NMBU

Reduction of Rearing Cost of Replacement Heifers by Genomic Selection

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Declaration

I, Robel Araya Ghebrewold, declare that this thesis is a result of my research work done by me as part of my Double Degree Program from the Norwegian University of Life Sciences (NMBU), ÅS, Norway and Wageningen University, The Netherlands.

Source of information other than my own have been appended. Moreover, this work has not been previously submitted to any other University for award of any type of academic degree, diploma, and fellowship.

ÅS, August 08, 2014 Robel Araya Ghebrewold

Abstract

The development of methodologies with genomic information to incorporate into genetic evaluation of animals and plants for selection purposes has been a breakthrough research of this decade. Since then, research has been focused and dedicated to obtain the most benefit out of it. Therefore, genomic selection changed the way breeding companies were operating. However, most of the research performed was focused on genetic improvement which was largely due to the fact that genomic selection played a significant role in reducing the generation interval, while increasing accuracy. But recently researchers have been becoming interested to understand if genomic selection could also assist in making farm decisions. Raising genetically superior heifers for cow replacement with minimum cost is the objective of most of dairy farmers. However, cost of raising heifer replacement has been overlooked. In this study, different herd sizes and cow replacement rates have been considered in evaluation, if genomic selection could be economically beneficial in making rearing heifer farm management decisions. Therefore, in the current study, it has been found that genomic selection could be economically beneficial in assisting farm management decisions if a farm has large herd size coupled with the practice of low replacement rates, as such farms may have more surplus heifers which farmers could select from.

***Key words**: Genomic selection, Replacement heifer, Farm management decision*

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1. Introduction

For the last decades, researchers in the dairy industry have been developing different breeding schemes to increase milk production and reduce production costs. However, fuel prices and feed costs continued to increase as well. Moreover, the industry is facing new challenges in relation to animal health and welfare, as well as environment (Hansen Axelsson 2013).

The continuity of a dairy herd is denoted by heifer replacements, because heifers determine the next generation of the herd (Heinrichs 1993; Evans 2009). Heifers are defined here as a young females that have not given birth to a calf. Economics of heifer is an important enterprise of the dairy business, as dairy farmers have to keep a pool of replacements to choose from to maintain their herd size (Bailey & Currin 2009). Therefore, the main aim of raising replacement heifers is to identify genetically superior heifers for herd replacements with minimum cost (Mourits *et al.* 1999). Heifers waiting for the farmers decision require management, labor, fuel, feed and time (Bailey & Currin 2009). As a result replacement heifer management contributes to the future profitability of farmers' investment if a strategic decision is made. Because at the end of the day, profit is the difference between income and cost. Moreover, due to the competitive nature of the business, dairy producers who retain the largest profit will stay in the business not those who have largest herd size.

Cost of rearing heifer for replacement is significant in dairy business because it is the second highest cost next to the feed costs (Heinrichs 1993; Bailey & Currin 2009). According to some dairy expenditure surveys, it covers from 9 to 20% of the total cost of the farm (Heinrichs 1993; Mourits *et al.* 1999; Bailey & Currin 2009). However, rearing cost has been overlooked by many farmers due to several reasons (Mourits *et al.* 1999). One reason is due to the fact that recording heifer replacement costs are difficult.

The age of a heifer at first calving is important to any dairy farm. Because heifers are non-productive to the dairy farm investment until they start lactation. Although it varies among different countries and dairy farms, studies show that cost of rearing heifer until the age of first calving, 24 months, could reach around $1,000 to $1,500 (Heinrichs 1993; Bailey & Currin 2009). Additional rearing cost to any delay of the first assumed lactating age is $50 to $65 per heifer per month (Heinrichs 1993; Bailey & Currin 2009). Moreover, any delay of first calving not only contributes to the increase of the cost of rearing but also hinders genetic improvement of the herd by increasing the generation interval (Bailey & Currin 2009). Therefore, reducing the age at first calving has dual benefit, in one hand rearing cost would be decreased and in the other hand generation interval would be reduced, which in turn contributes to the genetic gain of the herd (Muasya *et al.*) (year of publication is unknown).

With the advent of new technologies in DNA-genotyping in general, together with its low genotyping cost expectation and the release of the bovine genome in 2004 in particular (Murray 2013), dairy cattle breeding companies are able to look beyond the traditional quantitative selection methodologies (Fulton 2012). More than a decade ago, in its early stage of the current molecular technologies, Meuwissen *et al.* (2001) proposed how to predict the genetic value of an animal using genomic information with limited number of phenotypes. Soon after this Meuwissen et al., (2001) publication, Schaeffer (2006) also proposed that animals could be selected based on their genomic estimated breeding value (GEBV), if animals could be genotyped for thousands of single nucleotide polymorphisms (SNPs) and by analyzing the effects of each SNP. After these publications, genomic selection has been considered as a revolutionary change to the existing traditional methods which solely depends on progeny testing. Therefore, genomic selection gives a better estimate of the genetic value of candidates at a younger age than conventional strategies especially if it is coupled with performance and ancestry information (Kearney & McParland) (year of publication is unknown). As a result it was necessary for dairy breeding companies to redesign their breeding scheme in order to apply genomic selection (Lillehammer *et al.* 2011; Pryce & Daetwyler 2012; Pryce & Hayes 2012).

Genomic selection doubled the genetic progress and reduced costs by 92% compared to traditional selection by increasing the accuracy and shortening the generation interval if bulls are selected at the early age and large numbers of bulls are screened (Schaeffer 2006). Selection of animals based on genomic information creates new opportunities for selection decisions to be made at an early age of candidates where information is limited (i.e. heifer and bull) and this helps to reduce costs related to progeny tests (Dekkers 2012; Murray 2013). Moreover, researches show that genetic gain could be increased as high as 30 to 217%, if GEBV is used to select an animal in its early age instead of conventional method (Schaeffer 2006; König *et al.* 2009; Pryce *et al.* 2010b). As a result currently many countries have adopted this method, especially countries with large dairy breeding programmes (Pryce *et al.* 2010a; Boichard *et al.* 2012).

As mentioned earlier, due to its main effect in the generation interval and accuracy, the benefit of genomic selection was first reported and applied in dairy cattle, but to male pathways of selection (Pryce *et al.* 2012). During this early stage implementation of genomic selection, researches were focused on bull selection. However, later researches have assessed the effect of female genotyping on the genetic gain by increasing the accuracy of selection in the female pathways, thereby achieving larger reference populations (Mc Hugh *et al.* 2011; Pryce *et al.* 2012).

The idea and effort of genotyping cows to increase reference population size were one of the strategies used to avoid the decrease of reliability of genomic prediction because of using fewer selected bulls extensively (Pryce *et al.* 2012). Reliability of genomic prediction decreased because of the larger distance created among the current dairy population and the reference population (Lillehammer *et al.* 2011; Pryce *et al.* 2012). Sharing genotype information is another strategies used to increase reference population (Pryce *et al.* 2012). Still, the advantage of genotyping females might have an additional value in assisting farm management decisions and its potential impact has been less studied (Pryce *et al.* 2012). Moreover, Pryce *et al.* (2012) has pointed out benefits that could be gained from genotyping of females, to mention some

1) higher reliability of genomic selection for both bulls and heifers due to the increased number of animals in the reference population
2) identification of elite females
3) identification of potential heifers for herd replacements
4) identification of parentage of individual cows

The above mentioned benefits are some of the new opportunities created due to the latest development of genomic technologies and genomic information-based selection methods on the top of the advantages previously identified such as selection on sex-limited traits, sex-influenced traits and traits that are difficult to measure (Boichard *et al.* 2012; Fulton 2012). Nevertheless, cost of genotyping has been one of the main factors that hinders the implementation of genomic selection. In order for genotyping to be profitable, results received from genotyping companies should be worth its cost (Boichard *et al.* 2012). Recent developments of low density SNP Chip arrays coupled with lower price in the market bestowed alternatives for dairy farmers other than the 50K SNP panel to consider genotyping for management purposes (Pryce *et al.* 2012). So far it has been possible to attain a reliability equivalent to 3 lactation records of a cow which is more than 60% of reliabilities for most of the traits (Pryce *et al.* 2012). Therefore, genomic selection could be used to assist management decisions by genotyping heifer calves at their early age to select for herd replacements based on the result of genotyping.

2. Objectives

The main aim of this study is to investigate whether genotyping heifers at an early age and understanding their economically important traits can help to make management and breeding decisions and save costs associated to raising replacement heifers.

3. Materials and Methods

3.1. Economics of heifer replacement

Before looking at cost-benefit analysis of rearing heifers, it is important to consider the number of available and needed heifers per herd size per year.

The following two equations (Kilmer & Tranel 2014) have been used to calculate the expected number of heifer calves available for replacement at different ages of first calving and heifer replacement rates and the number of heifers needed per year to maintain a given herd size. The formula and assumptions used are the following:

Number of heifer available per year in a given herd size = 1($\boldsymbol{time\ period}$) ×HS× (12÷CI) ×SR × (1-CM) ×(AFC÷24) ………………………………………………….. (1)

Where

1. Time period = One year

2. HS = Herd size (milking and dry cows) = 25 cows, 50 cows, 75 cows and 100 cows, up to 200 cows.

3. CI=Calving interval = 13 months

4. SR = Calf sex ratio = 50%

5. CM=Calf mortality rate = 5%

6. AFC= Average age at first calving = varied from 22 months to 32 months for table 1 and 2, but for table 3: age at first calving was fixed at 24 months

The number of heifers needed annually to maintain a given herd size is also calculated using the formula below:

Number of heifers needed per year = $\mathbf{HS} \times (\mathbf{AFC} \div \mathbf{24}) \times \mathbf{CR} \times (\mathbf{1} + \mathbf{NCR})$................... (2)

Where

1. HS = Herd size = varied from 25 cows to 200 cows

2. AFC = Age at first calving = varied from 22 months to 32 months for table 1 and 2, but for table 3: age at first calving was fixed at 24 months

3. Herd cull rate (cow replacement rates in percentage) = Replacement rates was fixed at 25% for the calculations of table 1 and 2, but table 3 varies replacement rates.

4. NCR = Non-completion rate of heifers (NCR, heifers that enter the replacement growing business but do not enter the dairy herd) = 10%

4. Results

The following tables represent the results of the calculations discussed in the materials and methods,

Table 1: Total number of heifers available per year for varying herd size and age at first calving at 5% of calve mortality.

Number of cows in herd	Age at first calving					
	22 months	24 months	26 months	28 months	30 months	32 months
25 cows	10	11	12	13	14	15
50 cows	20	22	24	26	27	29
75 cows	30	33	36	38	41	44
100 cows	40	44	48	51	55	58
125 cows	50	55	59	64	69	73
150 cows	60	66	71	77	82	88
175 cows	70	77	83	90	96	102
200 cows	80	88	95	102	110	117

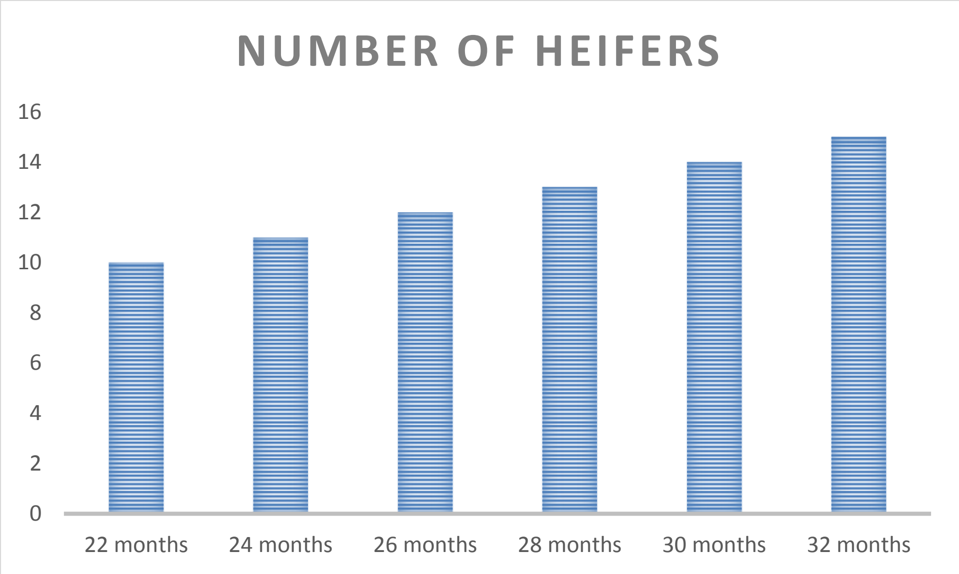

Figure 1: Number of heifers at different age of first calving for a herd size of 25 cows.

Table 2: Total number of heifers needed per year to maintain herd size for 25% cow replacement rate.

Number of cows in herd	Age at first calving					
	22 months	24 months	26 months	28 months	30 months	32 months
25 cows	6	7	7	8	9	9
50 cows	13	14	15	16	17	18
75 cows	20	21	22	24	26	28
100 cows	25	28	30	32	34	37
125 cows	32	34	37	40	43	46
150 cows	38	41	45	48	52	55
175 cows	44	48	52	56	60	64
200 cows	50	55	60	64	69	73

Table 3: Total number of heifers needed per year for various replacement rates and herd size: Calving at 24 months of age.

Number of cows in herd	Cow replacement rates (Culling rate)			
	25%	30%	35%	40%
25 cows	7	8	10	11
50 cows	14	17	19	22
75 cows	21	25	29	33
100 cows	28	33	39	44
125 cows	34	41	48	55
150 cows	41	50	58	66
175 cows	48	58	67	77
200 cows	55	66	77	88

4.1. Rearing and genotyping cost of heifers

Currently, a two years research project is going on at the Norwegian University of Life Sciences (NMBU), Department of Animal Sciences and Aquaculture to determine and estimate the exact costs incurred due to heifer rearing in Norway. For this research, information from a farmer cooperative and breeding organization for Norwegian Red (GENO) and a farmer cooperative livestock production company (Nortura Medlem) were used. Accordingly, the rough estimate cost to buy a two years old heifer could reach around 15,000 NOK (Agnar Hegrenes and Erling Thuen, personal communication). This includes the price of the calf which is around 2,600 NOK. Therefore, if we deduct the price of a calf from the total cost of a heifer of two years old, the remaining will be rearing cost, 12,400 NOK/24 months. This price was used in the subsequent calculations of rearing cost of heifers in a given herd size. For example, if we take a common herd size of a dairy farm in Norway, which is 25 cows (dry and milking) and assuming the age at first calving is 24 months, total number of heifer inventory would be 22 heifer calves (11 each year) (Table 1). The total cost of rearing heifers for this situation could be calculated simply by multiplying the total number of heifers available each year by the cost of rearing a heifer calf per year, 68,200 NOK (6200 NOK× 11) (Table 4). However, the actual numbers of heifers needed to maintain the size of the herd is 7 (Table 2). Where one could argue that this farm is investing additional unnecessary cost of 6200 NOK per year per heifer, while the farm could gain an income by selling a heifer calf or use it for beef production. Here comes the consideration of identifying heifers with high genetic merit and selecting using either parent average or genomic selection, so that the farm would be able to remove additional heifer calves with low genetic value and save costs associated to it. Moreover, for a farm, raising its own potential heifers for replacements, where its genetic value are known, could be mentioned as one of the most important advantages of a farm raising its own heifer replacements (Kilmer & Tranel 2014). However, as the cost of rearing heifer calves differs from country to country and farm to farm, the same is true with the purpose and aim of the farm. (Kilmer & Tranel 2014), mentioned some of the objectives of dairy farm producers for their heifer rearing replacement programmes and identified the last two groups as those who emphasized more on improving the genetic merit of their herd:

1. increase herd size by raising as many heifers as the farm can
2. maintain herd size by keeping and raising the necessary heifers needed for herd replacements

3. Or reduce herd size

The following table shows the cost of rearing heifers for each situation considered in the previous tables:

Table 4: Heifer rearing cost per year for varying herd size and age at first calving at 5% of calf mortality.

Number of cows in herd	Rearing cost of heifer at different age of first calving NOK/year/# of heifers					
	22 months	24 months	26 months	28 months	30 months	32 months
25 cows	62,000	68,200	74,400	80,600	86,800	93,000
50 cows	124,000	136,400	148,800	161,200	167,400	179,800
75 cows	186,000	204,600	223,200	253,600	254,200	272,800
100 cows	248,000	272,800	297,600	316,200	341,000	359,600
125 cows	310,000	341,000	365,800	396,800	427,800	452,600
150 cows	372,000	409,200	440,200	477,400	508,400	545,600
175 cows	434,000	477,400	514,600	558,000	595,200	632,400
200 cows	496,000	545,600	589,000	632,400	682,000	725,400

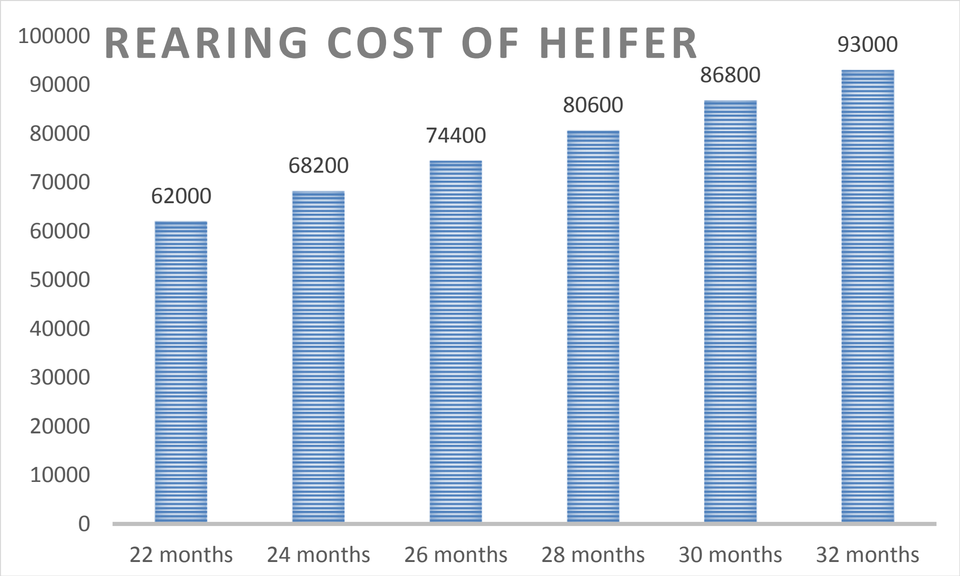

Figure 2: Rearing cost of heifers per year for varied age of first calving for herd size of 25 cows.

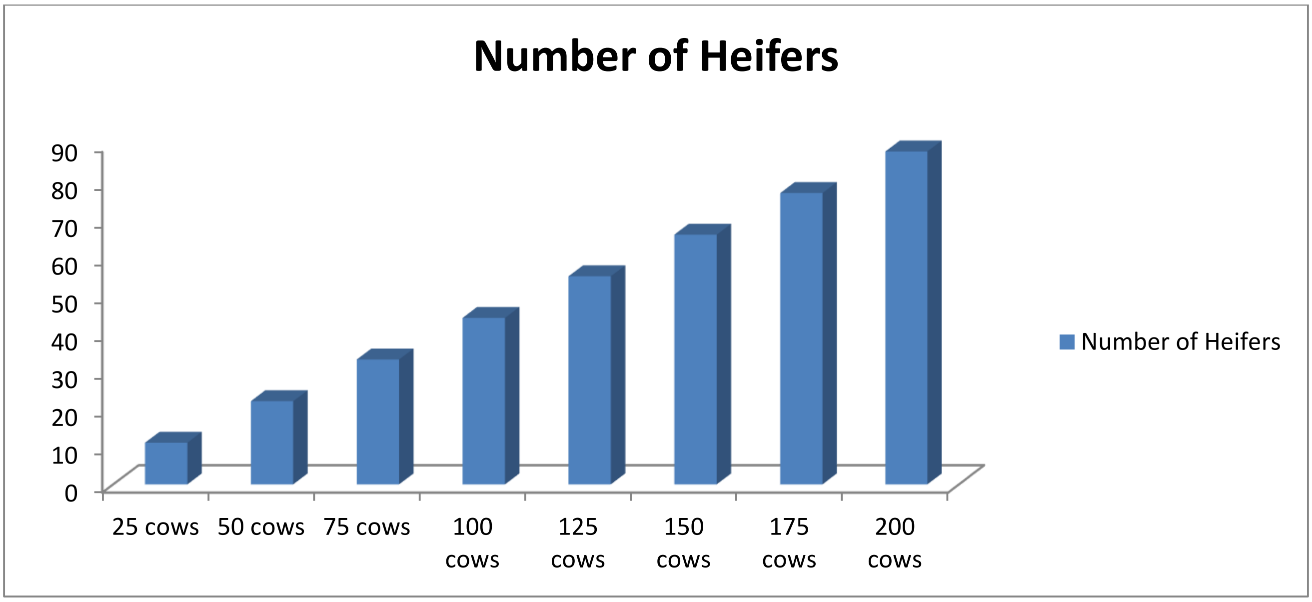

Figure 3: Numbers of heifers in the replacement pool for different herd size.

Table 5: Cost of rearing heifer needed per year to maintain varying herd size and age at first calving and 25% cow replacement rate.

Number of cows in herd	Rearing cost of heifers needed to maintain herd size at different age of first calving NOK/year/# of heifers					
	22 months	24 months	26 months	28 months	30 months	32 months
25 cows	37,200	43,400	43,400	49,600	55,800	55,800
50 cows	80,600	86,800	93,000	99,200	105,400	111,600
75 cows	124,000	130,200	136,400	148,800	161,200	173,600
100 cows	155,000	173,600	186,000	198,400	210,800	229,400
125 cows	198,400	210,800	229,400	248,000	266,600	285,200
150 cows	235,600	254,200	279,000	297,600	322,400	341,000
175 cows	272,800	297,600	322,400	347,200	372,000	396,800
200 cows	310,000	341,000	372,000	396,800	427,800	452,600

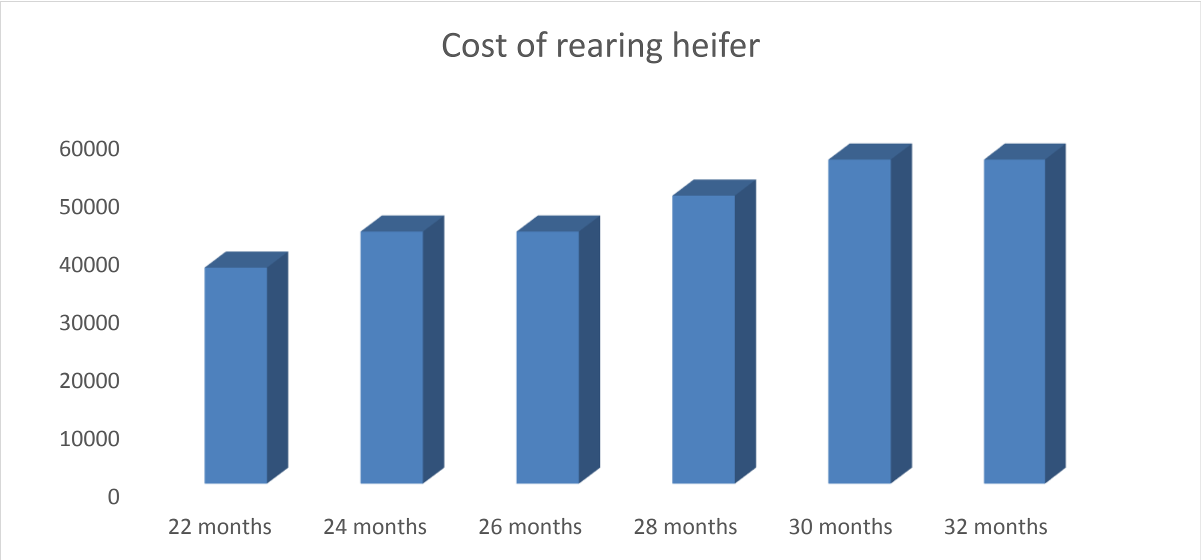

Figure 4: Effect of age at first calving on cost of rearing heifers needed to maintain specific herd size.

Table 6: Cost of rearing heifers needed per year for various replacement rates and herd size: Calving at 24 months of age.

Number of cows in herd	Cow replacement rates			
	25%	30%	35%	40%
25 cows	43,400	49,600	62,000	68,200
50 cows	86,800	105,400	117,800	136,400
75 cows	130,200	155,000	179,800	204,600
100 cows	173,600	204,600	241,800	272,800
125 cows	210,800	254,200	297,600	341,000
150 cows	254,200	310,000	359,600	409,200
175 cows	297,600	359,600	415,400	477,400
200 cows	341,000	409,200	477,400	545,600

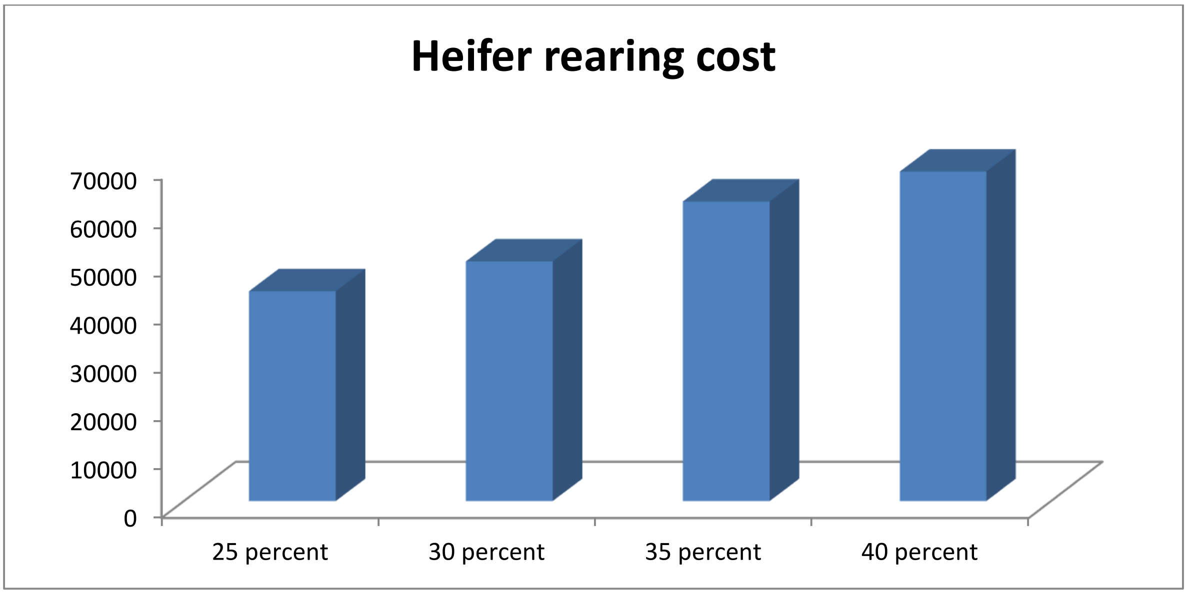

Figure 5: Relationship between costs of rearing heifers needed per year and cow replacement rates for herd size of 25 cows.

As mentioned earlier, if DNA information is used to help decision making of heifer selection then additional genotyping cost will be incurred. Therefore, the following table presents with the accountability of genotyping cost (450NOK/heifer for a 50K chip and 280NOK/heifer for a 6K chip, there could also be additional 100 NOK for other costs but for this research we used the mentioned price). The heifers are assumed to be genotyped while they are one or two months of age. From the previous assumptions that rearing cost of heifers in Norway is estimated to be 6200 NOK/heifer/year, assuming the costs are distributed equally over the 12 months, although in reality that is not the case, we can easily found the costs per month (6200NOK/12months=516.66 NOK/month).

Table 7: One month rearing cost of heifers available in herd per year including genotyping cost for 50K chip.

Number of cows in herd	Rearing cost of heifer at different age of first calving NOK/# of heifers available in herd					
	22 months	24 months	26 months	28 months	30 months	32 months
25 cows	9,670	10,637	11,604	12,571	13,538	14,505
50 cows	19,340	21,274	23,208	25,142	26,109	28,043
75 cows	29,010	31,911	34,812	36,746	39,647	42,548
100 cows	38,680	42,548	46,416	49,317	53,185	56,086
125 cows	48,350	53,185	57,053	61,888	66,723	70,591
150 cows	58,020	63,822	68,657	74,459	79,294	85,096
175 cows	67,690	74,459	80,261	87,030	92,832	98,634
200 cows	77,360	85,096	91,865	98,634	106,370	113,139

Table 8: One month rearing cost of heifers available per herd per year including genotyping cost for 6K chip.

Number of cows in herd	Rearing cost of heifer at different age of first calving NOK/month/# of heifers available in herd					
	22 months	24 months	26 months	28 months	30 months	32 months
25 cows	7,970	8,767	9,564	10,361	11,158	11,955
50 cows	15,940	17,534	19,128	20,722	21,519	23,113
75 cows	23,910	26,301	28,692	30,286	32,677	35,068
100 cows	31,880	35,068	38,256	40,647	43,835	25,504
125 cows	39,850	43,835	47,023	51,008	54,993	58,181
150 cows	47,820	52,602	56,587	61,369	65,354	70,136
175 cows	55,790	61,369	66,151	71,730	76,512	81,294
200 cows	63,760	70,136	75,715	81,294	87,670	93,249

It’s not necessary to calculate for the rearing and genotype cost of heifers needed per year to maintain varying herd size (Table 2) as well as total number of heifers needed per year for various replacement rates (Table 3) because these two tables inform us how many excess heifers are available in comparison with the actual number of heifers a farm has already.

Another important fact that should be considered here is the common practice of handling heifers in Norway with the Norwegian Red cattle. Moreover, farmers in Norway do not usually cull heifers even if the heifer is identified as a low genetic merit, instead it will be kept for meat production. This means that heifers that are identified as a low genetic value will be in the farm in anyway.

The other important point to be considered is whether it will be economically beneficial or not if a farmer could wait a heifer which is identified as a low genetic merit till the first lactation. However, in Norway farmers have milk quotas and a farmer who produces more milk might have difficulties in selling his/her excess milk.

5. Discussion

A farm raising its own heifer for replacement purpose is part of the financial investment of the dairy business and it is influenced by the total number of available heifers and the heifer calves produced per year (Wattiaux & McCullough). The cost of rearing heifer has a direct relationship with age at first calving. Normally a heifer is expected to give birth at the age of 24 or 25 months (Hoffman 1997) . However, if due to certain reasons the expected age at first calving is elongated, the cost of raising heifers will also increase, simply due to the accumulation of heifers in the replacement pool. For example, the total number of heifer inventory in a farm with a herd size of 25 cows and age at first calving of 24 months with 5% calf mortality were 22 (11 per year), (Table 1). In this case, the rearing cost per year was 68,200 NOK (6200NOK/heifer) (Table 4). However, with a two months delay at first calving the rearing cost increased by 9% (Table 4) (Figure 2). Additionally, if a heifer gives birth at 32 months of age instead of 24, which means she has been stayed in the replacement pool 33% more time than expected, thereby increasing the number of heifers and she has incurred additional rearing cost for more 8 months stay. As a result, the total number of heifers may increase from 11 to 15 as well (Table 1). This associates to an increase of 36.36% in the total number of heifers. Similarly, for each delay of two months at first calving the rearing cost increased at least by 7% (Figure 2).

It can also be observed that the number of heifers in the replacement pool could be affected not only by the delay at first calving but also by the number of cows in the herd. The result of the calculations of available heifers for different herd sizes in Table 1 and Figure 3 shows that a farm with large number of herd size has large number of available heifers in the replacement pool as expected. As a result the rearing cost in these farms is significantly higher (Table 4). For instance, if we take the same assumptions with the previously mentioned example, a farm with 200 cows of herd size has a total heifer inventory of 176 (88 per year) and rearing cost of 545,600 NOK while it has 68,000 NOK for a farm of 25 cows herd size (Table 1 and 4). A similar study from the University of Wisconsin-Madison by Michel A. Wattiaux and Doug McCullough (Wattiaux & McCullough) shows and discusses the direct effect of age at first calving on cost of rearing heifers.

Rearing cost of heifers has been discussed above as a function of age at first calving and herd size. However, the number of heifers needed to maintain a certain number of herd size differs according to the farm percentage of herd replacement rates. For example, 7 heifers needed to maintain a farm with 25 cows and age at first calving of 24 months with 25% of cow replacement rate (Table 3). However, the actual numbers of heifers available in this farm with the same assumptions were 11 heifers, which means that 4 additional heifers are available. Additional costs incurred due to these surplus heifers were around 24,800 NOK (6200 NOK/heifer) per year, an increase of 57% (Table 6). Moreover, the number of excess heifers increased as the herd size gets bigger, for instance, a farm with a herd size of 100 cows had 16 additional more heifers than it needed (Table 1 and 2), similarly a farm with 200 cows had 33 more additional heifers than needed to maintain the herd size with the same percentage of herd replacement rates (Table 1 and 2) (Figure 5). However, if a farm had high percentage of cow replacement rates, the opposite would happen (Table 3). As the cow replacement percentage increased the possibility of having surplus heifer's decreased. Therefore, a farm with a replacement rate of 35% and herd size of 25 cows had only one more additional heifer than the farm required to maintain the herd size (Table 3). Hence, this indicates that a farm with lower percentage of herd replacement rates and large number of herd size has more additional heifers than a farm with higher percentage of herd replacement.

In this study the cost of genotyping was assumed to be 450 NOK for the 50K Chip and 280 NOK for the 6K Chip. Although, the price could be more than the assumed cost by 100 NOK (Trygve Solberg, personal communication), we decided to use the mentioned cost for this study.

In this study, all available heifers were assumed genotyped. As a result the genotyping cost was considered in the cost-benefit analysis. Therefore, the genotyping cost was distributed equally among the number of heifers available in a given farm. A farm with large number of candidate heifers in the replacement pool would have a large genotyping cost. Moreover, costs associated with rearing were included in the calculations. Let us take the same assumptions as we had previously, and a farm with a herd size of 25 cows and first calving at 24 months and 25% of cow replacement rate had 11 available heifers per year (Table 1) and this farm needed only 7 heifers (Table 2) to maintain the herd size. In this study, it was assumed that genotyping test was carried out in the first month and not only genotyping costs but also costs associated to rearing during this month were taken into consideration (Table 7 and 8). In this case, the cost was 10,637 NOK (Table 7), and assuming this farm would keep only the desired heifers for the replacement, after deducting genotyping cost, the farm could save 17,754 NOK (4,438.5 NOK/heifer) per year by reducing the 4 additional heifers.

Let us take another bigger herd size with the same assumption, a farm with 100 and 200 cow herd size would need 28 and 55 heifers for replacement (Table 2), however, both farms had 44 and 88 available heifers (Table 1). Therefore, these farms had 16 and 33 surplus heifers than needed, or the farms had 36.36% and 37.5% additional heifers than needed. One-month rearing and genotyping costs were 42,548 NOK and 85,096 NOK, respectively (Table 7). Keeping only heifers needed, each farm could save around 71,016 NOK (4,438.5 NOK/heifer) and 147,719 NOK (4476.33 NOK/heifer), respectively.

It has been mentioned previously that the percentage of cow replacement has a significant effect on the number of heifers needed to maintain a certain number of farm size. Therefore, a farm with high percentage of cow replacement rates would have less additional heifers. Ultimately, there would be only heifers that could potentially sustain the herd size (Pryce *et al.* 2012). Consequently, this in turn affects the cost-benefit analysis of genotyping heifers. For instance, the number of heifers needed to maintain a farm size of 25 cows with 35% (farm A) and 40% (farm B) of cow replacement rates were 10 and 11 heifers (Table 3), respectively. In addition, the number of heifers available for these farms with the same replacement rates were 11 heifers (Table 1). It can be clearly observed that, there is only one additional heifer remained for farm A and none for farm B. Calculating the net profit, after considering genotyping and rearing costs, the return were only, 693 NOK for farm A and -4,994 NOK for farm B. The result definitely shows that genotyping heifers for farms with high percentage cow replacement rates may not be profitable due to the high number of heifers needed to maintain the herd size. Which means that there would be less additional heifers than the farm needed.

The above argument could be supported more clearly, if we consider the above assumptions farther and look at bigger farm sizes, such as farms with 100 and 200 cows, the number of heifers needed (Table 3) and the actual number of heifers available in the farm are actually equal (Table 1). This is because large herds with high cow replacement rates requires more number of heifers to maintain the farm size (Evans 2009). Therefore, there were not any surplus heifers available and because of genotyping cost, the total additional cost incurred on the top of the rearing cost were 19,800 NOK and 39,600 NOK. The total cost including genotyping and rearing cost per year were 292,600 NOK and 585,200 NOK (6650/heifer), respectively.

The other opportunity for farmers to identify the best heifers to become replacements is to genotype heifers with low-density SNP Chips such as the 6K panel, with 6,000 markers. Generally, the availability of low-density panel brought an option for farmers to genotype their heifers with a lower price than the 50K panel and then uses a process called imputation to rebuild its 50K genotype. In the case of this study, the cost difference between these two genotyping panels per head is only 170 NOK and this may not have significant profit for the small herd size farms as the 6K has lower accuracy than the 50K. However, this could make a significant difference when the herd size of the farm is bigger and wants to genotype large number of heifers. Although the costs could be the same relative to the farm size, farms with large herd size and low cow replacement rates tend to have more surplus heifers. As a result, farmers could have more option to select from. For example, considering the same assumptions as previous, the total cost of one-month rearing cost and genotyping cost were 8,767 NOK. If a farm with herd size of 25 cows wants to genotype all his heifers with 6K panel and cull the surplus heifers who were considered to be genetically low, after deducting genotyping cost the farm could save around 19,624 NOK per year (4,906 NOK/heifer), which is around 11% more profitable than the 50K panel. Moreover, if we see with larger herd sizes, say 100 cows and 200 cows, the profit is around 78,496 NOK (4906 NOK/heifer) and 162,679 NOK (4929.7 NOK/heifer).

The Norwegian dairy farming system is different from the other countries such as USA, Canada and Netherlands, not only in the type of dairy breeds they use but also in the size of the herd. Norwegian Red cattle (NRF) are usually the dominant dairy cattle breeds in Norway and they cover more than 75% of the dairy cattle in the nation. Moreover, NRF has dual purposes, milk and meat production. Therefore, farms usually practice high percentage of cow replacement rates, 35% to 40% (Morten Svendsen, personal communication). Usually cows replaced after their first lactation by the new heifer that are entering in to the herd. As a result, the highest cow replacement percentages practiced during the first lactation of the herd.

Having the above mentioned common dairy farming business practice in Norway, it is immediately clear that there are only just enough heifers to sustain the herd size. Consequently, farms in Norway do not have significant surplus heifers. As a result using genomic information to support management decisions may not be beneficial.

Furthermore, GENO has developed its own 50K SNP chip array (Trygve Solberg, personal communication) which helps them to genotype their own NRF breeds. Due to the reason that the low-density SNP array such as the 6K was developed using reference population of Holstein breeds, it is interesting to know that genotyping of NRF is usually based on this 50K array. Consequently, it limits the option to use the low-density SNP array, and leaves farmers with no option but to use the 50K array.

6. Conclusion

The dairy business industry may have much more chance to benefit from genotyping females such as identification of elite females for replacement purpose, parentage verification, and inbreeding control. However, in the current study, specifically for the Norwegian dairy farming system, we have found that a farm could benefit from genomic testing for heifer replacement selection if there are large number of heifers in the replacement pool to choose from coupled with a practice of low percentage cow replacement rates. Since NRF have high replacement rates, there may not be a significant profit from genotyping the NRF heifers and use the information to assist management decisions. The other more interesting situation in the Norwegian dairy farming system is the dual purpose production of NRF. Whether a calf heifer is identified as a potential genetically superior animal or not, the heifer will stay in the farm in anyway. If identified as a potential heifer for cow replacement with high GEBV, then it will be used for dairy at least for the first lactation. However, if it was identified as a low GEBV, it will still be in the farm for meat production purpose. Moreover, the Norwegian breeding companies have a good parental data system, which results in a parent average EBV which may help to identify potential heifer for cow replacement without incurring any additional costs.

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