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DERIVING ECONOMIC VALUES FOR REACTION NORMS OF GROWTH IN PIGS

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SUMMARY

Slopes of reaction norm models, also called reaction norms (RN), are alternative traits used in animal breeding for selection of genotypes that perform more consistently across a range of environments. Environmental sensitivity is of economic importance when the environment where selection takes place differs considerably from the commercial environment of slaughter pigs. The position on the environmental trajectory where intercept of reaction norm models is defined influences the economic values (EV) for slope and intercept. This position has to correspond to the trait definitions of intercept and slope of reaction norm models used to estimate variance components. The magnitude of EV for RN depends on the difference between the selection and production environments and the EV for the trait of interest. Economic values for RN may be negative or positive depending on whether the production environment is below or above the selection environment. Non-linear EV for growth across the environmental trajectory had minimal impact on the EV for RN of growth. Further genetic and economic analyses of extensive industry data are required to better quantify the economic importance of RN in pig breeding.

INTRODUCTION

Reaction norms quantify genotype by environment interactions by describing the response of genotypes to varying environmental conditions (Falconer and Mackay, 1996). As such, RN are alternative traits used in animal breeding for selection of genotypes that perform more consistently across a range of environments. For pig breeding, Knap (2005) derived the EV for the RN of days to reach market. It was assumed that pigs were selected in a superior environment typical for nucleus herds, while production was at an inferior environment representing the average customer farm with lower performance.

It was the aim of this paper to discuss economic implications of genetic differences in environmental sensitivity and to define EV for RN when selection is in the average environment using growth rate of pigs as an example trait.

METHODS

Selection in superior or inferior environments. Pigs are often selected in a superior nucleus environment and progeny of sires may have to perform in inferior environments prevalent on customer farms. International breeding companies, however, have nucleus herds in multiple countries with varying climatic and husbandry conditions. It is therefore feasible that sires may also be selected in an inferior environment with their commercial progeny raised in superior environments. Economic benefits of reduced environmental sensitivity of genotypes differ between these two scenarios. Low environmental sensitivity of genotypes is desirable when selection of sires occurs in the superior environment as it leads to superior performance of progeny in the inferior environments. In contrast, high environmental sensitivity of genotypes is economically beneficial when sires are selected in an inferior environment because progeny will be able to exhibit superior performance in better environments.

However, applying appropriate EV for RN when selection is in superior or inferior environments may not be the best approach because the intercept, which represents the traditional trait, is defined for the selection environment and not the average environment of the environmental trajectory. Van Tienderen and Koelewijn (1994) outlined the dependency of (co)variances of intercepts and slopes on the position of the intercept on the environmental scale and suggested to define the intercept for the average environment of the environmental trajectory. This recommendation has generally been adopted in animal breeding applications (e.g. Kolmodin and Bijma, 2004; Su *et al*. 2006). In principle it is still possible to use reaction norm models for the situations outlined above. Intercept is then defined for the selection environment, which is situated above or below the average of the environmental trajectory, to ensure that trait definitions of intercept and slope of reaction norm models correspond to the EV for RN.

Selection in average environment of trajectory. Centering environments on the average environment in genetic analyses based on RN models (van Tienderen and Koelewijn, 1994) implies that the intercept corresponds to the estimated breeding value of the trait in the average (zero) environment. Genetic merit of genotypes across the environmental trajectory is defined as:

$$G_{gi}(E_{jk}) = G_{gi}(E_{j0}) + b_{(G_{gi} \cdot E_j)} * (E_{jk} - E_{j0})$$

where $G_{gi}(E_{jk})$ is genetic merit of genotype g in trait *i* for the k^{th} value of environmental variable *j*; $G_{gi}(E_{j0})$ is genetic merit of genotype *g* in trait *i* for the average value (*0*) of environmental variable *j*; $b_{(G_{gi} \cdot E_j)}$ is the RN quantifying the response *G* of genotype *g* in trait *i* per unit change in environmental variable *j* and $(E_{jk} - E_{j0})$ is the difference between the average (*0*) and k^{th} value of environmental variable *j*.

Knap (2005) defined the EV of RN for days to reach market weight as the EV for days to reach market weight times the difference in the environmental variable between the selection and production environments. This specific example can be extended to the generic case and EV for RN ($EV\_b_{(i \cdot E_{jk})}$) are then:

$$EV\_b_{(i \cdot E_{jk})} = (E_{jk} - E_{j0}) * EV\_i(E_{jk})$$

where $(E_{jk} - E_{j0})$ has been explained above and $EV\_i(E_{jk})$ is the EV of trait *i* for the k^{th} value of environmental variable *j*. In this way, there is only an EV associated with a RN when the average production environment of progeny (E_{jk}) differs from the average selection environment (E_{j0}). The magnitude of the EV for RN depends on the difference between the average environment for which the intercept is defined and the production environment of progeny of sires below or above the average environment.

Economic value of a trait varies across the environmental trajectory. For lifetime average daily gain (*ADG*) together with feed conversion ratio in the breeding objective, the EV is:

$$EV\_ADG = \left(\frac{Age_P}{Gr_P}\right) \times C_{NF}$$

where Age_P is the age of a finished pig at 90 kg live weight (130 days); Gr_P is the growth rate of a finished pig just prior to slaughter (900 g·day^{-1}) and C_{NF} is the daily non-feed costs per pig from weaning to slaughter ($AU 0.8 per day). The EV for ADG is $AU 0.116 per g·day^{-1} for an ADG of 692 g·day^{-1}, which was also used to derive the EV for RN of growth.

The EV for growth is affected by the level of performance in growth. It varies from $AU 0.139 to $AU 0.098 per g·day^{-1} for environments with a group average of ADG of 60 g·day^{-1} below or above a group average of ADG of 692 g·day^{-1}. This variation in the EV for growth across the environmental trajectory contributes to economic benefits of lower environmental sensitivity. A less environmentally sensitive genotype is economically advantageous as the economic losses of a reduced growth in high environments are lower than the economic benefits resulting from a higher growth in the low environments due to the non-linear relationship between growth and farm profit. This economic advantage is quantified by the proportion of pigs at each environmental level times the relevant EV for growth at each environmental level and summed over all environmental levels. The economic advantage is larger for wider spread of progeny across the environmental trajectory.

RESULTS AND DISCUSSIONS

Economic values for RN are zero when the production environment of progeny equals the average environment. If progenies of a sire are raised in inferior or superior environments relative to the average environment, EV for RN of growth were \$AU ±3.71 and \$AU ±0.104 per ($g{\cdot}day^{-1}$) per standard deviation of each environmental variable (Table 1). Please note, EV for RN are negative or positive (symbolized as +/-) depending on whether the production environment of progeny is below or above the average selection environment. Four distinct health environments were used by Schinckel *et al*. (1999) to evaluate line by environment interactions. Environments differed by about 80 $g{\cdot}day^{-1}$, which corresponds to an EV for RN of growth of \$AU +/- 9.28 per pig. Li and Hermesch (2012) found significant RN for growth for two environmental variables which were based on least squares means (LSM) for ADG and backfat (BF) of contemporary groups. The standard deviations of these two environmental variables were 32 $g{\cdot}day^{-1}$ and 0.9 mm. The range of RN estimates for growth is also shown for both environmental variables to illustrate genetic differences between sires. The standard deviations of sire solutions were 12.7 for the intercept and 0.025 and 1.079 for RN based on environmental variables of LSM for ADG and BF. Economic values per standard deviation of sire solutions are then \$AU 1.47 for the intercept, \$AU 0.093 for RN based on LSM for ADG and \$AU 0.112 for RN based on LSM for BF.

Table 1 Standard deviations in environmental variables (SD EnVar, $g{\cdot}day^{-1}$ or mm), magnitude of economic value for reaction norm (RN) of average daily gain (ADG; \$AU/pig per $g{\cdot}day^{-1}$ times SD EnVar) and range of RN for ADG ($g{\cdot}day^{-1}$ per EnVar))

EnVar[1]	SD EnVar	EV for RN of ADG[2]	Range of RN of ADG
LSM for ADG of CG $g{\cdot}day^{-1}$	32	+/-3.71	-0.102 to 0.103
LSM for BF of CG mm	0.9	+/-0.104	-5.04 to 6.78

[1] LSM: least squares means, CG: contemporary group; [2] +/-: EV for RN may be positive or negative

Additional economic benefits resulting from lower environmental sensitivity depend on non-linearity of EV for growth across the environmental trajectory and the spread of progeny of sires across the environmental range below or above the average environment (Table 2). Economic values for growth are more variable across a lower environmental range, which lead to higher EV for RN for lower performance levels. Overall, the economic advantage of less environmentally sensitive genotypes is small because EV for growth is not sufficiently non-linear across a realistic environmental trajectory. However, this EV of RN ignores the benefits of more consistent performance across environments. For example, differences in environmental sensitivity of sires contribute to variability in performance of pigs within a batch. This variability within a batch may lead to non-linearity in profitability, resulting from lost revenues of light-weight pigs that do not reach target market weight. These under-weight pigs are sent to market in order to vacate housing facilities for the next batch. The EV for growth does not capture this loss in revenue as it assumes that all pigs reach target weight. Batch variability can be even more costly in production systems attempting to achieve a consistent market supply. This is because dips in growth create under-supplies of finished stock at certain times, and then over-supply subsequently.

The environmental variable is expected to be normally distributed for most situations as was found by Li and Hermesch (2012). Variation among contemporary groups may lead to skewness in the environmental variable as some values of the environmental variable may be more represented than others by individual contemporary groups. This may also lead to a skewed representation of sires across the environmental trajectory. However, provided sires are expected to make equal contributions across individual contemporary groups, there will be no economic advantage for less environmentally sensitive genotypes. This is because the cumulative superior (inferior) genetic merit of a sire for environments below the average environment is matched by the cumulative inferior (superior) genetic merit of a sire for environments above the average environment.

Non-linear RN are likely to lead to non-linear profitability across the environmental trajectory, which contributes to the EV for environmental sensitivity. Deriving EV for multiple, higher-order RN parameters would be challenging with a higher-order polynomial parameterisation because of multi co-linearity with the other RN traits in the breeding objective. However, an economic rationale could be established to penalise genotypes that were predicted as being likely to deteriorate rapidly at an extreme end of the environmental continuum. An empirical approach would be required to integrate the economic rationale with the polynomial coefficients.

Table 2 Economic values (EV) for reaction norms of growth (ADG) due to changes in EV for ADG across environmental trajectories with mean performances of 500 to 800 g·day^{-1} and varying spread of progenies of sires across environmental trajectory (EnVar)

Spread of progeny of sires in standard deviation of EnVar	Mean growth performance (g·day^{-1}) 500	600	700	800
40	1.361	0.78	0.488	0.326
20	0.365	0.211	0.133	0.089

CONCLUSIONS

Economic values of RN exist if the production environment of progeny differs from the average selection environment and when the EV of a trait varies considerably across the environmental trajectory. The magnitude of EV for RN depends predominantly on the difference between the selection environment and production environment of progeny as well as the EV for the trait of interest. Further genetic and economic analyses of extensive industry data are required to better quantify the economic importance of RN in pig breeding.

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