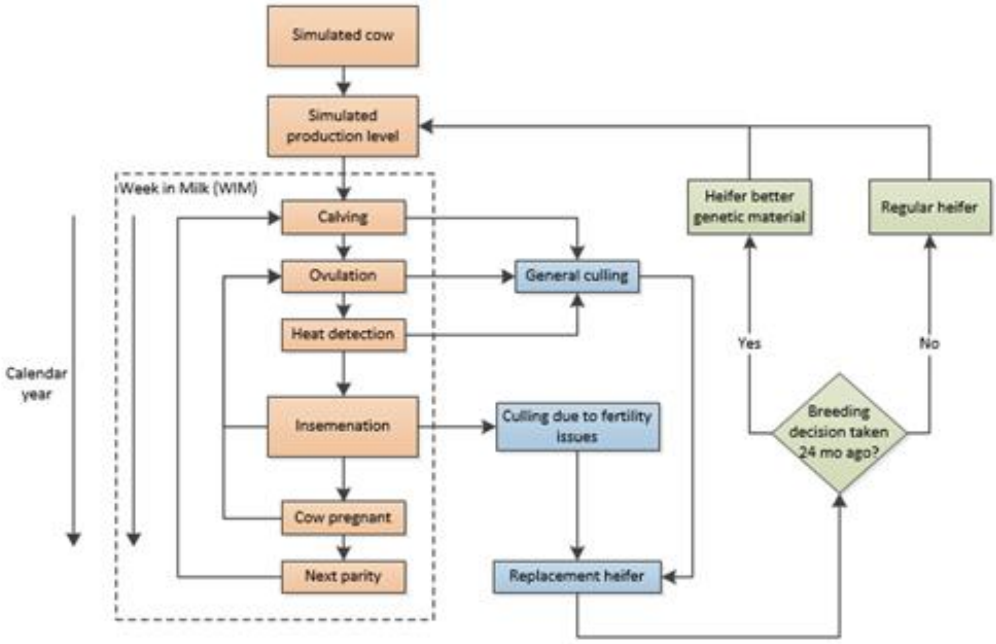

Figure 2: Schematic overview of cow simulation model, which represents the lactation. The model starts at calving and ends at culling or going to the next parity and simulates the events of a reproductive cycle. The model can differentiate cows based on genetic characteristics.

The scheme in figure 2 represents the functionality of our model. Additional to the model developed by Rutten et al. (2014) a decision moment was built in concerning the breeding strategy. Furthermore the ability of distinguishing between genetic parameters was added to the model. The differences in genetic parameters had effect on fertility rate, culling rate and replacement rate of heifers. Furthermore it had effect on the production level of the cows. The alterations to each of these components are described in more detail in the following sections.

4.2.Technical calculations

Type

At the start of each simulation all dairy cows started with status B, when the decision to breed for longevity was made this could change thereafter to L when a new heifer entered the herd.

To differentiate the longevity cows from the base cows a characteristic had to be added into the model. This typology is fixed per individual cow during the entire lifetime. The following formula determines the $TYPE_{ij}$ (L) or (B) of cow_i in $parity_j$:

$$TYPE_{ij} = \begin{cases} IF\ parity_j\ = 1\ AND\ current\ year \geq Year\ of\ Entry \\ \qquad\qquad THEN\ decision \\ \qquad\qquad ELSE\ \ TYPE_{i,j-1} \end{cases}$$

At each parity it was determined whether a new cow_i entered the cow place. This is the case when the $parity_j$ of cow_i was 1. When a new cow entered the cow place, it was determined if this was before or after the breeding decision was taken by measuring if the current year is equal or greater than the first possible year of entry (parameter based on first year that the model ran stable). If a new cow had entered and the current year was greater than the first possible year of entry the type was set as L or B depending on the scenario. If no new cow entered the cow place or when this was before the breeding decision was taken, $TYPE_{ij-1}$ was taken.

Conception rate (CR)

The CR is dependent on the parity and the correction factor that corresponds with the factor for parity (FP), the factor for lactation value (FLV), postpartum disorders such as metritis (ME) and the average herd CR. The average CR is set at 0.58 for longevity cows and 0.5 for base cows. The CR is dependent on the $TYPE_{ij}$ such that:

$$CR_{ij} = \begin{cases} IF\ TYPE_{ij} = (L) \\ THEN\ 0.58 \\ ELSE\ 0.50 \end{cases}$$

In appendix 1 it was established that breeding for longevity can improve the lifetime of dairy cows by around 250 days in one generation (personal communication). The fertility can improve to a CR up to 0.58 (personal communication).

To determine model CR for a longevity bred cow an initial parametrisation of the model had to be performed to determine the CR associated with an L type cow. To measure and check these effects, the average lifespan per cow, in days, of both scenarios was estimated. The first cow of each iteration usually doesn't start at parity 1 and the last cow might not be culled yet in the last modelled lactation period. To ensure the integrity of this figure, the first and the last cow of each iteration were not taken into account. First the effects of the improved fertility were modelled. To do so, general culling was excluded, since this would give a clouded view of the fertility effect. After an initial parametrisation a CR of 0.58 extended the lifetime, on average, with 250 days.

General culling rules

In the model a cow can either be culled due to fertility reasons, which are affected by the conception rate (previous paragraph) or culled due to general reasons. The percentage of general culling was assumed to be 80% and the remaining 20% was culled due to fertility reasons.

The general culling rules were adapted from Rutten et al. (2014). The modelling of general culling was adjusted by a correction factor (CF) to maintain equal probabilities for general culling in both scenarios. Following from the model specifications cows with a better fertility will have a higher probability to get culled for general culling. General culling is performed per lactation and not per year. Lactation length differs for L and B cows therefore a CF was appropriate. Because L cows have an improved CR, they experience less days in parity as they have a higher probability to conceive. When the days in parities get shorter, the cow will have more parities than a regular cow in the same time span and therefore it would have more chance of getting culled for general reasons. To control for the difference in the average number of days in parity between a longevity and base cow a correction factor was introduced. CF was determined by creating the same difference in lifetime in the situation where culling is 80% general and 20% fertility as it was when culling was 100% due to fertility. A correction factor of 0.52 was established. No correction factor was added when parity ≥ 6 to ensure a plausible herd parity distribution. The correction factor was in case of longevity cows 0.52 and in case of a B cow 1. General culling was estimated as:

$$CUL_{ij} = \begin{cases} IF\ Parity_{ij} = 1 \\ THEN\ Bernouilli\left\{\left[\frac{(P_1 - P_2)}{P_1}\right] * ADJ * CF\right\} \\ IF\ Parity_{ij} = 2 \\ THEN\ Bernouilli\left\{\left[\frac{(P_2 - P_3)}{P_2}\right] * ADJ * CF\right\} \\ IF\ Parity_{ij} = 3 \\ THEN\ Bernouilli\left\{\left[\frac{(P_3 - P_4)}{P_3}\right] * ADJ * CF\right\} \\ IF\ Parity_{ij} = 4 \\ THEN\ Bernouilli\left\{\left[\frac{(P_4 - P_5)}{P_4}\right] * ADJ * CF\right\} \\ IF\ Parity_{ij} \geq 5 \\ Bernouilli\left[\left(\frac{\{P_5 - [1-(P_1+P_2+P_3+P_4+P_5)]\}}{P_5}\right) * ADJ * CF\right] \\ IF\ Parity_{ij} > 5\ AND\ \leq 8 \\ THEN\ Bernouilli(0.5 * ADJ) \\ IF\ Parity_{ij} > 8 \\ Bernouilli(0.6 * ADJ) \end{cases}$$

In which CUL_{ij} is whether a cow gets culled or not. The probability whether a cow gets culled is based on the $parity_j$ of cow_i, the herd distribution $P_{1...5}$, the percentage of general culling (ADJ) and the scenario correction factor (CF).

Milk production.

It was assumed that the average milk production per cow would decrease for L cows with 310 kg/milk (personal communication) therefore 305d herd milk production was set at 8000 kg for L cows and 8310 for B cows.

$$HMP = \begin{cases} IF\ TYPE_{ij} = (L) \\ THEN\ 8000 \\ IF\ TYPE_{ij} = (B) \\ THEN\ 8310 \end{cases}$$

In which the milk production of cow *i* in parity *j* is based on the lactation value of cow i and the average herd production and parity j. In this research the average herd milk production (HMP) is different for longevity cows and base cows.

4.3. Support calculations. To determine the lifetime of an individual cow a cow identification number was to be added. The cow identification of cow_i is 1 at the start. At every replacement (when parity is 1) the cowID of cow_i $CowID_i$ +1.

$$CowID_i = \begin{cases} IF\ Parity = 1 \\ THEN\ CowID_i + 1 \\ ELSE\ CowID_i \end{cases}$$

To determine the total lifetime of a cow the days in parity (Total days a cow is in parity j) were summed for which the CowID was the same.

$$Productive\ days_i = \begin{cases} IF\ CowID = i \\ THEN \sum Days\ in\ Parity \end{cases}$$

4.4. Economic calculations. Economic calculations were added to the model. This was done by calculating the yearly margins. The margin was calculated using partial budgeting (Dijkhuizen & Morris, 1997) by subtracting the relevant cost factors from the revenue.

Total revenue	(Milk price * kg of milk)
Calf sales +	(# sold calves * sales price)
Total revenue	
Feed	(VEM * VEM price)
Insemination costs	(# inseminations * insemination price)
Veterinary costs	(1.1*milk production per cow/100)
Calf management	(# calves * price calf management)
Replacement costs –	(# replacements * (price heifer-slaughter value))
Margin	

Next to the net year results the Net Present Value (NPV) of the returns of the breeding decision was estimated/ calculated.

To determine the financial impact of the breeding decision, we calculated the change in financial outputs for the factors that were affected by the breeding decision. The parameters were: milk price, feed price, insemination costs, slaughter value, price of new heifer, veterinary costs, calf price and calving management. The milk price was based on a five year average of the LEI agricultural database (LEI, 2016). The inputs for feed price, insemination costs, slaughter value, heifer price, veterinary costs, calf sales and interest were based on Vermeij (2014). The cost for calf management were based on the research of Inchaisri (2010). The values for these inputs are given in table 3.

Table 3: Financial input model

Cost factor	€	unit	Source
Milk price	0.38	€/kg milk	Lei (LEI, 2016)
Feed price	0.14	€/VEM	KWIN (Vermeij, 2014)
Insemination costs	24.9	€/insemination	KWIN (Vermeij, 2014)
Slaughter value	660	€/cow	KWIN (Vermeij, 2014)
Price heifer	1,130	€/cow	KWIN (Vermeij, 2014)
Veterinary costs	1.1*milk production per cow/100	€/cow/year	KWIN (Vermeij, 2014)
Calf	45	€/calf	KWIN (Vermeij, 2014)
Calf management	152	€/calf	Inchaisri et al. (2010)
Interest percentage	4.5	%	KWIN (Vermeij, 2014)

4.5. Simulation settings & outputs. The culling rules of the model were stable from year 4 onwards and the milk production rules were stable from year 6 onwards. Therefore from year 7 onwards the longevity cows can enter the herd. After 3-5 years all cows are replaced by longevity cows. So therefore we look at the changes that occur from year 7-11.

To ensure stable, significant results and ensure and integer number of herds, 50,050 iterations were run for each analysis.

4.6. Sensitivity analysis. To measure the sensitivity of the model to input changes a sensitivity analysis was conducted. The inputs of the sensitivity analysis are given in table 4. The minimum and maximum input values were based on the last 5 years of data of the Lei (LEI, 2016) or on previous research of Inchaisri et al. (2010). Concerning the CR, milk yield and the correction factor for general culling, the inputs were based on the author's expertise. Cows were culled for either fertility problems or because of other reasons, called general culling.

Table 4: Input sensitivity analysis

Cost factor	Min	Max	unit
Milk price	0.29	0.49	€/kg milk
Feed price	0.116	0.153	€/VEM
Insemination costs	20	30	€/insemination
Slaughter value	550	760	€/cow
Price heifer	910	1250	€/cow
Veterinary costs	0.9*milk production per cow/100	1.3*milk production per cow/100	€/cow/year
Calf	10	70	€/calf
Calf management	130	170	€/calf
Conception Rate	0.54	0.62	%
Milk yield per cow	7800	8200	Kg milk
Correction gen. cul.	0.48	0.56	%

Since no suitable external data was available the model is validated internally. The model was tested for consistency, credibility and plausibility using a rationalism method. Furthermore the results under extreme inputs were evaluated.

5. RESULTS

5.1. Technical results. The differences between breeding for longevity and base scenario are presented in table 5. The reference year of the herd characteristics is 5 years after the first heifer enters the herd.

Table 5: Descriptive statistics of simulation results of longevity and base scenario in year 5 after L cows could enter the herd. The 5th and 95th percentile are given between parentheses.

	Base	Longevity	Unit
Milk production	8,014 (5.903, 10.225)	7,712 (5.806, 9,651)	Kg/year
Calving interval	416 (367, 500)	408 (366, 487)	Days
Productive days	1,081 (63, 2,650)	1,331 (98, 2,819)	Days
Average parity	2.8 (1, 6)	3.4 (1, 7)	Parity
Inseminations	1.7 (0, 4)	1.6 (0, 4)	#/year
KVEM (x1,000 VEM)	6,108 (5,082, 7.147)	5,933 (5,009, 6,862)	VEM/year
L cows after 5 years	0	88,8	%

The average milk production per cow was 302 kg per year higher in de B scenario, 8,014 (5th-95th percentile, 5,903-10,225) kg milk per year, compared to the L scenario, 7,712 (5th – 95th percentile, 5,806 – 9,561) kg milk per year. Cows in the L scenarios had a better reproductive performance requiring less inseminations per cow, 1.6 versus 1.7 in the B scenario. Consequentially, calving interval and average parity number was lower in the L scenario, 408 (5th – 95th percentile, 366 – 487) days and parity age 3.4, versus the B scenario, 416 days (5th – 95th percentile, 367 – 500) and parity age 2.8. After a period of 5 years 89% of the herd was replaced by L cows in the L scenario, logically no L cows were present in the B scenario.

Following from the better reproductive performance less cows were culled for fertility reasons, culling for general reasons remained equal for both model scenarios. An improved conception rate reduced the overall herd replacement rate from 33% to 21% in year 5 after L cows were introduced (figure 3). In the B scenario the replacement rate remained on a yearly average of 33%.

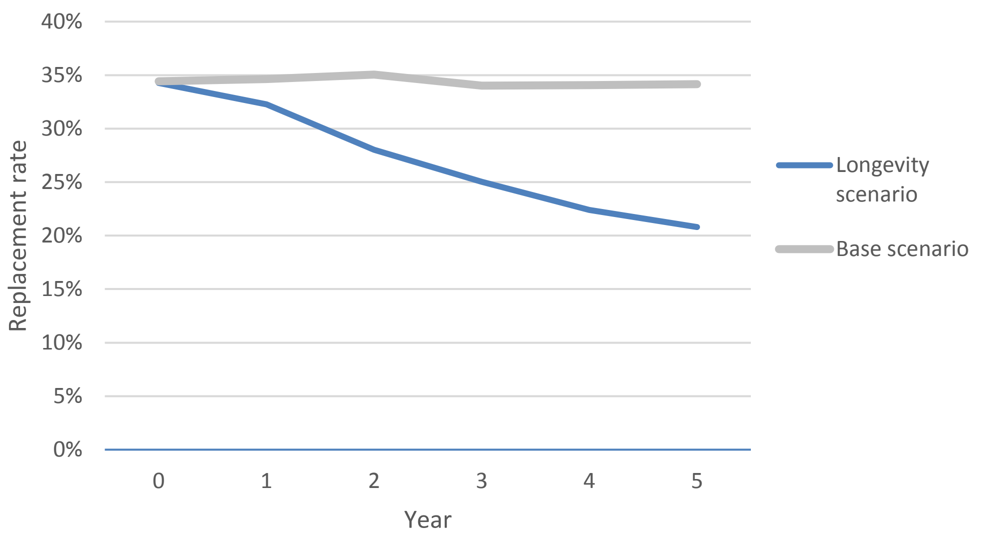

Figure 3: Development replacement rate of 5 years starting at the entry of the first cow that is bred for L or B.

Having less cows culled for fertility reasons increases the average age of the dairy cows present on the herd in the L scenario versus the B scenario. Following from a reduced replacement rate the parity distribution of the herd changes (Figure 4). In the L scenario in year 5, 21.8% of the dairy cows are in parity 1, 21.6% in parity 2, 20.1% in parity 3, 15.9% in parity 4, 11% in parity 5 and 9.5% above parity 5. In the B scenario in year 5, 31.1% of the dairy cows are in parity 1, 23.6% in parity 2, 16.8% in parity 3, 10.8% in parity 4, 8.6% in parity 5 and 9.0% above parity 5. A major difference between model scenarios was the difference in parity 2 and parity 3 cows in the L and B scenario, where in the latter more cows are culled from parity 2 to 3. The average productive lifetime of a dairy cow in the L scenario was 1331 (5^{th} – 95^{th} percentile, 98, 2819) days per cow and 1081 (5^{th} – 95^{th} percentile, 63, 2650) days per cow in the B scenario.

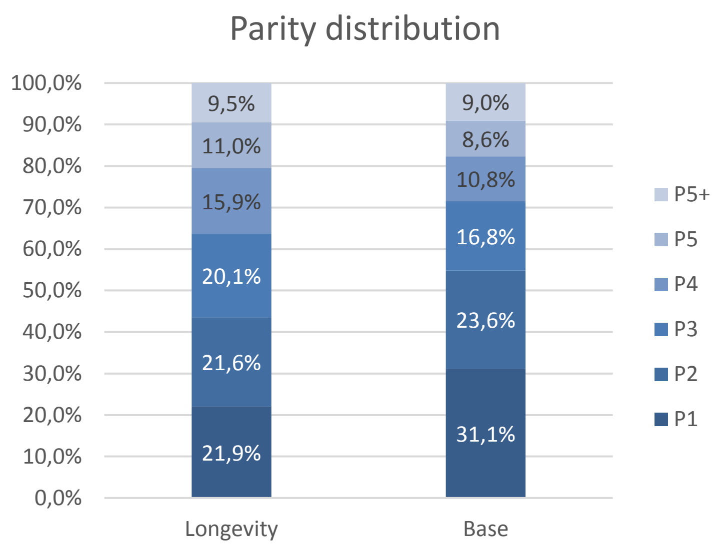

Figure 4: Parity distribution longevity scenario vs. base scenario in year 5 after L cows were introduced

5.2. *Financial results*. The margin of the first 5 years after the first longevity bred heifer enters the herd is given in figure 5. In the years 1, 2 and 3 the regular cows have an advantage on the longevity cows, with the difference with the base scenario being €8, €6, €1 respectively. As a bigger percentage of the herd is replaced, the longevity scenario was more profitable in year 4 and 5, with differences of €6 and €10 respectively. The base scenario has a discounted result of €7,368 (5th – 95th percentile, €4,232, €10,118) per cow place and the longevity scenario has a discounted result of €7,361 (5th – 95th percentile, €4,373, €10,012) per cow place.

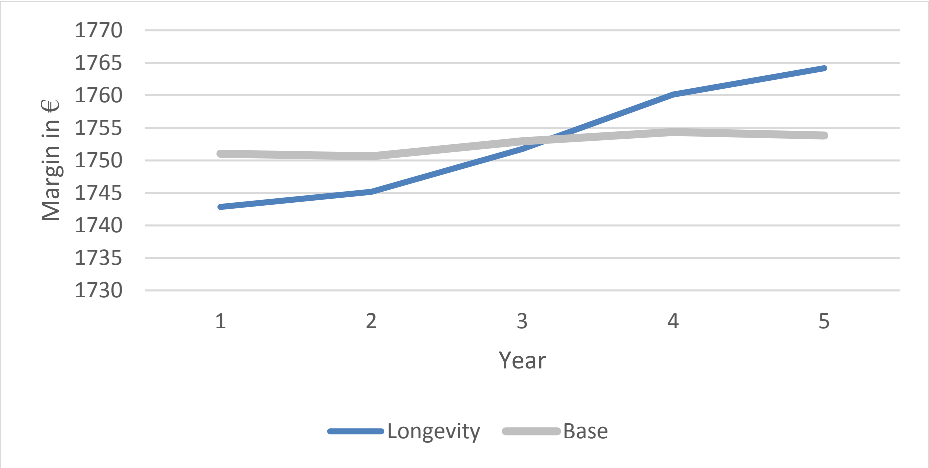

Figure 5: Financial results of the longevity scenario vs the base scenario given in euros per cow

The results of the cost factors are given in figure 5 and the details of the cost factors in table 6. In year 1 the first longevity bred cows enter the herd (L scenario). The returns for the L scenario decrease from €2,987 in year one to €2,931 in year 5, whilst for the B scenario the returns remain stable around €3,014. Also the underlying cost factors, calf sales, feed, insemination costs, veterinary costs, calf management and replacement costs remain stable in the B scenario giving a stable margin of around €1,752. For the longevity scenario the costs decrease for feed (€847 to €834), insemination (€42 to €39), veterinary (€86 to €85), calf management (€165 to €157) and replacement (€152 to €98). This results in an increased margin of €1743 (5th – 95th percentile, €1,011 - €2,410) in year one to €1,764 (5th – 95th percentile, €1,070 - €2,362) in year 5.

Table 6: Results scenarios in euros per cow place

Scenario	Year	Return	Calf sales	Feed	Insem-ination	Veter-inary	Calf mng.	Replace -ment	Margin
Base	1	€ 3,014	€ 50	€ 853	€ 43	€ 87	€ 168	€ 162	€ 1,751
Longevity	1	€ 2,987	€ 49	€ 847	€ 42	€ 86	€ 165	€ 152	€ 1,743
Base	2	€ 3,015	€ 50	€ 853	€ 43	€ 87	€ 168	€ 162	€ 1,751
Longevity	2	€ 2,961	€ 48	€ 843	€ 41	€ 86	€ 163	€ 132	€ 1,745
Base	3	€ 3,016	€ 50	€ 853	€ 43	€ 87	€ 168	€ 161	€ 1,753
Longevity	3	€ 2,948	€ 48	€ 840	€ 40	€ 85	€ 161	€ 118	€ 1,752
Base	4	€ 3,017	€ 50	€ 853	€ 43	€ 87	€ 167	€ 161	€ 1,754
Longevity	4	€ 2,938	€ 47	€ 836	€ 40	€ 85	€ 159	€ 105	€ 1,760
Base	5	€ 3,015	€ 50	€ 853	€ 43	€ 87	€ 168	€ 160	€ 1,754
Longevity	5	€ 2,931	€ 47	€ 834	€ 39	€ 85	€ 157	€ 98	€ 1,764

5.3.Sensitivity analysis.

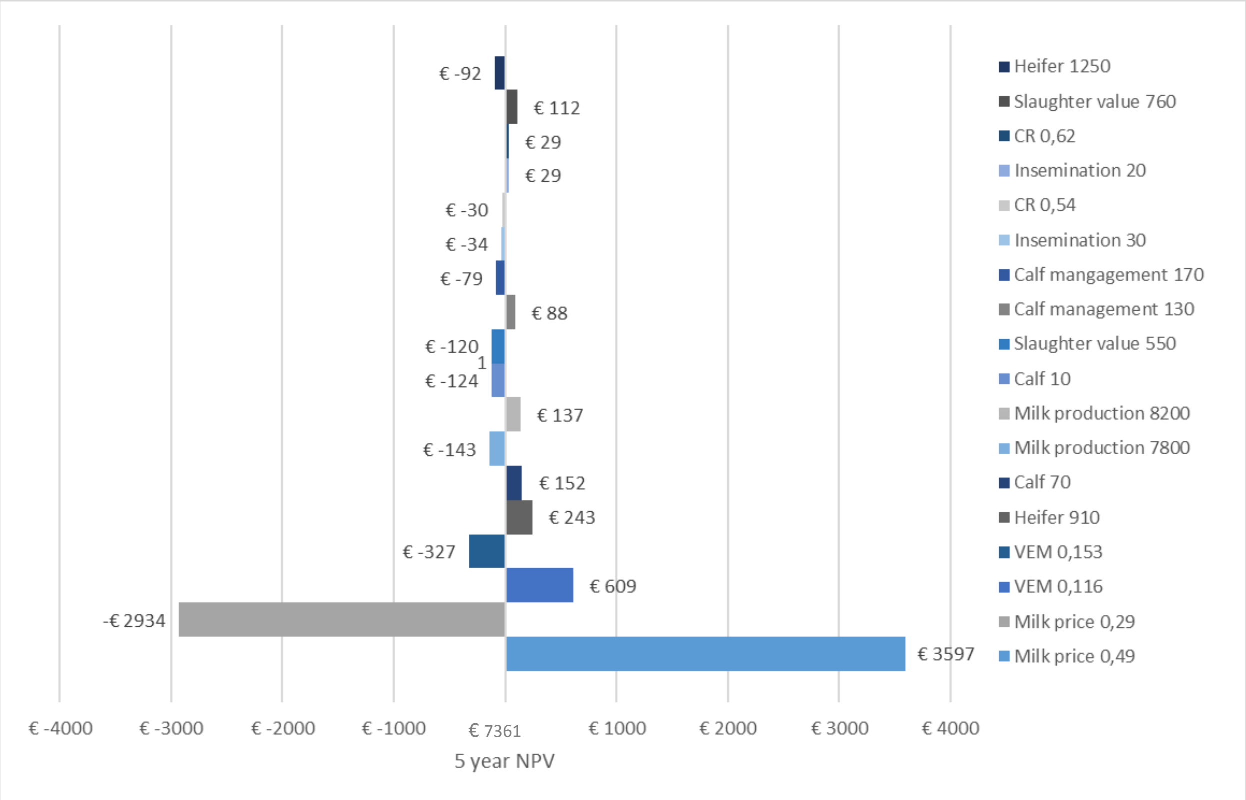

Figure 6: Sensitivity analysis showing the effects of high and low input values of milk price, VEM price, heifer price, calf price, milk production, slaughter value, insemination costs and correction factor on the five year NPV value. The result of 7361,3 of the longevity scenario is set as reference value.

Following from the sensitivity analysis output regarding the L scenario is most sensitive to changes in the milk price followed by changes in the feed price (Figure 6). The impact of milk price is substantial a low milk price (€ 0.29 per kg milk) results in a discounted result of €4,426.9 per cow per year. Whereas a high milk price (€ 0.49 per kg milk) results in €10,958.1.

As the impact of milk price was substantial we ran the B scenario with both a high and low milk price, to explore whether the decision to breed for longevity would change. In a scenario with a high milk price the discounted results suggested that the B scenario was favourable over the L scenario (€11,033 vs €10,958) (Figure 7). Contrary the low milk price favoured the L scenario over the B scenario (€4,427 vs €4,353). In both scenarios only milk price was changed all other costs factors were assumed equal.

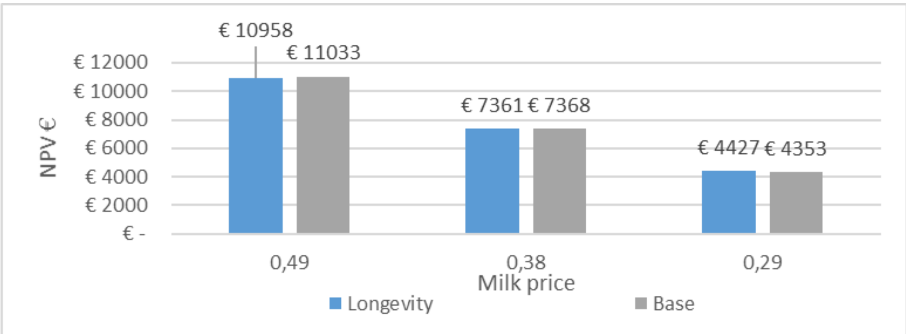

Figure 7: Comparison NPV's of longevity and base scenario under different milk prices

6. DISCUSSION

Although no data is available to validate the difference between the results of the longevity scenario in comparison with the base scenario, the results in general can be compared with data of Dutch dairy cows to ensure plausibility. With yearly milk production per cow of 7.807 kg in 2004 and 8,152 kg in 2008 the milk production results of the model, 8,014 and 7,712 are plausible (CRV, 2014). Also the calving interval, in our study 416 and 408 days, aligns with the CRV (2014) statistics having an average CI of 409 days in 2005 and 415 days in 2008. Also in terms of productive days the model produces logical numbers. In the last 15 years of CRV (2014) statistics the highest average result in the Netherlands was 1,328 days and the lowest 1,108 days. This is also comparable to the results of the model, being 1,081 and 1,331 days.

The differences between the NPV of the L and the B scenario were relatively small with €7 per cow per year favouring the B scenario. Herds which start breeding for longevity have a small disadvantage in margins compared (€8, €6, €1 respectively) to the regular cows in year 1, 2 and 3 after the first new heifers have entered the herd. Nevertheless, in year 4 and 5 the longevity cows have a small advantage (being €6, €10) compared to the base scenario cows. This meant that the loss in milk production is compensated by the savings that are made in costs for replacement, inseminations, feed, calf management and veterinary. When comparing the NPV's, the results are comparable with only € 7 difference between the base scenario and the longevity scenario over a 5 year NPV per cow place. Horn et al. (2012) found that extending longevity allows lower milk yields without lowering profitability. They divided their dataset of Austrian Simmental cows into groups based on how many lactations a cow lived for. For each group profitability and milk yield was plotted. Their results show that at constant profitability, longevity cows need less milk yield than short-living cows. This is another approach of saying that a trade-off on milk yield does not lower profitability. Steinwidder and Greimel (1999) found that cows that have an increased average parity at culling, the profitability could increase by €103 – €2,258 at constant milk yields. Stott (1994) found that longevity could lead to an increase in profitability of 20 pounds per lactation. Stott assumed that when the voluntary replacement is optimized (based on lactation curve and replacement cost) the difference in results of excluding involuntary culling is the quantification of longevity. The approaches of the mentioned studies are different from this study, so the economic impact is not directly comparable, however we can conclude that a difference of 10 euros in margins of year 5 does not contradict the results of the mentioned studies.

From the sensitivity analysis we found that the milk price has a great influence on the results. When looking only at 2016, the average milk price is € 31.3 per 100 kg milk which is about € 0.07 lower than the average milk price over the last 5 years (LEI, 2016). According to LTO Nederland the average milk price of the last 12 months is even € 29.59 per 100 kg milk (LTO Nederland, 2016). For the future a high volatility in milk price is predicted (Rabobank cijfers & trends, 2016). Following from the sensitivity analysis that at a lower milk price is favourable for the longevity scenario, this might be an extra incentive to choose for a longevity breeding strategy.

In our study we used a partial budgeting method in which only those costs are taken into account that are affected by the scenario. Costs that are not yet taken into account are the costs for ‘phosphate rights’ (= new Dutch regulation, which gives a farer the right/limitation to produce up to a certain level of phosphate emissions). This was not included because the regulation is not, yet, completely implemented in the Netherlands and therefore nothing is known yet about the prices for ‘phosphate rights’. What we do know about ‘phosphate rights’ is that they are transferable (van Dam, 2016). Furthermore we know that all farmers (apart from special cases) receive less ‘phosphate rights’ as a baseline than that they are currently using. Farmers have to decrease their phosphate emissions by on average 4% in 4 years (van Dam, 2016). This is because nationally in the Netherlands too much phosphate is produced in (dairy) farming. This would mean that as a starting point the market for ‘phosphate rights’ would give a high demand of ‘phosphate rights’, which implies that the value of the ‘phosphate rights’ could be considerable. As the costs for ‘phosphate rights’ increase the replacement costs, the high value of the ‘phosphate rights’ would be in favour of the longevity scenario. Depending on farm specifics, the total herd could also be seen as the sum of cow places and rearing places. Assuming cow places and rearing places are interchangeable and the ‘phosphate rights’ limit the sum of the cow places and rearing places, having a lower replacement rate means that more cow places can be used for productive cows instead of rearing places, which would increase returns. This would also be in favour of the longevity scenario.

Our results show that the decrease in milk revenues in the L scenario were outweighed by the decrease in rearing costs compared to the B scenario. In our study we assume that only calves are reared which are eligible for herd introduction as heifer and all other calves are sold. In practices farmers may decide to rear all calves regardless of the economic impact. When a farmer wants to achieve these results, he might have to change his strategy or attitude towards his calf management. When the replacement rate decreases, fewer calves have to be raised and therefore the costs for replacement decrease (Mohd Nor et al., 2012). Hence, a farmer must make a selection of all calves which ones to raise and which ones to sell. Farmers do not realize all costs for raising heifers (Mohd Nor et al., 2015a). This is why farmers may decide to just raise all of their calves. When the results of this research are to be realized in practice only the calves that are strictly necessary for replacement, must be raised. Otherwise the decrease in replacement costs is not met.

Apart from an effect on fertility and milk production, breeding with a longevity trait can have other effects as well. Pritchard et al. (2012) found correlations between longevity traits and health traits which could lead to a smaller disease incidence. Although at this point no quantification of those effects can be made, farmers do value a healthy herd (Valeeva et al., 2007). This characteristic is in favour of the longevity scenario. Future research would be necessary to find and apply those quantifications. Furthermore in this research only one generation of cows was taken into account. The effects of breeding with a longevity trait will have effect on multiple generations. It would be very interesting to model a herd which consists of multiple generations of longevity. For this we would need to know how the improvement curve for longevity changes in fertility and milk production over multiple generations. Also for this future research would be necessary.

7. CONCLUSION

The research question of this research was: *'What is the economic impact of breeding with longevity traits in Dutch dairy farms?'* This research has shown that the economic impact of breeding with longevity traits is comparable to regular breeding programs at average milk prices for the first 5 years after making a breeding decision with a difference of €7 in favour of the base scenario when looking at the NPV. When looking at the yearly margins, the first 3 years are in favour of the base scenario with a difference of €8, €6 and €1 respectively. From year 4 and onwards the margins of the longevity scenario are higher than the base scenario with a difference of €6 and €10 respectively. At high milk prices the NPV of the base scenario is favourable, having a greater NPV by €75 and at low milk prices the longevity scenario is favourable with a NPV difference of €74. Given the current situation of low milk prices the longevity scenario could be interesting.

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