ECONOMIC ADVANTAGES OF SELECTION BASED ON BLUP *VERSUS* PHENOTYPE IN A CLOSED PIG HERD

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INTRODUCTION

Several studies (Belonsky and Kennedy, 1988; Sorenson, 1988; Keele et al., 1988; Long, 1989; Wray, 1989; Roehe et al., 1990) have demonstrated the opportunity for higher genetic gains in pig breeding by using Best Linear Unbiased Prediction (BLUP) for genetic evaluation rather than selection on phenotype (SP) or traditional index selection. These studies did not examine the economic outcome of these biological gains, and the purpose of the present study was to do this.

MATERIALS AND METHODS

The study considered the traits: litter size born alive (LS), average daily gain (ADG), backfat (BF) and feed conversion ratio (FC). It was assumed that the breeder was recording data on LS, ADG and BF, with improvements in FC being realised through correlations. Since correlations may be affected by feeding system and management (e.g., McPhee et al., 1988), values used assumed *ad libitum* feeding and group housing. Phenotypic and genetic (co)variances used were based on results from Australian studies (Klassen, 1991).

Economic values for improvement for each trait were derived by Prof. T. Stewart (personal communication) using Australian data. These economic values were: LS \$23.25/pig/litter, ADG \$2.27/gram/day/litter, BF -\$29.75/millimeter/litter, and FC -\$150.00/unit/litter; being described on a per litter basis to assess advantage/sow/year. To investigate sensitivity, these economic weights were varied from -80 to +80% for each trait. Since no information was available on correlations between economic weights, these were assumed to be zero. This study also assumed fixed economic weights, i.e. that genetic improvement in the breeding herd being considered had no effect on industry average prices.

Based on these data, the program 'SELIND', by Cunningham (1970), was used to produce a selection index to assess improvement in the aggregate genotype. Using the above average values, the standard deviation of the index was 49.4, the standard deviation of the aggregate genotype was \$87.18, and the correlation between the index and the aggregate genotype was 0.57. Using the definition of Lin (1978), the heritability of the index was .32. This assumes selection on a traditional index rather than an index of mixed model estimated breeding values so could be considered a conservative estimate of the gain in the aggregate genotype.

Economic comparisons were made for three scenarios which were chosen to allow use of the results of Belonsky and Kennedy (1988). That simulation study was chosen because: 1) it evaluated response for a range of heritabilities, .10, .30 and .60, 2) it gave results in standardised genetic units so 'SELIND' could be easily applied to calculate the economic worth of that improvement, and 3) it evaluated the effects of using breeding values for culling and for selection decisions. The scenarios examined were:

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(A) SP versus BLUP selection for a single trait of heritability about .10.
(B) SP versus BLUP selection for a single trait of heritability about .30.
(C) Single trait phenotypic selection versus an index of BLUP EBVs with heritability of the index about .30.

Scenarios (A) and (B) involved straightforward applications of Australian economic values to the genetic responses for SP or BLUP given in Belonsky and Kennedy (1988). These responses were presented in terms of the average relative merit of progeny (in genetic standard deviation units) after 5 or 10 years of selection. The assumption was made that this response was linear over time, (i.e. an equilibrium response) since a fairly linear response was found by Belonsky and Kennedy (1988) and Wray (1989). We converted these results to dollars by multiplying them by the additive genetic standard deviation (Klassen, 1991) and the economic weight for the trait being considered. It was assumed that each sow produced two litters/year and that litter size was 8.75 pigs marketed/litter.

In order to use Belonsky and Kennedy's results for scenario (C), several assumptions were made. First, the aggregate genotype, as defined by the selection index described above, was used as the basis for comparison. This means that the improvement in other traits in the aggregate genotype, as a result of selection on the single trait, was accounted for when comparing the economic efficiency with that of the weighted EBV index. The second assumption was that the heritability of the weighted index was the same as that of the SELIND index described above. This is usually not true because the heritability of the weighted EBV index is a function of the prediction error variances and the economic values of the individual EBVs, and is therefore dependent on the data structure. For a balanced data structure, the weighted EBV index will have a higher accuracy than the previously defined selection index, because it uses information on relatives as well as information from other traits. This study would provide, therefore, a conservative estimate of the difference between SP and BLUP which could be thought of as a lower limit to the true benefit of BLUP.

For all comparisons a discount rate of 5% was used and a 10 year investment horizon was considered. Calculation of the discounted value of returns followed Smith (1978).

RESULTS

Results from comparisons (A) and (B) are presented in Table 1. An advantage is accrued beyond the first year and discounted in subsequent years so results presented are in 1991 Australian dollars. The discounted economic advantage of BLUP over SP was $4.47 and $18.67/sow/year for LS and ADG, respectively (for the average economic weights). This rose to $12.11 and $57.67 when BLUP was used for culling as well as selection decisions. Not surprisingly change in economic values of the traits had an important effect on this advantage ranging from $2.41 to $21.77 and $11.42 to $103.94 for LS and ADG, respectively, for the BCI scenario. The advantage for ADG was approximately 3 times as great as for LS, and all values were positive, indicating that even with very low economic values BLUP provided an advantage over SP.

Table 1 Advantage ($/sow/yr) of selection on BLUP vs phenotype for selection on 1 trait and a range of economic weightings

		% Change in Economic Weight from Average Value				
Selected Trait	Comparison	-80	-40	0	40	80
LS	BI*	0.90	2.67	4.47	6.24	8.00
	BCI**	2.41	7.24	12.11	16.94	21.77
ADG	BI	3.71	11.17	18.67	26.13	33.63
	BCI	11.42	34.56	57.67	80.80	103.94

* BLUP minus Selection on Phenotype
** BLUP minus Selection on Phenotype also with culling on BLUP EBVs

Table 2 presents the discounted advantage when an index of EBVs was considered, and economic weights were varied for one trait while the weights for the other three traits were held at the average values.

Table 2 Advantage ($/sow/yr) of selection on index of BLUP EBVs vs phenotype for a range of economic weightings on one trait in the index

		% Change in Economic Weight from Average Value for 1 trait*				
Index Trait	Comparison	-80	-40	0	40	80
LS	BI**	26.81	27.14	27.64	28.36	29.26
	BCI***	82.90	83.87	85.45	87.69	90.05
ADG	BI	18.78	22.42	27.64	33.74	40.29
	BCI	58.03	69.31	85.45	104.27	124.52
BF	BI	24.40	25.48	27.64	30.64	34.24
	BCI	75.40	78.79	85.45	94.72	105.89
FC	BI	23.61	25.59	27.64	29.77	31.93
	BCI	72.91	79.08	85.45	91.98	98.64

* Economic weight for trait changed while weights for other traits held at average value.
, * As in Table 1.

The discounted economic advantage for an index of BLUP EBVs over SP (for average economic values) was $27.64/sow/year, and this rose to $85.45/sow/year when culling decisions were also based on EBVs. Change in the economic value of one trait in the index had the greatest effect for ADG, ranging from $58.03 to $124.52 for the BCI scenario, indicating that ADG was the most sensitive of the traits considered, to changes in economic value. LS was the least sensitive of the 4 traits considered.

DISCUSSION

This study demonstrates that by using BLUP EBVs in an appropriately weighted index, economic gain can be substantially greater than that based on BLUP EBVs for a single trait or SP. When EBVs are used for selection and sequential culling of breeding stock, the potential economic gain is considerably increased again. Of course, the results obtained above are a function of assumptions made, and care has been taken to state these. For this study, the index considered was a general purpose index (rather than a maternal or terminal sire index), it was based on the genetic and phenotypic parameter estimates of Klassen (1991), and within herd selection was applied. If one were considering selection in specialised lines of pigs, the assumed economic weights would change as would the potential economic gain from selection on a single trait using BLUP versus SP. However, conservative assumptions in the evaluation of BLUP were used and the general trends found in this study would still hold.

De Vries et al. (1990) have questioned the advantage of sequential culling in a breeding program. They found an extra response of 2-3% when older animals competed with young replacements in selection/culling decisions, observing Belonsky and Kennedy obtained such large responses (41% when heritability was 30%) due to high maximum age for boars (3 years). De Vries et al. (1990) did not apply sequential culling to boars (only sows) because boars were used for 8 weeks only, and considered this would not significantly affect genetic gains. Wray (1989) observed an advantage of 5-6% when also using sequential culling with BLUP. She simulated the use of boars for a maximum of 30 weeks and considered a trait with a heritability of 20%. If these relative responses of Dr Vries et al. and Wray (3 and 6%) were applied in the present study, for a 10 year horizon, employing a 5% discount rate and heritability of 30%, the discounted average annual advantage of BLUP selection and culling over SP would be $32.04/sow/year and $35.82/sow/year, respectively. These values are considerably less than the value found using Belonsky and Kennedy's results ($85.45/sow/year) and much closer to the value found in this study for using BLUP without sequential culling ($27.64). The three simulation studies managed boars differently as regards the maximum time a boar could be used and whether boars and sows were culled on EBVs. The estimated economic advantage of using sequential culling over BLUP alone then could be dependent on strategies employed by breeders. Also, de Vries et al. (1990) found that sequential culling increased the proportion of gilts being farrowed, and the reduced production of first litter gilts versus older sows would have to be accounted for in assessing total economic advantage. The present study did not address this issue, dealing only with future rather than present gains (James, 1978).

Several researchers (Belonsky and Kennedy, 1988; Wray, 1989; de Vries et al. 1990) have also found selection on BLUP increased the rate of accumulation of inbreeding in a closed herd relative to SP, when the same mating strategy is employed. The present study did not account for the effects of inbreeding depression. This differential increase in inbreeding would also apply in this study as the same mating structures were employed throughout. However, when selection is based on a linear combination of BLUP EBVs as with the $INDEX procedure (Stewart et al., 1988), the inbreeding depression for any one trait would be less than those expected when single trait selection is applied. Further simulation studies are required to examine rates of inbreeding under multiple trait BLUP and alternative mating management. The studies mentioned above also assumed closed herds, which is not typical of most of the breeding herds in Australia. Most breeders occasionally introduce immigrants to their herds and this can markedly change rates of inbreeding.

The average economic values used in this study were derived from average costs/prices, and economic benefit was affected when these were varied. Also the assumption of no price correlations between the economic values for ADG and FC is untenable as reduced feed costs are involved with an improvement in ADG. There is need for better understanding of the economic values for traits of importance to the Australian pig industry, as also suggested for the Dutch industry (de Vries, 1989). The method employed in the study assumed that any additional cost to the breeder of using BLUP technology over other selection methods was negligible. Finally, we assumed that the breeder did not receive additional sales or a higher asking price from using an advanced genetic evaluation tool. Thus the discounted economic advantages calculated are gross rather than net benefits.

The current study was an initial step in assessing the potential economic gain from using BLUP for genetic evaluation in pigs. Results showed that selection based on an index of BLUP EBVs could have an economic advantage of from $27.64/sow/year to $85.45/sow/years over selection based on phenotype. Future studies involving optimal mating strategies, inbreeding management and assessing both current and future gains will clarify how this advanced tool for genetic evaluation in pigs can best be used to enhance profitability.

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