Connectedness in Across Herd Genetic Evaluations

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Introduction

Across herd genetic evaluation using BLUP procedures allows individuals from different herds to be validly compared in their relative genetic merit. The potential advantages of across herd analyses to the industry as a whole has meant that such analyses are routinely conducted in Canada and European countries. In Australia, across herd evaluations will become a major tool for small scale breeders wishing to maintain their competitiveness against larger, more economically efficient breeding companies.

From an industry perspective, the logical progression from within herd genetic evaluation (i.e. PIGBLUP) is the introduction of across herd evaluation to the Australian Pig Industry. Across herd evaluation has the following advantages:

1. Breeders will have access to a wider genetic base for selection decisions, thereby improving selection intensities.

2. With a larger effective population size breeders may be less concerned about inbreeding issues. Thus, selection and mating decisions will be less influenced by decisions relating to inbreeding.

3. Co-ordination of participants may reduce fragmented breeding objectives in the industry by standardising some management practices and definition of traits of economic importance.

4. Outstanding individuals may be more readily identified, and made widely available to the industry through AI.

5. The efficiency of central testing may be improved through better choice of young boars for individual testing and entry to AI centres.

6. It becomes feasible to include traits in the breeding objective which may show limited response for individual breeders due to small herd size (limiting selection intensities) or which are difficult to test on farm.

An essential ingredient of successful across herd analysis is an adequate level of genetic connectedness.

What is connectedness and why is it an issue?

A simple definition of connectedness is the sharing of genes from a common genetic source between herds. This is achieved by transfer of breeding stock between herds and/or the use of AI, with progeny from a common genetic source subsequently recorded in more than one herd. A large enough sample of these 'common genes' allows individuals from connected herds to be compared to a reference level of performance. In contrast, a small sample of these common genes means that chance effects may influence such comparisons - and accuracy of between herd comparisons will be reduced.

Without genetic connectedness it is not possible to compare EBVs for individuals from different herds with an acceptable degree of accuracy. Connectedness is essential for establishing the overall genetic ranking of herds across which individuals are to be compared. However, the level of genetic connectedness required for accurate across herd comparisons depends on characteristics of the traits analysed, the method of genetic evaluation, and the comparisons which are to be made.

Where across herd comparisons are desired, it becomes obvious that genetic connectedness must be established. However, there are some downsides to establishing connectedness from the breeders viewpoint:

1.   Unique identification of all individuals is required both within and across herds.

2.   The breeder must contribute some of their breeding resources **initially** to the mating of reference boars with 'unknown merit' relative to their own herd.

3.   With a fixed number of sows, devoting some matings to reference boars reduces the number of progeny produced from home bred boars.

4.   Technical problems (eg. AI technology).

5.   Logistics (eg. transport).

6.   Health issues (eg. introduced animals).

7.   Publication of results (eg. confidentiality etc.).

Point 1 is readily dealt with by following set protocol to ensure unique identification of all individuals. Points 2 and 3 may be in part dealt with if breeders feel confident that reference boars are of sufficient merit to include as sires in their herds, and that progeny from these sires will be competitive for selection purposes. In later years, the relative genetic merit of reference boars will be known if these are sourced from herds participating in the across herd analysis. This further reduces the potentially antagonistic nature of balancing reference boar matings with home boar matings. Technical problems (eg. low AI conception rates), logistical considerations (eg. organising semen transport, matings etc) and health issues must also be dealt with if genetic connectedness is to be achieved. Finally, some agreement must be reached between participants as to the strategy for publication of results.

How is connectedness achieved?

For a valid across herd genetic evaluation, connectedness must be achieved across herds and/or contemporary groups over time. Simultaneously, accuracy of within herd comparisons should not be compromised excessively through allocating too many matings to reference boars (as noted above).

Achieving good levels of genetic connectedness over time requires continued commitment, and may be achieved in several ways:

1.   Use of reference boar(s)

•   Provides the most important type of connection through a **direct comparison of reference progeny with contemporaries which are the progeny of home sires**. Use of reference boars(s) is most effective for establishing connectedness where they are used across all participating herds.

•   The actual number of reference sires used will be influenced by the breeders attitude to risk and the proportion of reference sire matings required.

•   Where reference boars are regularly replaced in AI centres at set time intervals, it is valuable to retain a proportion of boars longer to connect reference sire groups over time.

2. Buying breeding stock off participating herds - boars and gilts

- This connection improves **the direct comparison between the herds interchanging breeding stock**, but has little effect on improving knowledge of the relative ranking of other herds participating in the analysis. This is because connections with other herds as a result of these introductions will be **indirect**, and may be reduced in quantity with a fixed number of breeding stock.

- This connection is most valuable where breeding stock exchanged have themselves been performance tested in their original herd, and their progeny are performance tested in the new herd.

3. Retaining progeny from the above in the breeding herd

- Retaining progeny from introduced animals aids in maintaining connections over time. However, **the value of these connections at a particular time decreases as relationships become more distant**. Thus, one cannot rely on a single introduction to provide adequate levels of genetic connectedness, even if progeny are retained. This is because the original 'sample' of genes providing the reference level of performance is diluted with successive generations.

- Failure to retain progeny which provide a connection between herds means that their performance records only contribute to knowledge of relative herd merit at a single point of time. This is only remedied if their relatives (offspring or other relatives) are represented over time.

4. Retaining sows for more than one parity

- Repeated breeding of sows provides important within herd connections over time through her performance tested progeny.

Central testing of boars may also be used to evaluate the relative genetic merit of herds - the rationale being that environmental and management differences are removed in this comparison. However, to be effective each herd should participate with large groups of individuals, and intakes from different herds need to be compared at the same time. Generally, small intakes and failure to test boars from each participating herd simultaneously limit the effectiveness of central test stations to provide accurate predictions of the relative genetic merit for each herd. In combination with BLUP, however, this information may be better used.

What level of connectedness is required?

This question is not so easily answered for the pig breeding situation, particularly where across herd analysis for on farm recorded traits may be combined with traits recorded at central test stations. In addition, the range of desired comparisons between individuals may be much larger than is usually dealt with in connectedness theory.

For example, much of the theory of connectedness deals with optimising progeny testing of sires over herds of similar size or within a formalised trial. With a planned progeny test it is possible to formalise the design and define the number of young sires to be tested, the number of progeny required per young sire, and the proportion of matings to reference sires required to optimise comparisons between young sires for a given level of accuracy. However, this particular scenario is not particularly applicable in pig breeding where individual performance testing and continuous animal model evaluations are the norm. Thus, information from several sources must be accounted for. In addition, data structure is less formalised across herds within the pig industry, herd sizes may vary

considerably and desired comparisons generally do not lie solely with progeny tested boars.

However, theory does provide us with some basic guide-lines for establishing the level of connectedness required. Usually the desired level of connectedness is established to achieve a particular level of accuracy for animals which are to be compared. For a fixed herd size there are some basic factors which influence what proportion of matings should initially be assigned to reference boars. These include:

1. the desired accuracy of across herd comparisons

2. trait heritability and characteristics

3. frequency of across versus within herd comparisons.

For progeny testing of sires under a sire model (female pedigrees unknown), the optimum proportion of progeny from reference sire matings may exceed 30%, and increases as trait heritability decreases. In pig breeding, the optimum probably lies somewhere between 10-20%, although the exact proportion of matings is difficult to generalise. Over time, as genetic connections are strengthened through continual use of reference boars, and with progeny from these selected to remain in the herd, the proportion of matings devoted to reference boars may be reduced from initial levels. Similarly, with increasing herd size, the proportion of reference matings required will be lower than for herds of a much smaller size.

When is connectedness not important?

Within herd analyses make no use of genetic connections between herds, which is why it is not valid to compare animals across herds using within herd EBVs. In addition, connectedness is not important for an across herd analysis when there is no significant difference in the average genetic merit of different herds which wish to compare their animals. In this situation no reference sire progeny are required to validly compare across herds. However, it is difficult to prove/disprove that this is the case in reality. So the correct answer to the above is probably **NEVER**. Adequate genetic connectedness is always important for across herd comparisons unless you are a real risk taker. Undoubtedly, breeders attitudes differ as to whether there are real genetic differences between the herds of interest!

Examples of connectedness

A simple demonstration program has been written to illustrate how genetic connectedness is generated between herds by the introduction of breeding stock and/or use of reference boar(s). This is achieved by simulating various data structures and then analysing the proportion of genes shared between herds. This program was used to generate results presented in Tables 1 and 2.

The basic scenario (Basic)

- three herds of equal size
    - forty sows
    - four boars
    - four progeny tested per litter
- three generations of data
- 10% litters from reference boar matings
- same reference boars used over both generations
- **no progeny retained from the reference boar**
- no other introductions

Other scenarios

A: No use of reference boars

B: Increasing the proportion of reference matings
1. As with *basic* but 20% of progeny from reference boar(s).
2. As with *basic* but 30% of progeny from reference boar(s).

C: Altering the number of reference boars used
1. As with *basic* but with two reference boars used instead of one.
2. As with *basic* but with four reference boars used instead of one.

D: Using reference boars only once (1st generation only)

E: Introductions
1. New reference boars annually from herd 1.
2. Buying one (a) or two (b) replacement boars from herd 1 for herd 2.
3. Buying one (a), three (b) or six (c) gilts from herd 1 for herd 2.

Options which influence each of the three herds to the same degree are presented in Table 1 (Basic and options A to D). For option E, introductions were from herd 1 to herd 2, or involved the selection of reference boars from herd 1. Thus, results for each herd are not identical, and are presented along with results for the basic option using a different format in Table 2.

Table 1: The percentage of genes originating within herd (diag) or in common with other herds (off-diag) as well as measures of connectedness between pairs of herds and over all three herds.

Option	nref	perc	allgen	% genes		Connectedness	
				diag	off-diag	Between	Overall
Basic	1	.1	yes	.967	.017	.017	.034
A	0	0	no	1.00	0.00	0	0
B1	1	.2	yes	.933	.033	.036	.071
B2	1	.3	yes	.900	.050	.056	.111
C1	2	.1	yes	.967	.017	.017	.034
C2	3	.1	yes	.967	.017	.017	.034
D	1	.1	no	.989	.006	.006	.011

nref   =   number of reference boars used

perc   =   percent of matings allocated to reference boars

allgen =   reference boars used every generation (= yes) or not (= no)

Important conclusions from Table 1 are:

1.   Without outside introductions there is no genetic connectedness between herds (eg. 0% connectedness under option A).

2.   Allowing 10% of matings to be made annually by reference boars provides connectedness between herds (Connectedness = approx. 3% under the basic option). Only a relatively small proportion of genes are shared.

3.   Increasing the proportion of matings made by reference boars increases connectedness (from 3% to 11% overall under options B1-B2).

4.   Altering the number of boars used as reference sires has no effect on connectedness between herds if a fixed percentage of reference boar matings is considered (Options C1-C2). However, it does impact on the accuracy with which progeny from alternative reference boars may be compared.

5.   The value of progeny from reference matings to connectedness declines over time if no further reference progeny are generated (down to 1% under option D).

Table 2: The percentage of genes originating within herd for each herd (diagonals) as well as measures of connectedness between pairs of herds and over all three herds.

Option	new	boars	gilts	Diagonals			Connectedness			
				h1	h2	h3	12	13	23	Overall
Basic	no	0	0	.967	.967	.967	.017	.017	.017	.034
E1	yes	0	0	.989	.864	.864	.073	.073	.006	.104
E2a	no	1	0	.967	.892	.967	.058	.017	.018	.062
E2b	no	2	0	.967	.817	.967	.103	.017	.019	.091
E3a	no	0	1	.967	.954	.967	.024	.017	.017	.039
E3b	no	0	3	.967	.929	.967	.037	.017	.018	.048
E3c	no	0	6	.967	.892	.967	.058	.017	.018	.062

new = new reference boar used from herd 1 (= yes)

boars = number of boars bought from herd 1 to use in herd 2

gilts = number of gilts bought from herd 1 to use in herd 2

Important conclusions from Table 2 are:

1. Introducing new reference boars from participating herds will improve overall connectedness (eg. from approximately 3% under the basic option to 10% under option E1).

2. Relative comparisons between herds not contributing reference boars to the participating herds may decline as more animals tested within these herds originate genetically from a different herd (eg. connectedness between herds 2 and 3 decreases from 1.7% under the basic option to 0.6% under option El).

3. Exchanging breeding stock between herds will also improve connectedness between the herds involved in the exchange (see Options E2 and E3).

4. The value of the exchange to connectedness depends on the number of progeny generated by exchanged animals relative to homebred individuals (eg. exchange of boars may be more valuable initially due to the high number of progeny they may produce).

5. Exchanging breeding stock between two herds will generally not improve connectedness with other herds which do not participate in the exchange (see Options E3a-E3c).