ECONOMIC EVALUATION OF WHOLE GENOME SELECTION, USING MEAT SHEEP AS A CASE STUDY

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SUMMARY

A number of scenarios for meat sheep genetic improvement in Australia are evaluated, incorporating various combinations of additional performance recording via an Information Nucleus (IN), and implementation of Whole Genome Selection (WGS). The unsurprising results are obtained that the increment of economic return depends on the increments of accuracy, speed and cost. Perhaps more interestingly, it is clear that implementation of either IN and or WGS will almost certainly both require but also stimulate evolution of industry structure towards a more clearly defined nucleus:multiplier:commercial base model, and will require further evolution of co-investment, from the current mix of stud breeders, collective industry and taxpayer funds, to models likely to involve investment from processors, retailers and potential from genotyping companies.

INTRODUCTION

Whole genome selection (WGS, van der Werf 2009) is an anticipated outcome from current research into sheep (and other species) genomics, and has begun to be applied to dairy cattle breeding. Initial studies suggest that it offers potential improvement in accuracy of selection and in reducing generation intervals, at least for males (van der Werf 2009). In addition, the sheep industry has established an information nucleus (IN, (Banks *et al.* 2006), which provides capacity to record hard-to-measure traits and thus increase accuracy of selection for the breeding objective. The economic returns from application of WGS in conjunction with the IN will depend on the combination of the increase in rate of genetic progress achieved and the cost of the technology. This paper estimates those returns and the impact of varying the structure of the stud sector, and cost of WGS. The population modelled is the Australian slaughter lamb industry and the terminal sire stud sector which supplies it with rams.

MATERIALS AND METHODS

Model. A simple spreadsheet model was used, with the following parameters and assumptions:

- a commercial population of 10m ewes, mated to rams derived from the stud sector which are used for 4 years, with first progeny at 2 years
- a stud sector of 200,000 ewes with current recording costs in the studs of $10 per ewe, or $2.50 per ewe when WGS is applied (the latter reflecting many breeders choosing not to record if genotyping tools are available)
- current rate of progress in the stud sector of $2 per ewe joined per year (Swan *et al.* 2009)
- IN cost of $1.5m per year, and increase in rate of gain in the stud sector due to the IN of 7.5% (van der Werf 2009)
- increase in rate of progress due to WGS of 40% (van der Werf 2009)
- genotyping costs modelled at $20 per ewe or $50 per ewe
- where additional AI is used in conjunction with WGS, cost per ewe is $25
- costs and returns modelled over 25 years, with a discount rate of 7%

- only additional revenue due to genetic gain in carcase weight and carcase value was included in the returns.

Scenarios modelled:

A: this simply models the current situation, with no IN impact on either costs or returns. This represents what industry is currently achieving, and assumes no IN is established.

B: A plus an IN, and assumes that this is permanently in place.

C1 and C2: B with WGS added within the stud sector, with two genotyping costs modelled ($20 per ewe and $50 per ewe respectively)

C3: C2 but with recording costs per stud ewe reduced to $2.50, reflecting a partial replacement of current performance recording by WGS

D1: C2 with an elite nucleus, such that WGS is applied to only 10% of the stud sector, with the remaining stud ewes becoming a multiplier, lagging 2 years behind the elite 10%. This would be achieved by making all matings in the multiplier to young rams from the elite nucleus, used as ram lambs and used only once.

D2: this is the same as D1 but with all multiplier matings by AI at $25 per ewe

RESULTS AND DISCUSSION

Modelled parameters, costs and returns from each scenario are shown in Table 1.

Table 1. Summary of Economic Evaluation

Scenario	Parameters	Total Stud Recording Cost ($m pa)	Information Nucleus Cost ($m pa)	WGS Genotyping and AI Cost ($m pa)	Total Investment ($m pa) /Total cost per stud ewe ($)	Net Present Value over 25 years ($m)
A	Current	2	0	0	2/10	1,780 (100)*
B	+ IN	2	1.5	0	3.5/17.5	1,896 (107)
C1	+ IN + WGS at $20	2	1.5	4	7.5/37.5	2,432 (137)
C2	+ IN + WGS at $50	2	1.5	10	13.5/67.5	2,356 (132)
C3	+ IN + WGS at $50, reduced stud recording	0.5	1.5	10	12/60	2,375 (133)
D1	+ IN + WGS at $50, elite nucleus, no AI cost	0.5	1.5	1	3/15	1,959 (110)
D2	+ IN + WGS, elite nucleus, AI at $25	0.5	1.5	5.5	7.5/37.5	1,903 (107)

*: value in parentheses is the NPV relative to scenario A

There several aspects of these results, which can be taken in turn. Firstly, the current investment in and utilisation of BLUP technology by the terminal sire stud breeding sector (scenario A) is highly profitable in terms of industry NPV. To put this in context the Net Present Value (NPV) of the gross value of production (GVP) of lamb production over 25 years is approximately $32bn. Thus current genetic improvement in terminal sires adds approximately 5.5% of that GVP. There is very low risk around this NPV – the technology required is already in use, well adopted by both the stud breeder and via ram sales, by commercial producers.

Investment in the IN (scenario B) is predicted to generate an additional 7% NPV (compared to the current situation). This is dependent on the increase in accuracy of selection in the stud sector due to their relationship to animals tested in the IN. An important research question is how to maximise this relationship through optimisation of sire sampling, specifically how many sires should be evaluated, with what relationships amongst them, and how many progeny per sire.

There is low risk around the NPV estimated for scenario B. Essentially it is simply adding data on animals highly likely to make a significant genetic contribution, and via the relationships, on the whole population. The data that makes the difference is that on objective traits, rather than on the selection criteria currently used and which have a lower correlation with objective.

There is an additional benefit of the IN which is not modelled here. The IN includes recording for some traits which do not currently contribute to industry profitability and hence are not included in the objective, such as iron, zinc and omega-3 content. By recording these traits, industry immediately has the ability to at least monitor any correlated responses in them, and very quickly place selection pressure on them in the event that market signals for any become apparent. This provides both insurance and responsiveness benefits, both uncosted in this evaluation. The research questions around the IN which will assist industry to optimise the investment include the relationship with the rest of the stud sector, and how to optimise the traits actually recorded.

Scenarios C1, C2 and C3 add utilisation of WGS to the investment in the IN. Given the predicted increase in rate of progress, these scenarios all generate substantial increases in industry NPV. The differences reflect different assumptions about the price of WGS. The key uncertainty for these scenarios is whether the predicted increase in rate of progress can be achieved, and this in turn depends on whether the numbers of animals recorded for objective traits are sufficient to support the predictions of genetic merit.

A further researchable question regarding WGS is how many animals need to be phenotyped to calibrate a particular WGS prediction to the desired level of accuracy, and how quickly this calibration decays as genetic change proceeds. It will also be important for the sheep industry to build understanding of the linkage disequilibrium (LD) structure within and across the breeds used in slaughter lamb production: the terminal sires used are a mix of relatively recent breeds (eg. Poll Dorset, White Suffolk) and composites being formed from them, whilst the dams are a mix of Merino, Border Leicester-Merino and other breeds and crosses.

The most significant factor impacting industry implementation around the WGS scenarios is simply the increased level of investment required. This leads to discussion of the risk considerations of each scenario.

Risk Considerations. The current approach to genetic improvement in this sector (scenario A) is characterised by decision-making spread over some 400 stud breeders, all competing for ram sales, and with limited capacity to invest in technical or business development. Against this, the number, geographical spread and closeness of connection to ram buyers, provide a measure of robustness and adaptability to the system, coupled with a relatively low risk of total failure to achieve genetic progress. The other risk, or weakness, of this scenario, is that selection is for criteria only moderately correlated with a breeding objective defined from total value chain profitability.

Scenario B, which adds an IN, addresses this latter risk by incorporating measurement of objective traits, as well as of some traits anticipated to become important in the near future (such as the compositional traits). The technical risks here are that the wrong traits will be invested in, or traits will be invested in at the wrong level, and that it is not possible to increase the accuracy of genetic evaluation of stud candidates through their relationship with animals sampled for the IN. Two implementation risks are that animals sampled for the IN become less related to the animals that do end up being widely used, or conversely that too few are sampled and they have too much genetic impact on the total population, leading to inbreeding. These implementation risks are manageable. The technical risk around trait investment is simply a matter for careful forecasting and risk assessment, while that around impact on accuracy is a matter of calculation and optimisation.

When we consider the WGS scenarios, there are two obvious challenges. Firstly, we don't yet know the accuracy of WGS, how much data is required for calibration, or how quickly predictions decay. All three factors impact on the advantage offered by WGS and how much it costs to achieve that advantage. The second challenge is an implementation challenge, focussed on the level of investment required and the industry structure. The current stud breeder's margin on investment in LAMBPLAN is currently around \$25-50 per ewe mated. This margin would be nullified by either of the modelled genotyping costs (\$20 or \$50 per animal), and accordingly if these costs are realistic, WGS will simply not be taken up by breeders alone. This would likely remain the case even if substantial increases in profitability for processors and/or retailers were generated, since under the present industry structure, price signals from consumer to breeder are essentially averaged at each link in the value chain, and diminish as the number of links increases.

Recognising this potential limitation to adoption of WGS, scenarios D1 and D2 model the establishment of an elite (likely dispersed) nucleus, probably tightly coupled with, or involving, an IN. Given that the current IN is supported by industry and commonwealth funds, it is likely that at least some similar co-investment would be required to initiate scenarios resembling D1 or D2, and such co-investment, but including other partners such as processors, would be required for continuity.

An important point to stress regarding scenarios D1 and D2 is that they limit genotyping to perhaps 20,000 animals, or even less if possible. Indeed, D1 and D2 are quite robust to WGS not offering value at all, since essentially they are the logical next step in evolution of the industry improvement system once an IN is in place. These strategies thus reduce total investment significantly, but at the same time are predicted to deliver considerably lower additional NPV. These considerations around the D strategies highlight the challenge for industry relating to how to achieve the increased investments that seem likely to be needed, along with the uncertainties regarding the realised benefits of WGS.

These risk considerations suggest that the scenarios beyond B are much more uncertain, and to some extent less robust. This reflects the fact that whilst WGS offers scope for faster genetic progress, that scope is totally dependent on price and accuracy. In this sense WGS is simply another form of genetic evaluation, and its value is built on performance recording. Extracting maximum value from the minimum amount of recording is always the challenge.

REFERENCES

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