

## Direct and maternal genetic effects for body weight and price of calves sold for veal production<sup>1</sup>

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**ABSTRACT:** The aim of this study was to estimate direct and maternal genetic parameters for age at sale (AS, d), BW (kg), price (PR, €/kg), and market value (MV, €/calf) of Brown Swiss male calves (*Bos taurus*) from first- ( $n = 6,719$ ) and second- ( $n = 4,405$ ) parity dams marketed at livestock auctions from 2003 to 2007, and destined for veal production. Market value was calculated as the product of PR and BW. Restricted maximum likelihood procedures incorporating multiple trait animal models were used to infer genetic parameters for AS, BW, and PR, whereas estimates for MV were from single trait models. Bivariate analyses treating performance of calves from first- and second-parity cows as different traits were also

performed. Direct heritabilities for AS, BW, and cattle prices ranged from 0.046 to 0.090, 0.078 to 0.130, and 0.064 to 0.152, respectively, and the corresponding maternal heritabilities varied from 0.020 to 0.030, 0.036 to 0.079, and 0.020 to 0.045, respectively. Direct genetic correlations between the traits were generally moderate to high and negative, whereas direct-maternal relationships were moderate to low. Genetic correlation between the same trait recorded on calves from first- and second-parity dams was less than unity, but generally high and positive, suggesting that AS, BW, PR, and MV can be treated as the same traits across parities. As calf price is routinely collected at auctions and shows genetic variation, it can be genetically improved.

**Key words:** age, body weight, calf, genetic parameter, market value, price

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### INTRODUCTION

Livestock auctions are a common method of selling cattle in many countries, for example, in the USA (Barham and Troxel, 2007) and Ireland (Mc Hugh et al., 2010). This practice is common also in northeast Italy, where the marketing of purebred and crossbred calves from dairy herds represents an important source of revenue for the farmers (Dal Zotto et al., 2009). Twenty-

five to 30% of calves sold at auction are purebred Brown Swiss, and more than 95% of these are males (Bittante et al., 2011).

Factors determining cattle price at auction have been investigated in the past (Ruff et al., 1983; Faminow and Gum, 1986; Schroeder et al., 1988), and particularly in recent years (Barham and Troxel, 2007; Dal Zotto et al., 2009; Penasa et al., 2009; Schierenbeck et al., 2009; Mc Hugh et al., 2010). Results suggest that breed, sex, age, parity of the dam, calving difficulty, year and season of sale, and physical characteristics are important determinants of commercial value of animals.

Information on genetic variation for cattle price is scarce in the literature (Schierenbeck et al., 2009; Mc Hugh et al., 2011) and is lacking in Brown Swiss calves. Understanding if this trait is heritable could address future breeding strategies to increase income from selling young animals. Hence, the objective of this study was to infer direct and maternal heritability for price (PR,

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€/kg) of Brown Swiss calves destined for veal production as well as its relationships with BW (kg) and age at sale (AS, d).

## MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the data were from an existing database. The analyzed records were registered by the Kovieh Cooperative during public livestock auctions in Bolzano-Bozen (Italy) from January 2003 to December 2007. The authors did not have direct control over the care of the animals included in this study.

### Data and Editing Procedure

Body weight and PR (€/kg) of purebred Brown Swiss calves were recorded from January 2003 to December 2007 by the Kovieh Cooperative, a wholesale cattle organization operating in Bolzano-Bozen province (eastern Italian Alps). The Kovieh Cooperative collects calves from dairy herds and sells them individually during weekly public auctions in a permanent livestock venue located in Bolzano-Bozen. The selling price is established through offers, and buyers adjust their bids according to the characteristics they can appraise viewing the animal; also, the base value is strongly related to market circumstances. Calves are purchased by veal producers, fattened on farms located in northern Italy using a liquid diet and a small amount of roughage, and slaughtered when they are 5 to 6 mo old.

Only male progeny of first- and second-parity cows were retained in the dataset because there were very few females, as females are almost all kept within the herd as future replacements (Dal Zotto et al., 2009). Information on parity number of dams was not directly available and had to be calculated from the dataset. If a dam was older than 20 mo and younger than 40 mo at the birth of her first recorded calf, the cow was classified as first parity (average age at calving: 32 mo); if a dam was older than 30 mo and younger than 55 mo at the birth of her second recorded calf, the cow was classified as second parity (average age at calving: 46 mo). Later parities were not included in the study because of the small number of observations available to infer genetic parameters. Information on date of birth and herd of origin of calves was supplied by the Breeders Association of Bolzano-Bozen province. Age at sale (d) of calves was calculated as the difference between date of auction and date of birth, and market value (MV, €/calf) as the product of PR and BW. Each calf was required to have known parents and both maternal grandparents, herd of origin, AS, BW, and PR. Animals pertaining to twin births or produced by embryo transfer were discarded from the dataset, as well as calves

**Table 1.** Summary of data and descriptive statistics (mean  $\pm$  SD) of age at sale (AS, d), BW (kg), price (PR, €/kg), and market value (MV, €/calf) of male calves from first- and second-parity dams

| Item                                    | Parity of dam    |                  |
|---|------------------|------------------|
|   | First            | Second           |
| Calves, n                               | 6,719            | 4,405            |
| Herds, n                                | 1,076            | 799              |
| Dates of auction, n                     | 237              | 238              |
| Sires, n                                | 329              | 307              |
| With 1 to 10 calves                     | 183              | 173              |
| With 11 to 25 calves                    | 99               | 104              |
| With 26 to 50 calves                    | 17               | 15               |
| With 51 to 100 calves                   | 15               | 11               |
| With more than 100 calves               | 15               | 4                |
| Maternal grandsires, n                  | 427              | 392              |
| With 1 to 10 daughters                  | 290              | 323              |
| With 11 to 25 daughters                 | 86               | 32               |
| With 26 to 50 daughters                 | 23               | 19               |
| With 51 to 100 daughters                | 16               | 12               |
| With more than 100 daughters            | 12               | 6                |
| Sires being also maternal grandsires, n | 209              | 147              |
| Records in pedigree file, n             | 34,154           | 23,141           |
| AS, d                                   | 24.2 $\pm$ 8.7   | 22.9 $\pm$ 8.5   |
| BW, kg                                  | 61.0 $\pm$ 8.1   | 63.4 $\pm$ 8.1   |
| PR, €/kg                                | 2.35 $\pm$ 0.69  | 2.47 $\pm$ 0.70  |
| MV, €/calf                              | 145.5 $\pm$ 50.2 | 158.2 $\pm$ 51.2 |

presented more than once at auction. Body weight was restricted to be between 32 and 96 kg, AS between 7 and 50 d, and PR between €1.00/kg and €5.00/kg.

Two contemporary groups were defined: herd of origin and date of auction. At least 3 observations were required within each herd, as well as within each date of auction. Also, only herds with calves sold during at least 2 different dates of auction were retained. After editing, 11,124 calves (6,719 from first- and 4,405 from second-parity cows) were available for subsequent statistical investigation. Characteristics of the final dataset are shown in Table 1.

### Statistical Analysis

**Non-Genetic Effects.** Non-genetic fixed factors to be included in mixed models for AS, BW, PR, and MV were identified through preliminary least-squares analysis using the GLM procedure (SAS Inst. Inc., Cary, NC). The effect of date of auction significantly ( $P < 0.001$ ) influenced all traits, and thus it was included in all analyses. In addition, age of dam at calving was considered in models for BW ( $P < 0.05$ ) of calves from both first- and second-parity dams, and for MV ( $P < 0.01$ ) of calves from first-parity cows. Age at calving was grouped into these class-

es: <30, 30 to 35, and >35 mo for first-parity, and <44, 44 to 49, and >49 mo for second-parity cows.

**Genetic Analysis.** Variance and covariance components for the random effects were estimated with the VCE software package (Neumaier and Groeneveld, 1998) through REML procedures. Multiple trait mixed models were used for the analysis of AS, BW, and PR, whereas estimates for MV were obtained using a single trait analysis; this avoided potential confusion in the interpretation of parameters due to part whole relationships. Besides fixed factors previously described, all models fitted random effects of herd, direct and maternal additive genetic, and residual. Random terms were assumed to be normally distributed with null means and variance-covariance structures of herd, additive genetic (**G**), and residual (**R**) effects equal to  $\mathbf{H} \otimes \mathbf{I}$ ,  $\mathbf{G}_0 \otimes \mathbf{A}$ , and  $\mathbf{R}_0 \otimes \mathbf{I}$ , respectively, where **H** is the (co)variance matrix of herd effects,  $\mathbf{G}_0$  is the (co)variance matrix of direct and maternal genetic effects, **A** is the numerator of Wright's relationship matrix,  $\mathbf{R}_0$  is the residual (co)variance matrix, **I** is an identity matrix of appropriate order, and  $\otimes$  denotes the Kronecker product. The number of animals in the additive relationship matrix was 34,154 and 23,141 for calves from first- and second-parity dams, respectively, and included all individuals with phenotypic records and their ancestors up to 5 generations back. Pedigree information was provided by the Italian Brown Swiss Cattle Breeders Association (ANARB, Verona, Italy).

To investigate the relationship between the same trait recorded on calves from first- and second-parity dams, bivariate animal models were performed treating AS, BW, PR, and MV of calves from different parities as different traits. Assumptions for all random effects were normal distribution with zero means and (co)variance structure:

$$\text{Var} \begin{bmatrix} \mathbf{a}^f \\ \mathbf{a}^s \\ \mathbf{m}^f \\ \mathbf{m}^s \end{bmatrix} = \begin{bmatrix} \sigma_a^{2(f)} & \sigma_a^{(fs)} & \sigma_{am}^{(f)} & \sigma_{am}^{(fs)} \\ & \sigma_a^{2(s)} & \sigma_{am}^{(sf)} & \sigma_{am}^{(sf)} \\ & & \sigma_m^{2(f)} & \sigma_m^{(fs)} \\ \text{Sym.} & & & \sigma_m^{2(s)} \end{bmatrix} \otimes \mathbf{A},$$

$$\text{Var} \begin{bmatrix} \mathbf{h}^f \\ \mathbf{h}^s \end{bmatrix} = \begin{bmatrix} \sigma_h^{2(f)} & 0 \\ 0 & \sigma_h^{2(s)} \end{bmatrix} \otimes \mathbf{I},$$

$$\text{and } \text{Var} \begin{bmatrix} \mathbf{e}^f \\ \mathbf{e}^s \end{bmatrix} = \begin{bmatrix} \sigma_e^{2(f)} & 0 \\ 0 & \sigma_e^{2(s)} \end{bmatrix} \otimes \mathbf{I}$$

where  $\sigma_a^{2(f)}$  [ $\sigma_a^{2(s)}$ ] is the additive direct genetic variance of AS, BW, PR, or MV of calves from first- (second-) parity dams;  $\sigma_m^{2(f)}$  [ $\sigma_m^{2(s)}$ ] is the additive maternal genetic variance of calves from first- (second-) parity dams;  $\sigma_{am}^{(f)}$  [ $\sigma_{am}^{(s)}$ ] is the additive genetic covariance between direct

and maternal effects in calves from first- (second-) parity dams;  $\sigma_a^{(fs)}$  is the covariance between additive direct genetic effects of calves from first- and second-parity dams;  $\sigma_m^{(fs)}$  is the covariance between additive maternal genetic effects of calves from first- and second-parity dams;  $\sigma_{am}^{(fs)}$  is the covariance between additive direct genetic effects of calves from first-parity dams and additive maternal effects of calves from second-parity dams;  $\sigma_{am}^{(sf)}$  is the covariance between additive direct genetic effects of calves from second-parity dams and maternal genetic effects of calves from first-parity dams;  $\sigma_h^{2(f)}$  [ $\sigma_h^{2(s)}$ ] is the herd variance of calves from first- (second-) parity dams; and  $\sigma_e^{2(f)}$  [ $\sigma_e^{2(s)}$ ] is the residual variance of AS, BW, PR, or MV of calves from first- (second-) parity dams.

Heritability for direct and maternal effects was calculated as in Carnier et al. (2000) and Eriksson et al. (2004):

$$h_a^2 = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_m^2 + \sigma_{am}^2 + \sigma_e^2}$$

and

$$h_m^2 = \frac{\sigma_m^2}{\sigma_a^2 + \sigma_m^2 + \sigma_{am}^2 + \sigma_e^2}$$

Standard errors of heritabilities and genetic correlations were computed using formulae of Falconer and Mackay (1996).

## RESULTS AND DISCUSSION

### Means and Variation

On average, calves from second-parity dams were slightly younger (−1.3 d), heavier (+2.4 kg), and received greater PR (+€0.12/kg) than calves from first-parity dams; as a result, MV differed by approximately €13/calf, being €158.2 and €145.5, respectively (Table 1). Recently, Mc Hugh et al. (2010) reported a mean MV of €157 for calves sold at livestock marts in Ireland, which is in agreement with our findings, even if values from the Irish study referred to males and females of different purebreds and crossbreds. In the same research, AS ranged from 2 to 84 d, and 91% of individuals were sold before 42 d, which is very similar to AS from our research (7 to 50 d). The SD of MV was approximately €30 lower in our data compared with Mc Hugh et al. (2010) and reflects the difference of variability between purebred population and population with different purebred and crossbred animals.

### Heritability

Direct and maternal estimates of heritability for PR were greater for calves from second- (0.143 and 0.026, respectively) than first- (0.094 and 0.020, respectively)

**Table 2.** Estimates<sup>1</sup> of variance components and heritabilities ( $\pm$  approximated SE) of age at sale (AS, d), BW (kg), price (PR, €/kg), and market value (MV, €/calf) of male calves from first- and second-parity dams

| Parameter          | Trait             |                   |                   |                   |
|--------------------|-------------------|-------------------|-------------------|-------------------|
|                    | AS <sup>2</sup>   | BW <sup>2</sup>   | PR <sup>2</sup>   | MV <sup>3</sup>   |
| First-parity dams  |                   |                   |                   |                   |
| $\sigma_a^2$       | 2.758             | 5.251             | 0.019             | 142.435           |
| $\sigma_m^2$       | 1.328             | 3.315             | 0.004             | 51.392            |
| $\sigma_{am}$      | 0.217             | -1.283            | -0.003            | -35.851           |
| $\sigma_h^2$       | 22.924            | 23.088            | 0.040             | 434.864           |
| $\sigma_e^2$       | 46.216            | 34.563            | 0.182             | 985.572           |
| $h_a^2$            | 0.055 $\pm$ 0.020 | 0.125 $\pm$ 0.024 | 0.094 $\pm$ 0.022 | 0.125 $\pm$ 0.024 |
| $h_m^2$            | 0.026 $\pm$ 0.020 | 0.079 $\pm$ 0.023 | 0.020 $\pm$ 0.019 | 0.045 $\pm$ 0.021 |
| Second-parity dams |                   |                   |                   |                   |
| $\sigma_a^2$       | 4.677             | 3.447             | 0.027             | 71.788            |
| $\sigma_m^2$       | 1.373             | 1.567             | 0.005             | 41.967            |
| $\sigma_{am}$      | 0.078             | -0.038            | -0.006            | -20.734           |
| $\sigma_h^2$       | 19.600            | 20.572            | 0.026             | 349.165           |
| $\sigma_e^2$       | 45.682            | 38.940            | 0.163             | 1,033.876         |
| $h_a^2$            | 0.090 $\pm$ 0.030 | 0.078 $\pm$ 0.029 | 0.143 $\pm$ 0.033 | 0.064 $\pm$ 0.028 |
| $h_m^2$            | 0.027 $\pm$ 0.028 | 0.036 $\pm$ 0.029 | 0.026 $\pm$ 0.028 | 0.037 $\pm$ 0.029 |

<sup>1</sup>The term  $\sigma_a^2$  is the genetic variance of direct effects,  $\sigma_m^2$  is the genetic variance of maternal effects,  $\sigma_{am}$  is the genetic covariance between direct and maternal effects,  $\sigma_h^2$  is the herd variance,  $\sigma_e^2$  is the residual variance,  $h_a^2$  is the heritability for direct effects,  $h_m^2$  is the heritability for maternal effects.  $h_a^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_m^2 + \sigma_{am} + \sigma_e^2)$  and  $h_m^2 = \sigma_m^2 / (\sigma_a^2 + \sigma_m^2 + \sigma_{am} + \sigma_e^2)$ .

<sup>2</sup>From multiple trait analysis of AS, BW, and PR.

<sup>3</sup>From single trait analysis.

parity dams (Table 2), whereas estimates for MV were greater for calves from first- (0.125 and 0.045, respectively) than second- (0.064 and 0.037, respectively) parity cows. Coefficients of direct and maternal genetic variation for PR were slightly larger for individual progeny of second- (6.7 and 2.9%, respectively) than first- (5.9 and 2.7%, respectively) parity dams, whereas for MV much greater variation was found in calves from first- (8.2 and 4.9%, respectively) than second-parity (5.4 and 4.1%, respectively) cows. Heritabilities from bivariate analyses slightly differed from those presented in Table 2, and were greater for direct effects when calculated from bivariate models (Table 3).

Information on genetic variation for cattle price is very scarce in the scientific literature and, to our knowledge, only a few studies have been attempted to estimate

**Table 3.** Estimates<sup>1</sup> of genetic parameters ( $\pm$  approximated SE) obtained in bivariate analyses in which age at sale (AS, d), BW (kg), price (PR, €/kg), and market value (MV, €/calf) of male calves from first- and second-parity dams were considered as different traits

| Parameter    | Trait             |                   |                   |                   |
|--------------|-------------------|-------------------|-------------------|-------------------|
|              | AS                | BW                | PR                | MV                |
| $h_a^{2(f)}$ | 0.046 $\pm$ 0.019 | 0.130 $\pm$ 0.025 | 0.109 $\pm$ 0.023 | 0.138 $\pm$ 0.025 |
| $h_a^{2(s)}$ | 0.064 $\pm$ 0.028 | 0.080 $\pm$ 0.029 | 0.152 $\pm$ 0.034 | 0.085 $\pm$ 0.029 |
| $h_m^{2(f)}$ | 0.020 $\pm$ 0.019 | 0.076 $\pm$ 0.023 | 0.020 $\pm$ 0.019 | 0.043 $\pm$ 0.021 |
| $h_m^{2(s)}$ | 0.030 $\pm$ 0.028 | 0.045 $\pm$ 0.029 | 0.037 $\pm$ 0.029 | 0.037 $\pm$ 0.029 |
| $r_a^{(fs)}$ | 0.944 $\pm$ 0.033 | 0.926 $\pm$ 0.027 | 0.915 $\pm$ 0.025 | 0.977 $\pm$ 0.008 |
| $r_m^{(fs)}$ | 0.942 $\pm$ 0.075 | 0.753 $\pm$ 0.135 | 0.690 $\pm$ 0.320 | 0.783 $\pm$ 0.169 |

<sup>1</sup>The term  $h_a^{2(f)}$  [ $h_a^{2(s)}$ ] is the direct heritability of calves from first- (second-) parity dams,  $h_m^{2(f)}$  [ $h_m^{2(s)}$ ] is the maternal heritability of calves from first- (second-) parity dams,  $r_a^{(fs)}$  is the genetic correlation between direct effects of calves from first- and second-parity dams, and  $r_m^{(fs)}$  is the genetic correlation between maternal effects of calves from first- and second-parity dams.  $h_a^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_m^2 + \sigma_{am} + \sigma_e^2)$  and  $h_m^2 = \sigma_m^2 / (\sigma_a^2 + \sigma_m^2 + \sigma_{am} + \sigma_e^2)$ .

genetic parameters for this trait (Schierenbeck et al., 2009; Mc Hugh et al., 2011). Specifically, Schierenbeck et al. (2009) reported direct heritability of 0.27 for MV of first-parity Holstein cows sold as breeding stock at auction in Germany, and the estimate for the same trait in calves from dairy cows sold between 2 and 84 d of age at livestock marts in Ireland was 0.34 (Mc Hugh et al., 2011). That is, much greater than values from our research (Tables 2 and 3). However, it is worth noting that animals of the German study were adults, and in the Irish study calves belonged to several breed combinations. Heritability estimates for PR and MV in the present work are similar to those for other traits currently included in the selection index of the Brown Swiss breed in Italy, such as protein yield and somatic cell score (Dal Zotto et al., 2007), and functional longevity (Samoré et al., 2010). Several recent studies inferred direct genetic effects for carcass price and carcass market value in Japanese Black (Ibi et al., 2006) and Korean (Kim et al., 2010) cattle; heritability estimates from Ibi et al. (2006) were moderate to high and ranged from 0.32 to 0.46, depending on the period considered, whereas Kim et al. (2010) reported heritability of 0.21 and 0.13 for carcass PR and MV, respectively. Maternal heritability for MV was not different from 0 in Mc Hugh et al. (2011), and was low in our research (Tables 2 and 3). The Irish study also estimated a heritability of 0.10 for MV of cows from several breed combinations and parities, which is similar to our results on calves but much lower than findings from Schierenbeck et al. (2009) on primiparous Holstein cows.



Age of calves was not introduced as an explanatory variable in the model for BW to adjust it to a fixed time because a previous study (Bittante et al., 2011) demonstrated that genetic variation for AS exists under certain circumstances (e.g., the selling of calves at auction), especially if farmers decide to sell animals according to BW and not AS; therefore, biases may occur in subsequent prediction of breeding values for BW if an adjustment for age is performed. Instead, combining AS and BW in multivariate analyses which account for the strong and negative genetic correlation between the traits leads to unbiased predictions of breeding values (Bittante et al., 2011). In the present study, estimates of direct heritability for AS were greater for calves from second- (0.090) than from first- (0.055) parity dams, whereas estimates for BW were greater for the latter (0.125) than for the former (0.078) animals. Maternal effects for BW were larger in calves from primiparous (0.079) than second-parity (0.036) cows. The coefficient of direct genetic variation for AS was slightly larger for the progeny of second- (9.4%) than first- (6.9%) parity dams, whereas for BW greater variation was found in progeny of primiparous (3.8%) than second-parity (2.9%) cows. Coefficient of maternal genetic variation for AS was similar across parities (4.8 and 5.1%, respectively) and for BW was greater for calves from first- (3.0%) than second- (2.0%) parity dams. Heritability estimates for direct effects obtained under bivariate analyses treating AS of calves from different parities as different traits (Table 3) were slightly smaller than those reported in Table 2, whereas estimates for BW were greater when assessed using bivariate analyses.

Direct heritability for AS (Tables 2 and 3) is in agreement with a previous study (Bittante et al., 2011) and, to our knowledge, no other estimates of both direct and maternal effects for this trait are currently available. Genetic parameters for BW have been widely investigated in the literature, even though most estimates refer to birth and weaning weight of purebred or crossbred beef animals much older than calves from our study. Information on

BW of calves was not available in Mc Hugh et al. (2011); however, the authors estimated direct and maternal heritability of 0.25 and 0.07, respectively, in weanlings sold between 6 and 12 mo of age. Shojo et al. (2006) reported estimates for calf market weight in Japanese Black cattle that ranged from 0.22 to 0.37 for direct, and from 0.07 to 0.15 for maternal genetic effects. Heritabilities of birth and weaning BW in Australian Angus cattle were 0.35 and 0.20, respectively, for direct effects, and 0.08 and 0.09 for maternal effects (Robinson, 1996). Depending on the model used, estimates for the same traits in 4 lines of Hereford cattle varied from 0.38 to 0.47 and 0.10 to 0.18, respectively, for direct effects, and from 0.09 to 0.14 and 0.13 to 0.34, respectively, for maternal effects (Dodenhoff et al., 1998). Direct heritability of weaning weight in 9 parental breeds of beef cattle from the United States ranged from 0.11 (Charolais) to 0.34 (Pinzgauer), and from 0.27 to 0.30 for Braunvieh, according to the model used (Dodenhoff et al., 1999). The corresponding maternal heritability from that study varied from 0.04 (Pinzgauer) to 0.32 (Charolais), and from 0.09 to 0.17 for Braunvieh, which is not greatly different from our findings on BW of calves from first-parity cows (Tables 2 and 3). Genetic parameters of pre-weaning traits in the Braunvieh breed were also obtained by Cucco et al. (2009), who reported values from 0.23 to 0.41 for direct, and from 0.08 to 0.22 for maternal heritability. A study on Simmental calves (Wright et al., 1987), estimated direct and maternal heritability for weaning weight of 0.12 and 0.09, respectively; these results are similar to our findings on calves from first-parity dams (Tables 2 and 3). Overall, estimates for direct effects from previous studies were generally much greater than our findings, whereas for maternal effects were almost consistent with our results.

### Genetic Correlations

Estimates of genetic correlations between direct effects on AS and BW, and AS and PR were negative and

**Table 4.** Estimates of direct and direct-maternal genetic correlations ( $\pm$  approximated SE) between age at sale (AS, d), BW (kg), and price (PR, €/kg) of male calves from first- and second-parity dams obtained under multiple trait animal models<sup>1</sup>

|                         | First-parity dams |                    |                    | Second-parity dams |                    |                    |
|-------------------------|-------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
|                         | AS                | BW                 | PR                 | AS                 | BW                 | PR                 |
| Direct effects          |                   |                    |                    |                    |                    |                    |
| AS                      |                   | -0.866 $\pm$ 0.047 | -0.635 $\pm$ 0.123 |                    | -0.584 $\pm$ 0.164 | -0.670 $\pm$ 0.108 |
| BW                      |                   |                    | 0.283 $\pm$ 0.138  |                    |                    | -0.117 $\pm$ 0.204 |
| Direct-maternal effects |                   |                    |                    |                    |                    |                    |
| AS                      | 0.113 $\pm$ 0.369 |                    |                    | 0.031 $\pm$ 0.415  |                    |                    |
| BW                      |                   | -0.307 $\pm$ 0.151 |                    |                    | -0.016 $\pm$ 0.387 |                    |
| PR                      |                   |                    | -0.362 $\pm$ 0.290 |                    |                    | -0.479 $\pm$ 0.272 |

<sup>1</sup>Genetic correlations between direct and maternal effects for market value (MV, €/calf) were estimated from single trait animal model, and were  $-0.419 \pm 0.175$  and  $-0.378 \pm 0.355$  for calves from first- and second-parity dams, respectively.

moderate to high, being  $-0.866$  and  $-0.635$  in calves from first-parity dams, respectively, and  $-0.584$  and  $-0.670$  in calves from second-parity dams, respectively (Table 4). Low genetic correlations were found between BW and PR. Estimates between direct effects on AS and BW are in agreement with results of a previous study on calves of the same breed born at first-parity (Bittante et al., 2011). Genetic correlations between MV and BW were positive and varied from 0.55 to 0.91 in Mc Hugh et al. (2011), depending on the maturity category. Schierenbeck et al. (2009) reported a genetic correlation of 0.38 between MV and overall conformation of Holstein cows. Finally, genetic correlations between carcass PR and carcass weight ranged from  $-0.03$  to 0.28 in Ibi et al. (2006) and was  $-0.35$  in Kim et al. (2010). The authors are not aware of estimates between AS and PR that are currently available in published studies.

Genetic correlations between direct and maternal effects were moderate to low, and negative for PR, BW, and MV (Table 4). Estimates ranged from  $-0.479$  for PR in calves from second- to 0.113 for AS in calves from first-parity cows, and showed large SE. Literature on correlations between direct and maternal effects for BW is extensive, and estimates are not always negative. Shojo et al. (2006) reported values of 0.17 and  $-0.63$  for calf market weight in Japanese Black cattle from 2 prefectures, and Wright et al. (1987) estimated a value of 0.16 for weaning weight in Simmental calves. Direct-maternal correlations ranged from  $-0.07$  to 0.29 for birth weight and  $-0.11$  to  $-0.44$  for weaning weight in Hereford cattle (Dodenhoff et al., 1998), and they were 0.28 and 0.38 for weaning weight in the Braunvieh breed in the United States (Dodenhoff et al., 1999). The estimate for the same trait assessed on Braunvieh animals under tropical conditions was  $-0.80$  (Cucco et al., 2009). No information on genetic correlations between direct and maternal effects for AS, PR, and MV has been found in the literature.

Genetic correlations obtained in bivariate models in which AS, BW, PR, and MV of calves from first- and second-parity dams were considered as different traits are shown in Table 3. Estimates between direct genetic effects were greater than 0.90 for all traits, and between maternal genetic effects were high and ranged from 0.690 for PR to 0.942 for AS. Despite being less than unity, estimates suggest that AS, BW, PR, and MV on calves born at first and second parity are indeed genetically the same traits. Previous work has reported that a genetic correlation of 0.60 (Mulder et al., 2006) or 0.80 (Robertson, 1959) should be set as the threshold that allows for a combining of traits within breeding schemes.

In conclusion, estimates of heritability for studied traits were generally low, but the magnitude of coefficients of genetic variation indicates that they can be genetically improved. Genetic correlations for AS, BW, PR, and MV in

calves from first- and second-parity dams were less than unity, but generally high, suggesting that there is no need to consider them as different traits. Instead, a combined analysis of calves across parities of their dams would be the best option and would notably simplify the genetic evaluation of sires. Although the Brown Swiss is typically a dairy animal, there is an interest to enhance the profitability of farmers by improving the price of male calves destined for veal production using data routinely collected at weekly auctions.

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