Australian Farm Business Management
2019, Volume 16, Paper 4
ISSN: 1449-7875

Trends in Dairy Herd Genetic, Production and Reproductive Performance and Impact on Farm Profit

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Abstract

There is little sound information about the impact of cow genetic selection programs on whole farm profit. In this paper aggregate industry data about dairy herds are analysed to identify trends in dairy herd genetic, production and reproductive performance. The genetic distribution within herds that would result over time from a long-term genetic selection program is simulated, and a representative whole-farm bioeconomic model is used to explore the impact of genetic change in a dairy herd on the profit of a representative case farm. Analysis of an industry herd recording database revealed an average annual rate of increase in the Balanced Production Index (BPI) of 7 units for the herd (2.9 and 10.1 for the bottom and top BPI quartiles) and 10.8 units for artificial insemination sires used within herds. Modelling these trends for herds, with an age-cohort range average of 43 units of BPI and 20 per cent cohort attrition rates, shows that the natural range between bottom and top BPI quartiles expands gradually but remains between 75–100 units in most herds across 50 years of selection. This finding of persistence in the distribution of genetic merit around the herd mean indicates that the common application of comparing performance of BPI quartiles within herds provides almost no insight into impacts of genetic selection on farm profit. Bioeconomic modelling revealed that the genetic gain of a herd achieving an annual rate of increase in herd BPI of around 10 units per year contributed an average of around $2,500 extra to farm profit per annum for a 250-cow herd representative farm. Applying more widely the findings and insights from modelling genetic gain in a representative pasture-based dairy farm suggests it is likely that that, on many, or even most, dairy farms, the gains in profit from cow genetic selection is likely to be modest in light of other investment opportunities and is thus not something to be focussed on to the effective exclusion of other more profitable resource uses. 'Ignore the principle of equi-marginal returns to all inputs at your peril' is sage farm management economics advice to those who believe that all animal farmers need do is to improve the genetic potential of their animals. Good advice to dairy farmers would be to: (i) have realistic expectations about the role of genetic gain in their business; (ii) evaluate returns from investment in herd genetics; and (iii) compare expected returns from investments into all limiting factors present on the farm.

Key words: genetic improvement, dairy cows, balanced performance index, economic benefits

Introduction

The commercial purpose of introducing superior genetics into a population of farm animals is to move the herd mean genetic potential, and the probability distribution of genetic merit of the animals around the mean, outwards from the origin, with the aim of improving profit and return on capital. Gaining an understanding of, and estimating, the contribution an animal comprising a mix of genetic traits can make to the profit of a farm can be done by using either the profit function of quantitative geneticists and their associated so-called 'profit indices', or by using the considerably more detailed bioeconomic models, containing as much technical and economic information about the farm system and their relationships as possible, represented as fully as can be done (Amer and Fox, 1992).

Economics and genetics intersect occasionally in the animal science literature: questions about the economic worth of genetic improvement and ways of harvesting such benefits are raised and investigated. Kaniyamattam et al. (2016) used a daily stochastic dynamic dairy simulation model that included multitrait genetics and explored the effects of reduced genetic models and various reproduction and selection strategies on the genetic, technical, and financial performance of a dairy herd. De Vries (2017) showed that counting the hidden effects (in opportunity cost terms) of postponed replacement when valuing differences in genetic merit of animals changed their rankings in breeding indices.

The profit functions of quantitative geneticists are assumed to be linear or slightly non-linear (Goddard, 1983). It is widely recognised that biological and economic systems do not operate usually in straight lines (Dillon and Anderson, 1990). Diminishing marginal output responses occur to added inputs, including genetic traits, over much of the response function. The small size of the (linear estimates of) additions to profit arising from additional genetic traits in farm systems has influenced quantitative geneticists to assume the profit relationship is 'near enough' to linearity and this relationship can thus be applied to guide animal selection and breeding decisions (Goddard, 1983).

The Australian dairy industry has developed a genetic selection index for ranking dairy cows and sires according to their genetic potential (DataGene, 2019). The Balanced Production Index (BPI) replaces the Australian Profit Ranking and balances longevity, health, type and efficient production. The BPI is a weighted index of traits combining information on predicted production, type and health performance into an estimate of difference in a representative farm model of the expected contribution to farm output and profit of a cow with additional levels of genetic traits, relative to the expected contribution to farm output and profit from a cow with a BPI of 0 (DataGene, 2016). Two additional indices are the Health Weighted Index (HWI) and the Type Weighted Index (TWI).

The impact of animals selected using these cow-level genetic indices on whole-farm performance and profit is essentially unknown. A recent analysis (Newton et. al., 2017) attempted to estimate the relationship between the contribution of individual cows to farm profit and the BPI of cows within a herd by analysing historical and average data from three case study herds. It was estimated that cows in the top quartile for BPI in the case study herds contributed $150–$235 more to farm profit per year than did cows in the bottom quartile for BPI. More recent industry extension messages claim $300 more profit per cow per year from cows in the top BPI quartile compared to herd mates in the bottom BPI quartile (DataGene, 2019). Taken simplistically and superficially, these large differences in individual cow contribution to farm profit generating capabilities imply that a focused genetic selection strategy will provide rapid improvement in farm profit of similar order if successfully applied. The analytical approach used to reach these surprising conclusions has the cow as the unit of analysis, through impacts on farm profit, but changes to farm systems can only be assessed at the whole-farm level using marginal analysis.

In this paper we analyse aggregate industry data to identify trends that have occurred over a run of years in dairy herd genetic, production and reproductive performance. We model change in the distribution of cow genetic merit within herds across time from applying a long-term genetic selection program. We also examine whole-farm profit estimated from bioeconomic modelling of the whole farm to estimate the impact of genetic change at herd level on whole farm profit.

Materials and Methods

Analysis of real-farm data provides information about the potential impact on farm profit of the annual rate of genetic change in a herd (using BPI) within the Australian pasture-based dairy environment. Findings can be further modelled to examine how the distribution of genetic merit within a herd may change over time following application of a genetic selection program. The physical trends identified from analysis of industry data is compared to similar estimates obtained from a bioeconomic simulation model. This represents a validity test of the bioeconomic model: do predicted physical responses and trends mirror findings from real farm data analysis? If validated, the bioeconomic model predictions of whole-farm profit response to genetic selection is useful to inform dairy farmers about the relative emphasis to place on herd genetics and other farm inputs with the limited capital available to invest in increasing productivity.

The HiCo Herd Recording Centre Software Database (HHRD) of HiCo Australia Pty Ltd (http://www.hico.com.au/) contains herd, cow, lactation and event records from many commercial dairy farm clients, mostly located in Victoria. Access to de-identified HHRD data was obtained in December 2018. Records for each year since 2010 of cow and herd genetic, production and reproduction data, from herds of at least 50 cows, were available for analysis. Cow records from animals with recorded birthdates, born after 2010 and with a BPI record, were obtained from HHRD herds. This yielded 208,227 cows from 407 herds. Of these, 204,400 cows had sire BPI data and 183,550 had dam records. The average range in cow BPI within birth-age cohorts was estimated, along with the average rate of increase in the BPI of artificial insemination (AI) sires. This information was used to model the expected trend in the distribution of the cow BPIs within the herd over time under a consistent genetic selection policy.

The herd parameter estimates for cow genetic merit distribution by age-cohort, the average annual rate of changes of AI sires used and of herd genetic merit obtained from HHRD data analysis, were used to physically model the expected trend and within-herd range of cow BPIs across time, in herds that used AI sires with average sire BPI values in the year of use. The operation of this physical model controls for herd age structures, cow survival, within-age-cohort cow BPI distribution and changes to cow survival (that reflect improvements in fertility), as the distribution of the genetic merit of the animals in the herd changes. Baseline cow lactation survival rates of 0.8 were adjusted for cow BPI by multiplying the baseline BPI odds by the cow's BPI/50 with the result converted back to an annual probability of lactation survival.

In the second analysis, the results of the analysis of the HHRD data are compared with the results from a bioeconomic farm/herd model. The results of the analysis of the HHRD data are compared with annualised output ($ annuity) of the cumulative net benefits (Net Present Value) of running a representative pasture-based dairy system operating in 2015 for 10 years, estimated using the bioeconomic model.

The bioeconomic model is a discrete, dynamic probabilistic simulation model of individual cow production, reproduction and survival in a representative grazing dairy herd. The modelled herds operate according to over-arching management rules (e.g. mating and calving rules, supplementary feeding rules) and had fixed (constant) but seasonal pasture production. Herd feeding was via home-grown pasture and from purchased grain. A representative irrigation (Macalister Irrigation District) herd total energy demand and herd total daily pasture energy growth, based on a pasture growth curve for the region, were calculated. Pasture is assumed to contain 11 MJ of ME per Kg of DM and grain 12 MJ ME per kg DM. If herd energy demand exceeded pasture energy supply, the deficit was made up in purchased grain. If farm pasture energy supply exceeded herd energy demand, the grain-equivalent tonnage of the surplus was 'converted' to hay which was effectively sold. Daily herd energy demand was calculated using ARC growth equations (ARC, 1980) to estimate daily feed demand for young stock, and a maintenance and production energy demand for adults was estimated from milk production.

Herd and shed costs, hay and grain prices, milk prices and cow values were from recent industry data collated in the Victorian Dairy Farm Monitor, Gippsland region (Victorian Department of Primary Industry, various issues).

The physical results from the bioeconomic model for rate of annual change in the herd BPI, top and bottom cow BPI quartiles, and herd AI sires' BPI were compared to results obtained from actual farms across a similar period obtained from analysis of HHRD data. In the bioeconomic model, the marginal effects of increased genetic potential are incorporated, and extra costs associated with producing extra output are met. However, changing responses to extra genetic traits as the distribution of herd genetics shifts rightward from the origin over time are not captured; that is, the extra expression of extra genetic traits is assumed to be linear regardless of the level of genetic merit of the herd to which the improved genetics are introduced. In practice, the extra output from extra genetic inputs will differ according to the genetic merit of the animals to which these inputs are added but, as these relationships are unknown, they could not be incorporated into the model.

The bioeconomic model provides estimates of average whole-farm gross margin and profit associated with the various genetic selection strategies applied to the herd. Changes in the bioeconomic model were validated by comparison to real farm data. The average farm/herd gross margin changes across a 10-year period were estimated, with these equating to changes in profit due to unchanged overhead costs across strategies, for simulated herds from the bioeconomic model whose management strategy included applying a profit-based herd genetic selection program[1] to identify superior AI sires.

Results

Whole herd analysis of HHRD data

These data were used to estimate the average BPI for the whole herd, and the average BPI was also estimated for cows in the bottom and top quartiles for BPI in each year. Lactation records were obtained from HHRD herds providing test records of at least 50-cow herds each year in the period 2007–18. This resulted in 404[2] herds containing 443,892 cows and encompassing 1.29 million lactations. These data were used to estimate the average solids production per lactation for the whole herd, and for cows in the bottom and top quartiles for BPI in each year, and to calculate the proportion of cows that re-calved within 400 days of their previous calving date for the whole herd, and for cows in the top and bottom BPI quartiles within each year. The annual 400-day herd re-calve rate is a robust measure of whole-herd reproductive performance. A key advantage of this measure is that, to calculate it, only calving date records are required.

The average BPI for the whole herd and for cows in the bottom and top quartiles for BPI, along with the average BPI of AI sires used in the herd for each year from 2013 to 2018, is presented in Figure 1. The average and trend line for BPI of the HHRD herd (within-herd, interquartile, BPI range shown) and herd average and trend line for lactation solids production (with interquartile, average lactation production range for within-herd cow BPI), for each year from 2010 to 2017, is presented in Figure 2. Herd average and average of the top and bottom quartiles for cow balanced performance index (BPI) and for the proportion of cows that re-calve within 400 days of their preceding calving date by year

. The HHRD herd average and trend line for BPI (within-herd, interquartile, BPI range shown) and herd average and trend line for the proportion of cows that re-calve within 400 days of their previous calving date (with BPI interquartile 400-day re-calving proportion range for within-herd cow) is

1 Balanced Selection Index; BSI—a profit index combining production and fertility traits into an estimate of impact on annual animal profitability in dollars.

2 Subsets of herds providing cow BPI records.

presented in Figure 2. Herd average and average of the top and bottom quartiles for cow balanced performance index (BPI) and for the proportion of cows that re-calve within 400 days of their preceding calving date by year

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Figure 1. Herd and top and bottom quartiles averages for cow Balanced Performance Index (BPI), herd average AI sire BPI and linear trend lines by year

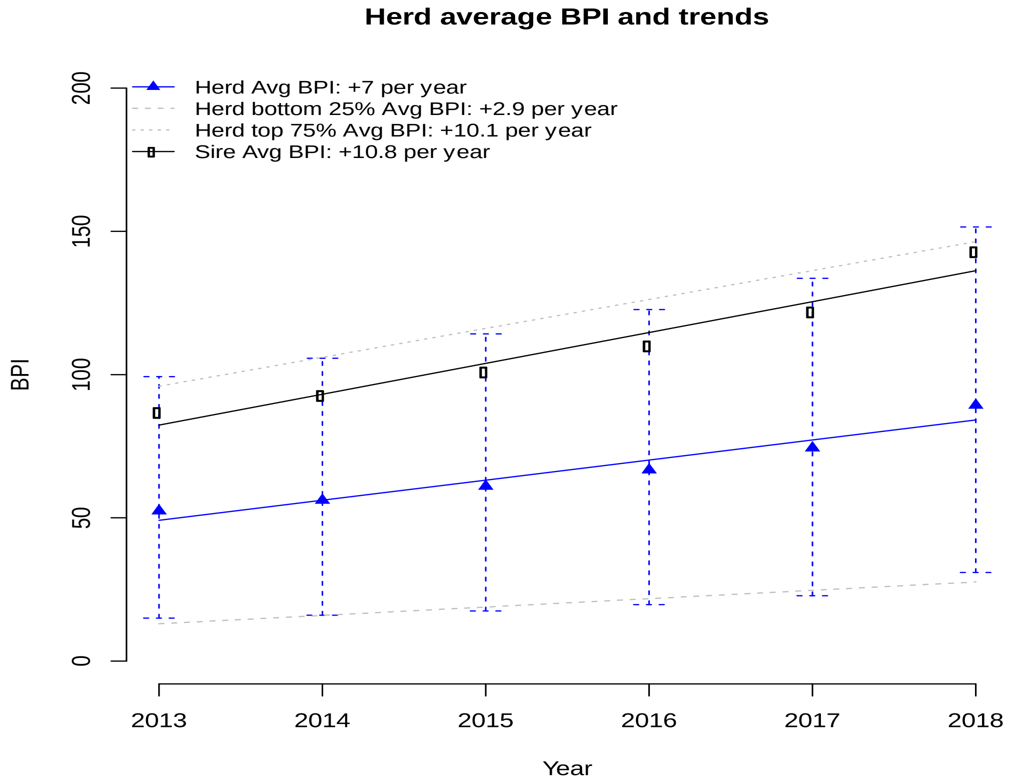


Figure 2. Herd average and average of the top and bottom quartiles for cow balanced performance index (BPI) and lactation solids production by year

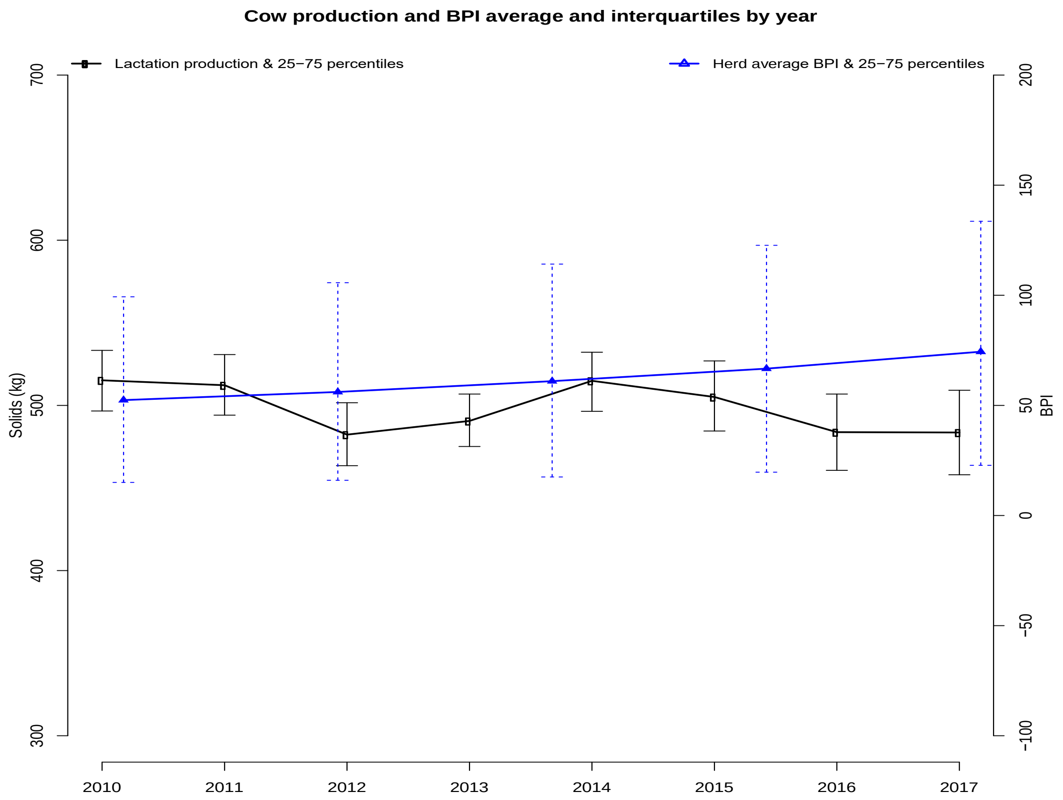
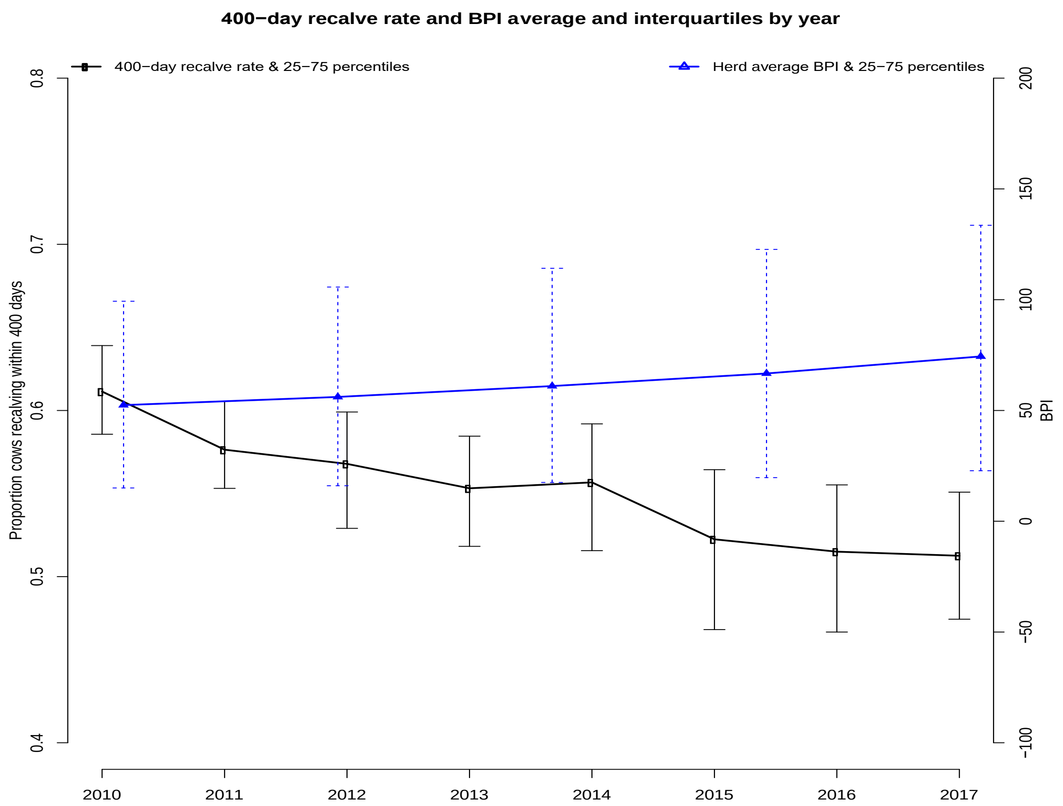


Figure 2. Herd average and average of the top and bottom quartiles for cow balanced performance index (BPI) and for the proportion of cows that re-calve within 400 days of their preceding calving date by year



Trends in distribution of cow BPI within herds across time, under a consistent genetic selection policy

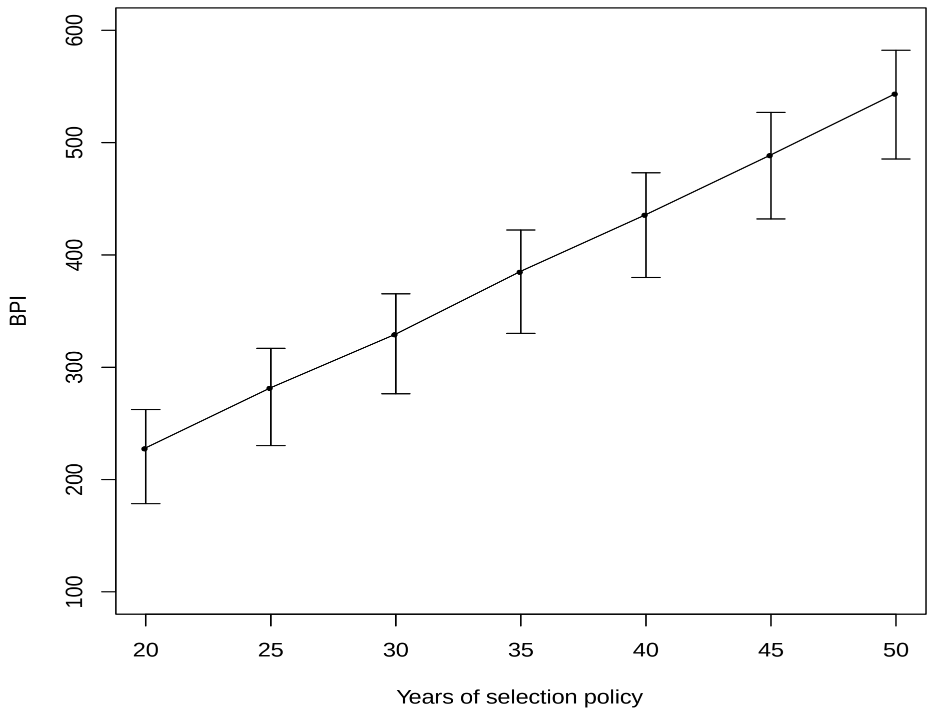
Analysis of the distribution of cow BPIs in the dairy herds in the HHRD data revealed that the average range in cow BPI within birth-age cohorts was 43 units of BPI, and the average rate of increase in AI average sire BPI was 11 units per year. Results of the physical simulation model are presented in **Error! Reference source not found.**. The physical model predicts herd BPI to increase at an average annual rate of 9.5 units; slightly more than, but in the region of, the actual 7-unit increase in HHRD herds and the 8-unit increase reported by Newton et al. (2017). The prediction of the model is that the range between the average BPIs for herd top and bottom BPI quartiles will increase slightly from 80 to around 95 by year 50. This mirrors the slight increase in the range between average BPIs of first and fourth quartile within herd in the HHRD data (for example, as shown in Figure 1).

Whole-herd bioeconomic simulation modelling

Physical performance predictions from bioeconomic modelling

In the whole-herd bioeconomic simulation modelling, AI sire selection strategies were applied to increase cow 'profitability' by simulating improvement in the AI sire population at the current industry rate and selecting superior AI sires for the herd from this annually generated population. This resulted in an average annual 9.5-unit increase in herd Balanced Selection Index (BSI); a result that matches observations of rate of increase in BPI in HHRD herds and gains as reported by Newton et al. (2017)[3].

Figure 3. Trends in average BPI for herd and within-herd interquartile BPI range (the range being the difference between the average BPIs of quartile 1 and quartile 4) over time under a consistent AI sire selection policy



Lactation milk production per cow per year increased by 24.9 litres and 1.69 kg of solids. The 400-day herd re-calving rate increased by 0.53 per cent per year.

3 Both BSI and BPI are economic indexes that use the same units ($ of profit); therefore, they are comparable.

The rate of increase of modelled BSI mirrors closely the rate of observed actual increase in herd average BPI in the HHRD herds. Given that both the BPI and the BSI are indices expressed in real dollar terms, the whole-farm bioeconomic simulation model reflected actual rates of genetic change occurring in herds in the real world. The whole-herd simulation model predicted slight annual increases in lactation milk production and herd 400-day re-calving rate, whereas these measures declined in the HHRD herds. These differences most likely reflect wide seasonal and yearly variability present in the real-world data that was not replicated in the bioeconomic modelling (where seasons and prices were held constant). The impacts of seasonal and price variability are areas for further work. The bioeconomic model results mirrored industry average herd reproductive measures such as herd 6-week in-calf rate, 3-week submission rate and first-service conception rate as at 2015. This provides added confidence in the validity of the model.

Farm gross margin predictions from bioeconomic modelling

Four 'reproduction intervention' scenarios were examined using bioeconomic modelling of the operation of a 250-cow dairy farm over 10 years. Farm annual gross margin and discounted net present value and annuity of the stream of farm annual gross margin were calculated, using a 5 per cent discount rate. The intervention scenarios were designed to answer questions about the effects of different degrees of selection pressure for fertility, different culling rates, and combined effects of these two criteria, are set out in Figure 5.

The annuities of the net present value of the 10-year farm/herd gross margin from whole-farm bioeconomic modelling are presented in
Table *1*.

Figure 5. Reproduction intervention scenarios

		AI sire fertility selection pressure	
		High	*Low*
Culling pressure	*High*	Selection for fertility + voluntary culling	No selection for fertility + voluntary culling
	Low	Selection for fertility + no voluntary culling	No selection for fertility + no voluntary culling

Table 1. Whole-farm 10-year annuity of farm gross margin from modelling selection and culling strategies (herd size: 250 cows, projection: 10 years)

Calving pattern	Test scenario	Net dollars ($)	Change dollars ($)	Change (%)
Year round	No selection - Low culling	341,122	-	-
	No selection - Mod culling	341,751	629	0.2
	No selection - High culling	337,600	-3,522	-1

	selection - Low culling	343,820	2,698	0.8
	selection - Mod culling	344,394	3,272	1
	selection - High culling	340,317	-805	-0.2
Split Calve	No selection - Low culling	289,988	-	-
	No selection - Mod culling	288,519	-1,470	-0.5
	No selection - High culling	284,951	-5,037	-1.8
	selection - Low culling	291,858	1,870	0.6
	selection - Mod culling	291,212	1,224	0.4
	selection - High culling	286,964	-3,025	-1.1
Seasonal Calve	No selection - Low culling	348,461	-	-
	No selection - Mod culling	348,930	469	0.1
	No selection - High culling	348,740	279	0.1
	selection - Low culling	354,146	5,684	1.6
	selection - Mod culling	354,263	5,802	1.6
	selection - High culling	355,377	6,916	1.9

Discussion

The trends in herd performance obtained from analysing the HHRD data since 2010 show that the average BPI of all the herds increased by approximately 7 BPI units per year. This is close to the estimate of average rate of annual herd increase in BPI of 8 units of year from similar analysis as reported by Newton et al. (2017). Analysis of HHRD data showed the distribution of herd BPIs found cows in the bottom and top quartiles of herd BPI increased by approximately 3 and 10 BPI units on average per year, respectively, and herd AI sire BPI increased by an average of approximately 11 units per year. This analysis also showed that from 2010–18 there was a slight decline in the average lactation milk solids production per cow in herds. This decline occurred in both the top and bottom cow BPI quartiles within the herds. A significant year effect was also observed, presumably reflecting wide yearly fluctuations in season quality and input effects arising from milk prices. Herd reproductive performance also showed a persistent decline across this period. Again, this decline was also present within the top and bottom cow BPI quartiles of the herds.

Modelling the physical impact of a consistent genetic selection policy showed that a within-herd range of approximately 100 units of BPI persisted in the herd distribution of BPIs, between the herd's top and bottom quartiles of cow BPI, for at least 50 years (the limit of the modelling). This persistence of the range of BPIs in the herd distribution, between the top and bottom groups of cows, is essentially a result of the combination of having different average genetic merit for each cow age cohort in the herd, and the Mendelian selection effect for multi-gene traits such as milk production and reproduction. Persisting wide distributions of BPIs around the mean within herds over time imply that there is little point in measuring, or focusing on, differences in genetic merit, cow performance or estimated cow contribution to profit, between the top and bottom sub-herds of the whole herd, as any relationship between these measures and farm profit will be weak at best and absent at worst.

The breeding process with a consistent selection policy means a persistent range of genetic merit within the herd is inevitable and unavoidable. The message is that focus for decisions about herd genetic improvement has to be on the overall performance and profitability of the whole herd (and whole farm too); focus on performance differences between subsets within the herd provides no meaningful or actionable information.

The declines in per-cow lactation production and fertility in herds present in HHRD data since 2010 suggest that contribution to farm profit of individual cows has also been declining, especially given that there have been years with low milk price in the period 2010–18. This downward trend in per-cow lactation, fertility and contribution to farm profit questions the merit of an excessive focus of investment of scarce capital in cow genetics if this is at the expense of investment in other, possibly more profitable, aspects of the farm system, such as feed, labour and scale.

The whole-of-herd outcomes matter. Comparing the relative individual profit performances of individual herd mates of different genetic merit is not a guide to evaluating the overall performance of a herd genetics program, or the farm system. Declining per-cow lactation production and fertility since 2010 is the whole story. Information on the estimated impact of the herd genetic selection program on whole-of-herd gross margin and on whole-farm profit over time is required to inform usefully the decision-making of dairy farmers. As it happens, the relationship between changes to herd genetic programs and consequent changes in herd genetic make-up and potential, and whole-farm profit, is intrinsically complicated to both define and then isolate. Farm profit is the result of many factors interacting, only one of which is the input of the herd genetic make-up and potential. The way the profit of a farm changes in response to changes in the genetic merit of a herd differs between every farm, and farm manager, and within every farm over time. This could be examined by studying the herd responses to genetic investment across many farms; however, the resources to conduct a study of such complexity, cost and time are not at hand.

In the absence of quality and large-scale observational data on whole farm physical and financial performance, including detail on the marginal responses in farm systems to changes in genetic make-up of herds, whole-farm bioeconomic modelling is a way to investigate the economics of genetic improvement. Such modelling can incorporate diminishing marginal returns to additional inputs and economies and diseconomies of scale effects, fully accounting for additional and total capital implications of investments, as well as allowing the financial and risk implications of farm improvements to be taken into account. Competing possible investments in farm improvements, too, can be evaluated, using the general criteria of return on marginal capital in this use versus some other use, always considering the risk implications. Such whole-farm models can be (partly) validated against existing datasets that record some elements of farm activities, which was done here using the HHRD data.

The average annual increase in farm profit for the 250-cow dairy farm system whose operation was simulated using a bioeconomic model with a 10-year BSI-based selection policy, compared with the equivalent herd type without such a genetic selection policy, was estimated to be $2,626 (with all other components held equal); this is $10.50 extra profit per cow per year. The average annual rate of increase in herd BSI for the simulated herd with a genetic advancement (BSI-based) selection policy was approximately 8.0 units per year. The implication of 8 BPI units gain per cow on average per year and $10.50 extra profit per cow on average per year in the farm system as modelled, and with the selection policy as modelled, is that the maximum contribution to farm profit from a unit increase in herd BPI was $1.31 per unit of extra BPI per year—for the farm system that was modelled—noting that other farms will most likely vary around this individual estimated response. This is less than the within-herd difference estimate obtained by Newton et al. (2017). These researchers reported average differences in annualised profit generated between cows in the top BPI quartile compared to cows in the bottom BPI quartile for three study herds of between $150–$235 per cow per year, which equates to $1.60–$2.28 per unit of BPI (see Table 2).

Table 2. Estimated profit value of a unit of BPI

Farm	BPI interquartile difference	Profit interquartile difference ($)	Profit/unit ($/BPI)
1	78	178.00	2.28
2	94	150.00	1.60
3	116	235.00	2.03
Average	96	187.70	1.96

Source: from Newton et al. (2017)

The Newton et al. (2017) historical case studies based on cow and herd annual production were not able to reveal the actual marginal responses to feed of the marginal production of the high producing BPI cows. Whilst the study confirmed that high BPI cows are generally more suitable for dairying than herd mates with low BPI (high BPI cows outperformed low BPI cows in all herds), such findings do not inform farmers about how much capital is profitable to invest in herd genetics, which particular level of herd genetics one should aim for, nor how much to invest in genetics relative to all the other factors that contribute to profit in their systems. Only whole-herd, whole-farm and marginal analyses can be sources of this advice. There cannot be a continuous linear increase in profits as herd genetic merit increases because: there are extra costs to lift the other constraints that limit the herd (such as farm pasture production); there will be a decreasing response to extra inputs (in this case, genetics) when applied to an already constrained limitation (again, such as farm pasture production); and the response of extra genetic trait inputs will differ according to the existing level of genetic merit of the cows to which the extra traits are added. The Law of Diminishing Marginal Returns has not yet been repealed. The amount of extra gain from a unit of extra superior genetic material in a farm system will depend on the starting point genetic merit of the cows in the herd. The initial distribution of herd genetic merit affects the subsequent additional performance that occurs as a result of additional inputs of improved genetic traits.

The questions that commercial dairy farmers need answered on investing in superior genetic potential of animals revolve around quantifying the impact of herd genetic change on herd performance; not the relative performance of subsets of the herd. This whole-of-herd information is essential to allow farmers to compare validly an investment in herd genetics against any other investments on farm (e.g. pasture renovation, scale, labour) or off-farm, that competes for limited surplus capital.

Information required to inform decisions about how much (or little) to invest in superior genetics include (a) how much more profit is likely in my herd and farm business if I select for BPI?, and (b) what constraints exist that may prevent the herd from expressing their genetic (BPI) potential? In other words, what other changes (and costs) are necessary to enable full expression of extra genetic potential? And, as the business intensifies, how does business risk change?

The bioeconomic model that simulated the annual and cumulative genetic change over 10 years of a dairy herd, with a consistent selection policy and constant herd size, found average extra annual contribution to farm profit of around $10/BPI. This $10/BPI on average across a herd accounts for necessary (minor) farm changes and improvements (such as pasture quantity and quality) which add to extra variable costs to service the increased herd productive capacity arising from the change in herd genetic potential, recognising that changes in genetic potential incur additional costs.

If the $10 extra contribution to farm profit on average from an extra unit of BPI, as found in the bioeconomic modelling of a representative pasture-based dairy farm, is applied to 350-cow dairy herd, this would equate to an annual increase in herd gross margin, and farm profit, of $3,500. The Dairy

Farm Monitor Project of the Victorian DPI found the average Victorian study herd of 352 cows returned a gross margin of $550,178 and an EBIT of $158,519 in 2017–18 (DEDJTR, 2018). Combining these results would suggest that 7-8 BPI units per annum genetic improvement, which for the analysis is unrealistically assumed to be a linear effect regardless of the existing genetic merit of a herd, and which is of the order of that found in the bioeconomic modelling of a representative dairy herd, and the average annual increase in herd BPI actually achieved in the HHRD herds over the past decade, would represent an annual increase in farm/herd gross margin of 0.6 per cent. In the herd simulation analysis, no extra overhead costs were incurred to enable full expression of extra genetic potential; so the marginal gross margin resulting from expressing improved genetic potential is also an addition to farm profit. In this case, $10 addition to farm profit for an increase of on average 8 units of BPI per year, on average for a 350-cow herd, would represent an additional 2.25 per cent EBIT per annum for an average 350 cow Victorian dairy herd.

Provided the capital investment is commensurate, and the whole-farm economic principle of equi-marginal returns[4] is not overlooked, all such productivity improvements have a role to play to help farmers counter the ever-present average cost-price squeeze that each year confronts farm businesses in Australia.

A key question is 'how much extra investment in cow genetics would be justified economically *if* the response of an annual increase in profit of a dairy herd from improved genetics were similar to that found in the simulation exercise and was expected to be around an average $1.30 per BPI unit or $10.00 for a 7-unit annual increase in herd BPI coming from a 11-unit increase in AI sire average BPI?'

Investment in genetics has a time lag before benefits accrue, and then a series of benefits that accumulate over the life of the genetic traits in the herd. This means the future benefits and costs of investment in improved genetic potential of cows need adjusting (discounting) to their equivalent present value, using the opportunity cost of the capital as the adjustment (discount) factor. The appropriate discount rate is the opportunity cost of capital which is the required return on extra capital invested. Using this approach, with a 10 per cent discount rate and a 15-year life of expression of the superior genetics, and with $1.30 extra profit per unit of BPI, to provide a 10 per cent p.a. required return on extra capital invested the maximum premium payable per straw of superior AI sire is $5.47 ($0.50 per unit of extra BPI) above the price paid for the lesser sires last year. This reduces to $4.15 ($0.38 per unit of extra BPI) if the required return on extra capital is 20 per cent p.a.

Conclusion

Since 2010 the annual rate of increase of HHRD herd BPI has been 7 BPI units. During this time, for a range of reasons, cow annual milk production and fertility (as measured by the 400-day re-calving rate) declined. These trends are the same for herd top and bottom cow BPI quartiles.

Simulation modelling of a representative farm over 10 years indicated that modest improvement in farm economic performance was available from genetic improvement of the herd. On this analysis, a typical, pasture-based 350-cow herd achieving an 8-unit per annum increase in herd BPI achieved an extra $3,500 in farm/herd gross margin, and in farm profit ($10 per cow), after allowances for changes in herd structure, herd depreciation and all other increased costs.

A separate analysis estimated that once the gene flow over 15 years was accounted for, and the benefits and costs in the future were discounted to current values at a 10 per cent p.a. required rate of return, the maximum extra that could be paid for a straw of semen of superior AI sires was between

[4] The principle of equi-marginal returns holds that the allocation of limited capital amongst farm inputs to production maximizes farm profit when the capital is used on inputs so that the returns from the last units of the inputs used are equal. If this is not the case, there is scope to reduce the use of one input whose last unit is adding less to profit than would an additional unit of a different input. Substituting the low marginal profit input for a higher marginal profit input will increase total farm profit.

$0.38–$0.50 per unit of BPI superiority (where BPI superiority is the difference in average sire BPI between this year and last year).

Information about investment in genetic improvement of animals in the whole herd and whole farm system, analysed using sound technical and economic methods, allows better-informed, well-considered decisions by commercial dairy farmers about intensifying the farm business by investing in genetics, based on the relative returns on marginal capital in genetics and other farm inputs. The performance and profit of farm businesses is the result of combining all inputs. Improving profit involves lifting the most pressing constraints to farm performance. The small and slow gains from improved cow (and plant) genetics are but one part of the solution to the challenge of maintaining and increasing profit.

References

Agricultural Research Council (ARC) (1980), *The nutrient requirements of ruminant livestock: technical review by an agricultural research council working party,* Published on behalf of the Agricultural Research Council by Commonwealth Agricultural Bureaux, Slough.

Amer, P. and Fox, G. (1992), "Estimation of economic weights in genetic improvement using neoclassical production theory: an alternative to rescaling", *Animal Production*, 54, 341-350.

DataGene (accessed 15 January 2019), *Australia's Three Breeding Indices*. https://www.datagene.com.au/ct-menu-item-7/australia-s-three-indices

DataGene (2016), *Assessing dairy cows using ABV's: Technote 6.* *https://www.datagene.com/pdf/may2017*.

DataGene (accessed 15 January 2019), *Improving Herds — summary of findings.* https://www.datagene.com.au/ct-menu-item-7/projects-industry-initiatives/improving-herds-project

De Vries, A. (2017), "Economic trade-offs between genetic improvement and longevity in dairy cattle", *Journal of Dairy Science*, 100 (5), 4184-4192.

Dillon, J.L. and Anderson, J.R. (1990), *The analysis of response in crop and livestock production*, 3rd ed., Pergamon Press, Oxford.

Goddard, M. (1983), "Selection indices for non-linear profit functions", *Theoretical Applied Genetics*, 64, 339-344.

Kaniyamattam, K., Elzo, M.A., Cole, J.B. and De Vries, A. (2016), "Stochastic dynamic simulation modelling including multitrait genetics to estimate genetic, technical, and financial consequences of dairy farm reproduction and selection strategies", *Journal of Dairy Science,* 99, 8187–8202.

Newton, J.E., Goddard, M.E., Phuong, H.N., Axford, M.A., Ho, C.K.M., Nelson, N.C., Waterman, C.F., Hayes, B.J. and Pryce, J.E. (2017), "High genetic merit dairy cows contribute more to farm profit: case studies of 3 Australian dairy herds", *Proceedings of the Association for the Advancement of Animal Breeding and Genetics*, 22, 19-22 (Townsville, Qld, 2–5 July 2017)

Victorian Department of Primary Industry (2018 and earlier years), *Dairy Farm Monitor Project, Victoria Annual Report 2017–18*, DEDJTR, Melbourne.