GENETIC AND ECONOMIC EFFECTS OF GENOMIC SELECTION AMONGST SURPLUS DAIRY HEIFERS IN AUSTRALIAN DAIRY HERDS

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SUMMARY

When dairy farmers have reared surplus dairy heifers, a subset are selected for retention and entry to the milking group. We used stochastic simulation modelling followed by economic modelling to compare effects of 1) selection of heifers based on genomic Balanced Performance Index estimates to either 2) selection of early-born heifers in seasonal and split calving herds (the most common calving systems in Australia), or 3) random selection in year-round calving herds.

Based on those results, for Holsteins in seasonal and split calving herds, selection in a single birth-year group based on Balanced Performance Index typically delivers a small profit over the medium term (i.e. estimated net present value for the first 7 years $1,704 for a 300 cow herd) but larger profits over 12 ($5,354) and 17 ($6,942) years. These estimates did not include the additional costs incurred due to retaining later-born heifers when heifers are selected based on Balanced Performance Index estimates compared to selection of early-born heifers. Effects on profit were estimated as typically being larger in year-round calving herds ($4,897, $9,958 and $12,124, respectively). In Jerseys, effects would be expected to be a little less than these as there was typically less variation in Balanced Performance Index estimates within groups of Jersey heifers.

These results indicate that, under the model assumptions, the medium-term effects of using genomic selection to select replacements from surplus dairy heifers on herd profit are typically small in seasonal and split calving herds, but are larger in year-round calving herds. However, there was large stochastic variation between birth-year groups of 100 heifers in effects of selection strategy on true breeding values for Balanced Performance Index, indicating that effects would vary substantially between individual birth-year groups.

INTRODUCTION

When dairy farmers have reared surplus dairy heifers, a subset are selected for retention, calving and entry to the milking group and the remainder are sold before their first calving. Heifers can be selected based on various attributes. In seasonal and split calving herds (the most common calving systems in Australia), preferential selection of early-born heifers helps ensure all heifers are at target liveweight by yearling mating start date. Alternatively, selection can be based on genetic estimates for the heifers. With the availability of commercial genomic testing services, genetic estimates based jointly on animal pedigree and genomic results are readily available for heifers prior to their first calving.

The aim of this work was not to assess the profitability of rearing and selling surplus dairy-breed heifers relative to other management strategies available for the herd but rather, for herds that have an excess of AI-sired dairy heifers, to estimate the effects of selection of a subset of those heifers for retention based on genomic Balanced Performance Index estimates compared to each of a) selection of early-born heifers in seasonal and split calving herds or b) random selection in year-round calving herds (representing any selection strategy that is independent of both the heifers' true Balanced Performance Index values and birth date).

MATERIALS AND METHODS

We used stochastic simulation modelling followed by economic modelling to compare selection strategies in a single birth-year group in a commercial herd. To provide input parameter values for this modelling, we analysed genomic Balanced Performance Index estimates and reliabilities, and birth dates from 25,423 Holstein heifers born in 2019 or 2020 from 205 herds, and 61,631 Jersey heifers born in 2019, 2020, or 2021 from 396 herds. Only genomic estimates from before the heifers' first calving dates were used.

The steps in the simulation modelling were as follows:

1. Generate a simulated group of 100 heifers, each with a true breeding value for Balanced Performance Index and a birth date
2. Generate Balanced Performance Index estimates for each heifer
3. Select 50 heifers from the 100 heifers using each of three methods:
    a. Select the 50 heifers with highest Balanced Performance Index estimates
    b. Select the 50 earliest-born heifers
    c. Select 50 heifers independently of their genetic attributes and birth date (simulated by random selection)
4. Calculate mean true breeding value for Balanced Performance Index under each strategy, and calculate differences between means for strategy a versus strategy b and strategy a versus strategy c
5. Also calculate differences in distributions of birth dates under each strategy
6. Repeat steps 1 to 5 a further 9,999 times, and summarise differences

True breeding values for Balanced Performance Index were simulated using specified parameter values for 1) the standard deviation of Balanced Performance Index estimates in the source population from which the birth year group of heifers were drawn, 2) Balanced Performance Index estimate reliabilities and 3) the genetic correlation between Balanced Performance Index and birth date. Birth dates were selected from a log-normal distribution based on that observed in the study dairy heifers and the observed value for the (negative) correlation between Balanced Performance Index estimate and $\log_e$-transformed birth date in Holstein study heifers of -0.21 used as the genetic correlation parameter value. The Balanced Performance Index includes the daughter fertility estimated breeding value (Australian Breeding Value or ABV) so cows with higher Balanced Performance Index values on average, conceive and so calve earlier in the calving period in seasonal and split calving herds. As daughter fertility ABVs between dams and daughters are correlated, it was expected that Balanced Performance Index would be correlated with birth data, and this is what we found in our analyses.

Economic effects of selection based on Balanced Performance Index estimates relative to each of the other strategies in a single birth-year group were assessed for a 300-cow herd rearing 132 dairy heifers each year and retaining 66 to calve in the herd (i.e. 22% replacement rate). Herd replacement rates and age structures were held constant in every year under all three strategies. Differences between means for the strategies from the simulation modelling (Table 1) were estimated with the standard deviation of Balanced Performance Index values in the source population from which the birth year group of heifers were drawn of 85.9 units, with Balanced Performance Index estimate reliabilities of 0.64, with genomic testing costs of $53 per heifer ($50 testing cost plus $3 labour). We assumed that each 1 unit increase in herd average true breeding value for Balanced Performance Index in a particular year over the previous year causes a $1 increase in herd profit in that year, as inferred by Byrne (2016). Effects of higher Balanced Performance Index values of the selected birth-year group on true breeding value for Balanced Performance Index of their daughters, granddaughters etc were incorporated when calculating differences in herd average true breeding values for Balanced Performance Index by year. Economic effects were estimated for 17 years where year 1 is the year of birth of the selected group. Net present values were calculated using a 5% discount rate. The additional costs incurred due to retaining later-born heifers (additional feed costs to attain higher growth rates to the herd's yearling mating start date and/or economic costs of failing to achieve the same liveweights by then) when heifers are selected based on Balanced Performance Index estimates compared to selection of early-born heifers were not included in economic calculations.

RESULTS AND DISCUSSION

Means of true breeding values for Balanced Performance Index amongst 50 heifers selected from 100 heifers based on Balanced Performance Index estimates were, on average, modestly higher than for other selection methods but there was large stochastic variation between birth-year groups (Table 1 and Figure 1). The mean of differences relative to random selection of 54.6 was close to the expected value from the breeders' equation (Falconer 1989) of 54.8. Relative to selection of the earliest-born heifers, more of the heifers selected based on Balanced Performance Index estimates had been born after day 42 of the herd's calving period, (Table 1).

Table 1. Distribution of differences in means of true breeding values for Balanced Performance Index and percentages of heifers born after day 42 of the herd's calving period between 50 simulated Holstein heifers selected from 100 heifers as those with the highest Balanced Performance Index estimates and either the 50 earliest-born heifers or 50 randomly selected heifers selected from the same 100 heifers; distributions were from 10,000 replications

Outcome variable and statistic	Relative to selection of earliest-born heifers	Relative to random selection of heifers
Means of true breeding values for Balanced Performance Index		
Mean of differences	39.9	54.6
Standard deviation of differences	9.6	10.8
Range of differences	7.2 to 82.9	16.2 to 103.9
Percentages of heifers born after day 42 of the herd's calving period		
Mean of differences	17%[1]	-4%
Standard deviation of differences	5%	6%
Range of differences	0% to 40%	-26% to +18%

[1]For example, the percentage of the 50 heifers selected as those with the highest Balanced Performance Index estimates that had been born after day 42 of the herd's calving period was, on average, 17% more (range 0% to 40%) than that for the 50 earliest-born heifers

From the economic modelling, for seasonal and split calving herds, selection in a single birth year based on Balanced Performance Index typically delivers a small profit over the medium term (i.e. estimated net present value for the first 7 years $1,704 for a 300 cow herd) but larger profits over 12 ($5,354) and 17 ($6,942) years. The larger profits for 12 and 17 years relative to 7 years were mainly due to higher Balanced Performance Index values in the daughters, granddaughters etc of the selected heifers. Effects of selection on profit were estimated as typically being larger in year-round calving herds ($4,897, $9,958 and $12,124, respectively). Newton *et al* (2018) also reported small estimated profits from selected heifers based on genomic Balanced Performance Index estimates in seasonal calving herds compared to selection in the absence of genetic information. Due to stochastic variation in genetic effects between single birth-year groups under each heifer selection method, in seasonal and split calving herds, net present value for the first 7 years would be expected to be negative (i.e. the benefits being less than the costs of genomic testing) for 20.4% of birth-year groups but net present value for the first 17 years would be expected to be negative for only 1.2% of birth-year groups. In contrast, in year-round calving herds, negative net present values due to stochastic variation in genetic effects would be very unlikely (1.4% and 0.04% of birth-year groups, respectively).

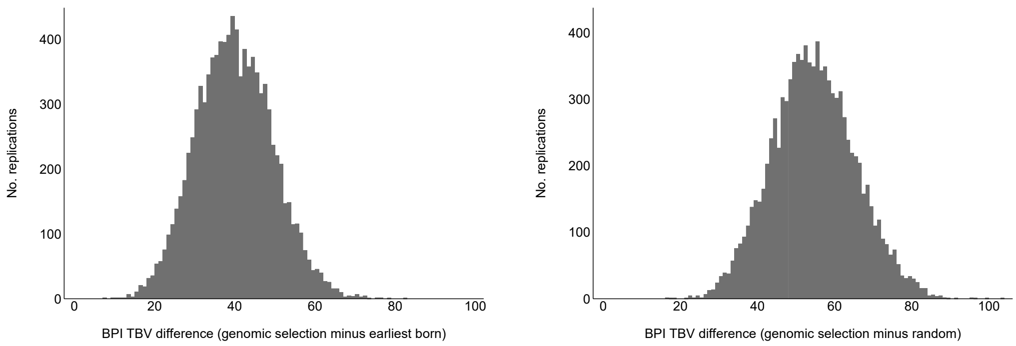

Figure 1. Distribution of differences in means of true breeding values (TBVs) for Balanced Performance Index ('BPI TBV difference') between 50 simulated Holstein heifers selected from 100 heifers as those with the highest Balanced Performance Index estimates and a) left-hand graph: selection of the 50 earliest-born heifer and b) right-hand graph: 50 heifers randomly selected from the same 100 heifers. Distributions were from 10,000 replications

There was typically less variation in Balanced Performance Index estimates for groups of Jersey heifers (median of the standard deviations 63.5 compared to 68.7 for Holsteins). Accordingly, economic effects of selection on Balanced Performance Index estimates would be expected to be a little less for groups of Jersey heifers than for Holsteins as reported above.

CONCLUSIONS

These results indicate that currently the medium-term effects of genomic selection from surplus dairy heifers on profit are typically small in seasonal and split calving herds but are larger in year-round calving herds, on average. Genomic testing can also assist in correcting pedigrees and reducing inbreeding, avoiding recessive lethal genes, and selecting for desired genetic variants, and the benefits of these effects were not included in the economic analyses.

ACKNOWLEDGEMENTS

The authors thank Dairy Australia for funding time inputs by the first-named author, Stephanie Bullen and Michelle Axford for ongoing inputs into study design and interpretation of results from this study, and DataGene for providing the heifer data used in this study.

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