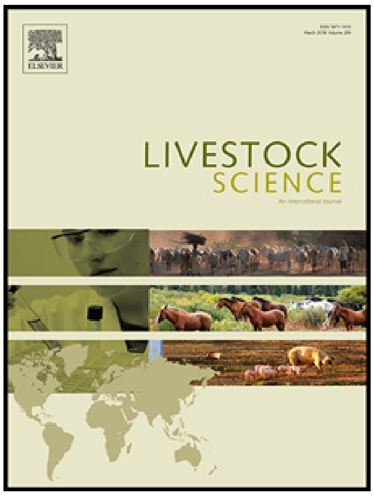

Genetic parameters for reproductive, longevity and lifetime production traits in Bísaro pigs

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Highlights

- Bísaro pig have modest reproductive values
- Heritabilities for litter size traits were low but the genetic variability was high
- Longevity and lifetime production traits were strongly related between
- Genetic trends showed no major changes during the last two decades
- Selecting for litter size traits should focus on number of piglets born alive

Genetic parameters for reproductive, longevity and lifetime production traits in Bísaro pigs

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Abstract

The Bísaro pig has gained popularity in recent years reflecting the success of the conservation program. Nevertheless, no data is available for animal genetic evaluation in this breed. Therefore, this study aimed to estimate genetic parameters and trends for reproduction related traits in Bísaro pigs. Through a restricted maximum likelihood procedure applied to mixed linear models, 27,844 farrowing records, from 1995 to 2017, were used to analyse total number of pigs born per litter (NBT), number of pigs born alive (NBA), number of stillborn (NSB), number of pigs weaned per litter (NBW), age at first farrowing (AFF), farrowing interval (FIT), length of productive life (LPL), lifetime number of litters (LNL), lifetime pig production (LTP) and lifetime efficiency (LTP365). The heritability estimates for litter size traits were low and ranged from 0.007±0.004 to 0.015±0.006. Differently, the heritabilities for traits related to longevity and lifetime production traits were higher (0.078±0.026 to 0.121±0.030). AFF registered the highest heritability value (0.345±0.028).

NSB and FIT presented high values of additive genetic coefficient of variation (0.177 and 0.271) in contrast with low heritability estimates (0.007±0.004 and 0.002±0.005). Very tight genetic correlations were found between NBT and NBA (0.968), NBW and NBT (0.974), and NBW and NBA (0.945). Weak genetic correlations were found between both NBT and NSB (0.352) and between NBA and NSB (0.107). Longevity and lifetime production traits presented high positive genetic correlations (0.811-0.969) and moderate to high phenotypic correlations (0.266-0.946). No major genetic changes were registered over time for most of the analysed traits, except for AFF and LPL, having registered an overall decreased of mean estimated breeding values (21.3 and 17.5) and negative genetic trends of -0.6 and -0.4 ($P<0.001$), respectively.

Keywords

genetic correlation; genetic trend; indigenous breed; length of productive life; lifetime production; swine

Introduction

Reliable estimates of genetics parameters are essential in breeding programs as they lead to efficient pork production (Chimonyo et al., 2006; Zhang et al., 2016). During selection, not only a trait value is selected but an animal as a whole is considered. Thus, to estimate these parameters, a combined genetic evaluation for all possible traits should be preferred (Krupa et al., 2016). Genetic improvement of production traits in pigs can be challenging due to difficulties in measuring these traits. In fact, individual birth weights, weight at weaning and many other weight-related parameters are rarely recorded because of the additional labour, time and costs involved. Contrarily, some reproduction related parameters are often recorded, for conservation programs, in the herd book. To date, reproduction traits of economic importance include litter weight at birth (LBWT), total number of pigs born per litter (NBT), number of pigs born alive (NBA), number of stillborn (NSB), number of pigs weaned per litter (NBW), age at first farrowing (AFF), maternal ability (MA), gestation length (GL) and farrowing interval (FIT) (Akanno et al., 2013). Over the last decades, longevity traits have gained importance in pig production systems. Length of productive life (LPL) is one of the most used traits and can dictate high economic influence on farmer's profitability and animal welfare (Serenius and Stalder, 2007) and is linked with reproductive performance through the voluntary culling of sows with inferior fertility or prolificacy (Yazdi et al., 2000). Lifetime production traits, such as lifetime number of litters (LNL) or lifetime pig production (LTP) are also important because of their association with stayability, productivity and the cost of production (Noppibool et al., 2016). In addition, lifetime efficiency (LTP365) can also be estimated from a previously mentioned trait (LTP) divided by LPL, in years (Sobczyńska et al., 2013).

The development of mixed models using restricted maximum likelihood (REML) and the advances in computing capacity, employing best linear unbiased models (BLUP), had facilitated the genetic estimations. However, this process requires deep and reliable pedigree information, which is not always available. Female reproductive traits have low-to-moderate heritabilities (Bidanel, 2011), yet the high degree of genetic variability is often considered enough for selection purpose (Lopez et al., 2017). Therefore, considering additional genetic parameters such as genetic correlations and inbreeding coefficient contribute to increase the accuracy of the genetic evaluation (Krupa et al., 2016).

In the recent years, the Bísaro population and producers have been thriving, contradicting the endangered condition of this indigenous Portuguese breed, characterized by excellent meat quality and well known by its smoked cured products. Despite the growing tendency, the BP population is characterized by high inbreeding levels and low effective population size (Paixão et al., 2018a). Reproductive management is often neglected; heat detection is not commonly used, and only a few producers make use of artificial insemination as breeding method (Paixão et al., 2018b). Litter sizes are modest, with NBT around 9; sows are usually one year old at their first farrowing, and the FIT varies between 5 and 6.5 months (Outor-Monteiro et al., 1998; Silva, 2017).

Despite the mentioned descriptive studies, no traits have been genetically evaluated before. Yet, genetic parameters including genetic correlations and heritabilities are essential to design effective breeding strategies necessary to improve economically relevant traits and profitability in livestock animals. Thus the objectives of this study were to estimate variance components, genetic parameters and correlations for reproductive and longevity traits in Bísaro pigs.

Material and methods

Data

The database included 27,844 farrowing records, retrieved from April 1995 to October 2017. The pedigree file had 219,701 individual animal records. The average number of equivalent traced generations for the sows included in the database was four. All data was made available from National Bísaro Pig Producer Association (ANCSUB).

Records were excluded from the analysis when NBA (>16) and NBT (>20) exceeded realistic limits. Records were not considered when not within the following intervals: 240 to 540 days to AFF, and 135-300 days to FIT. Any records with missing or incongruous information in the fixed effect values were removed from the database. After data editing, a total of valid 26,903 farrowing records from 10,988 sows were available for subsequent analysis. 11,677 farrowing records belonged to sows that were still in production whereas 14,007 records related to sows that had finished their production life.

Estimation of genetic parameters

In this study, several reproduction related traits were analysed in genetic terms: NBT, NSB, NBA, NBW, FIT, AFF, LPL, LNL, LTP and LPT365. LPL is defined as the time interval (days) from birth to last farrowing. LTP corresponds to the lifetime number of weaned piglets and LPT365 as the ratio between LTP and LPL, in years.

Genetic parameters were estimated via a restricted maximum likelihood (REML) procedure applied to mixed linear models using the ASREML 4 software (Gilmour et al., 2015).

Univariate analysis was performed for all the previously mentioned traits. Model (1) was used for non-repetitive traits (AFF, LPL, LNL, LTP and LTP365); model (2) was used for traits with multiple recordings from the same individual (NBT, NSB, NBA, NBW and FIT). The models used are shown as follows:

(1) $\vec{y} = X\vec{b} + Z\vec{a} + \vec{e}$

(2) $\vec{y} = X\vec{b} + Z\vec{a} + W\overrightarrow{pe} + \vec{e}$

Where $\vec{y}$ is the vector of observations, $\vec{b}$ is the vector of fixed effects, $\vec{a}$ is the vector of the direct additive genetic effects, $\overrightarrow{pe}$ is the vector of the permanent environmental effects and $\vec{e}$ corresponds to the vector of residual effects. X, Z and W are incidence matrices relating the corresponding effects to the traits. Multivariate analysis was also performed to obtain phenotypic and genetic correlations between traits.

The general linear model (GLM), performed in the statistical software JMP 7 (SAS Institute Inc., Cary, North Carolina, USA), was used to investigate the influence of factors to be included in the models on all studied traits. The fixed effects included in both the models were herd-year (HY) season (S) and the linear and quadratic age (AGE and AGE^2). Flexible allocation of records to HY was applied. Small HY classes were joined with successive chronological classes within herds so that at least 10 observations were present at each HY class. Herds with less than 10 records were pooled into one group and classified according to the year. Thus, resulting in a total of 801 HY classes, for litter size traits, with an average number of 34 observations. The same procedure was applied to other traits, registering 357 and 376 HY classes for FIT and AFF, and 286 for LPL, LNL, LTP and LTP365, respectively. Season was constituted based on natural seasons: spring, summer, autumn and winter, each with three months duration (March through May, June through August, September through November and December through February). Maternal genetic effects were not included since they have been reported to be not significant on litter/farrowing traits (Chen et al., 2003; Lopez et al., 2017). Mating type was not recorded systematically, so it was excluded from the model. The parity class or number was not included because farrowing intervals were often too long, meaning that a farrowing record might not have been registered. Individual inbreeding coefficients were calculated beforehand, with a mean of 11.9%, yet they did not influence significantly the analysed traits and thus were not included in the model. The large majority of boars had only one or few registered litters and therefore were also not included.

The random effects $\vec{e}$ and $\overrightarrow{pe}$ were assumed to be normally distributed, with zero mean and with $Var(\vec{a}) = I\sigma_a^2$, $Var(\overrightarrow{pe}) = I\sigma_{pe}^2$ and $Var(\vec{e}) = I\sigma_e^2$. The heritability ($h^2$) was defined as proportion of additive genetic variance (σ_a^2) on phenotypic variance. The permanent non-genetic proportion of phenotypic variation (pe^2) was defined as the proportion of permanent environmental variance (σ_{pe}^2) on phenotypic variance.

The additive genetic coefficient of variation (CV_a) was calculated according to Houle's (1992) proposed formula: $CV_a = \sigma_a/mean$.

The genetic trends were calculated by the linear regression of the estimated breeding values (EBV) over time and represented graphically through the mean EBV of animals with reproductive phenotypic values included in the database, by year of birth of the sow.

Results

The arithmetic means, standard deviations, and minimum and maximum values for the analysed traits are summarized in Table 1. On average, litters are constituted by 9.3 piglets, 8.9 of those born alive and 0.4 are stillbirths. 7.4 piglets survive the lactating period and are weaned, resulting in a mean pre-weaning mortality of 16.4%. Usually, the first farrowing happens just after the sow completes one year of age and subsequent litters after six months. The typical Bísaro sow is kept in production for two years with an average number of 2.6 litters. The results from the GLM analysis of fixed effects included in both models are given in Table 2. Despite farrowings were mildly concentrated in summer (28.3%) and spring (27.5%), the farrowing season (S) did not significantly affect NBT (P>0.05).

Variance components and proportions of variance

The estimated variance components and proportions of variance for the studied traits are shown in Table 3. The heritability estimates for litter size traits were low and varied from 0.007±0.004 to 0.015±0.006. Differently, the heritabilities for traits related with longevity and lifetime production traits were higher (0.078±0.026 to 0.121±0.030). AFF registered the highest heritability value (0.345±0.028) and FIT the lowest (0.002±0.005). Permanent environmental effects accounted for 9-10% for NBT and NBA and none for FIT. The highest additive genetic variation corresponded to FIT with 27.1% variation.

Genetic and phenotypic correlations

Estimates of additive genetic and phenotypic correlations among the four litter size traits are presented in Table 4. The genetic correlation between NBT and NBA was very high and positive (0.968). Estimates of correlations between NSB-NBA and NSB-NBW were low; the first pair had positive values (0.107 and 0.005) whereas the second had negative (-0.010 and -0.126). Genetic and phenotypic estimated correlations had the highest difference between pairs NBW-NBT (0.350) and NBW-NBA (0.228). The genetic and phenotypic correlations between longevity and lifetime production traits are shown in Table 5. All pairs presented high positive genetic correlations (0.811-0.969) and moderate to high phenotypic correlations (0.266-0.946).

Genetic trends

Mean EBV and standard deviations for the four litter size traits are shown in Figure 1. From 1995 to 2015, mean EBV for NBT and NBA registered an overall increase of 0.03 and 0.02 average piglets per litter, respectively. NBW followed the previously described traits with a lower overall improvement of 0.01 registered in the 20-year period. NSB showed no major fluctuations in EBV over time. All standard deviations of EBV for litter size traits had suffered an overall increase. The linear regression analysis showed small negative genetic trends of -

1.5×10^{-3} and -1.7×10^{-3} for NBT and NBA, and negligible positive coefficients of 4.8×10^{-4} and 2.8×10^{-6} for NBW and NSB, respectively (P<0.001).

Mean EBV for AFF and LPL fell considerably over time and registered an overall decreased of 21.3 and 17.5 days, respectively (Figure 2). The linear regression analysis of these traits corroborated these results with considerable negative genetic trends of -0.6 and -0.4 for AFF and LPL respectively (P<0.001). In contrast, FIT, LNL, LTP and LTP365 mean EBV did not fluctuate substantially over time (data not shown) and registered small coefficients: 2.6×10^{-3}, -9.2×10^{-4}, 3.2×10^{-3} and -1.5×10^{-3} respectively (P<0.001).

Discussion

The descriptive analysis of the database confirmed the modest phenotypic values presented by previous works regarding reproductive traits in Bísaro pigs (Outor-Monteiro, 1998; Silva, 2017). Litter size mean values were higher than other local breeds: Alentejano (Ferreira, 2008) and Iberian pig (Saura et al., 2015), and European breeds: Mangalitsa (Petrovic et al., 2013), Black Slavonian (Skorput et al., 2014) and Nero di Parma (Menčik et al, 2017); only close to the Malhado de Alcobaça (Vicente, 2006), another Portuguese breed. Yet, values fall considerably lower when compared to exotic breeds used in intensive pig production systems (Nagyné-Kiszlinger et al., 2013; Krupa et al., 2016; Li et al., 2017; Lopez et al., 2017).

There are many reports regarding genetic determination for litter size traits for pigs, but estimated values vary significantly across studies. Indigenous breeds tend to have lower heritability values than exotic breeds (Akanno et al., 2013). Notwithstanding, it is consensually agreed that most of litter traits have low heritabilities (Bidanel, 2011; Uzzaman et al., 2018). The heritabilities for litter traits estimated in the present study are within the range of Bidanel's review (2011), although slightly below the mean values presented by Akanno et al. (2013). The estimates of heritabilities for NBT and NBA for Bísaro pigs were only closer to those retrieved by Chimonyo et al (2006) in Mukota pigs, Vicente (2006) in Malhado de Alcobaça, and Perez-Enciso and Gianola (1992) for the Iberian pig, but considerably lower than the reported in most studies using exotic breeds or crossbreeds (Ehlers et al., 2005; Kapell et al., 2011; Abell et al., 2012). The explanation for the lower heritabilities regarding the litter traits found in our study and others involving indigenous breeds remains unclear. Notwithstanding, low heritabilities do not necessarily imply low additive genetic variances (Visscher et al., 2008). In this study, two of the analysed traits (NSB and FIT) presented high values of CV_a (0.177 and 0.271) in contrast with the low heritability estimates (0.007 and 0.002). This finding corroborates Visscher's theory (Visscher et al., 2008) and indicates that selection of these traits are feasible.

Contrarily to litter size traits, few studies are available for reproduction traits related to production intervals or longevity. Even though, in our study, the estimated heritability for FIT was lower than the mean value achieved by Akanno et al. (2013) (0.02) and Nagyné-Kiszlinger et al. (2013) (0.06). The estimated heritability for AFF (0.35) was slightly higher than the reported by Akanno et al. (2013) (0.23) but similar to other directly related traits, including the age at puberty (Bidanel, 2011) (0.37) and the age at first insemination as reported by Hanenberg et al. (2001) (0.32) and Nagyné-Kiszlinger et al. (2013) (0.26-0.41).

The length of productive life (LPL) is commonly defined as time (days) between the sow age at first farrowing and the age at culling/mortality (Yazdi et al., 2000; Serenius and Stalder, 2007), last farrowing (Sobczyńska et al., 2013) or weaning of last litter (Noppibool et al., 2016; Noppibool et al., 2017). In our study, many sows had only one registered litter as they were kept off breeding prematurely, ergo LPL was defined as time from birth to last farrowing. Despite this difference and the fact that all these studies have been conducted in industrial pig populations, the heritability achieved in our study approximated to those reported by Yazdi et al. (2000) (0.11), Serenius and Stalder (2004) (0.05-0.10), more recently Sobczyńska et al. (2013) (0.10) and Nikkilä et al. (2013) (0.14). Lifetime production (LNL and LTP) had close heritability values, reflecting the intimate relation between them. Similar values for LNL (0.10-0.11) and LTP (0.09-0.12) are also found in the literature (Serenius and Stalder, 2004; Sobczyńska et al., 2013). Contrarily, LTP365 presented lower estimates than those calculated for Polish (Sobczyńska et al., 2013) (0.11-0.13) and Thai sows (Noppibool et al., 2017) (0.13). These results indicate that longevity, lifetime production and efficiency traits should be part of selection programs.

The knowledge of genetic and phenotypic correlations between traits can maximize the accuracy of genetic evaluation and thus help animal selection. The genetic correlation between NBT and NBA (0.968) is in agreement, however slightly higher, with previous studies (Chimonyo et al., 2006; Li et al., 2017). Very tight genetic correlations were found between NBW and NBT (0.974), and NBW and NBA (0.945). Notwithstanding, the value corresponding to the first pair was higher than the reported in Czech breeds (Krupa and Wolf 2013; Krupa et al. 2016) (0.78-0.86), by Akanno et al. (2013) (0.70) in a meta-analysis of pigs reared in tropics, or by Vicente (2006) for the Malhado de Alcobaça pig (0.78). Moreover, weak positive genetic correlations were found between both NBT and NSB, and between NBA and NSB, however higher for NBT (0.352) than NBA (0.107). These undesirable connections, along with the favourable relationship between NBA and NBW confirms that NBA should be preferred as a selection trait rather than NBT (Li et al., 2017).

Differently, positive favourable genetic and phenotypic correlations were found between longevity (LPL) and lifetime production traits (LNL, LTP and LTP365). These results agree with previous studies (Sobczyńska et al., 2013; Noppibool et al., 2017). It also demonstrates that sows with higher EBV and phenotypic values for lifetime production traits are kept longer in the herd. The close relation between all these pairs strengthens the importance of these traits as a selection criterion in pig breeding due to its high economic importance.

An overall perusal of the genetic trends showed no major changes during the last two decades and reflected the inexistence of an effective selection program established for this breed.

The estimated genetic parameters retrieved in this study confirm the large genetic potential that is not being currently explored in the Bísaro pig breed. Even considering the generally low heritabilities of most reproductive traits, the moderate variance components achieved in this study indicate that these traits might respond well to selection. In a period of time in which piglets represent the majority of the production (Paixão et al., 2018b) reproductive traits may have a greater impact on the farm's productivity and farmer's profit. In a long-term perspective, production traits should also be estimated, if data is available. Comprising the inbreeding coefficient together with a combined genetic evaluation of multiple traits is needed to put into practice an effective selection program.

Conclusions

Phenotypic values for reproduction traits in Bísaro pigs were low to moderate. Estimated genetic parameters for litter size traits were low, whereas for longevity and lifetime production traits were noteworthy. No major genetic changes were registered over time for most of analysed traits, except for AFF and LPL. Animal selection should prioritize NBA for litter size traits because denoted the most favourable genetic correlation. Longevity and lifetime production traits were strongly related between them, therefore any of these traits should be incorporated as a selection criterion.

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Table 1

Descriptive statistics of reproductive and longevity traits in Bísaro pigs.

Trait	Units	n[1]	Mean	SD	Min	Max
NBT	Piglets	26903	9.32	2.73	1	20
NSB	Piglets	26903	0.40	0.99	0	14
NBA	Piglets	26903	8.92	2.57	1	16
NBW	Piglets	26903	7.45	2.27	1	16
FIT	Days	12368	179.62	39.18	135	300
AFF	Days	7274	382.23	75.70	240	540
LPL	Days	5103	731.53	447.48	240	2985
LNL	Litters	5103	2.56	2.03	1	13
LTP	Piglets	5103	19.05	16.06	1	96
LTP365	Piglets	5103	8.90	3.39	0.69	21.99

[1] number of observations

NBT = total number of pigs born per litter; NSB = number of stillborn; NBA = number of pigs born alive; NBW = number of pigs weaned per litter; FIT = farrowing interval; AFF = age at first farrowing; LPL = length of productive life; LNL = lifetime number of litters; LTP = lifetime pig production; LTP365 = lifetime efficiency.

Table 2

Statistical significance of fixed effects and covariates.

	Fixed effects		Covariates		
Trait	HY	S	AGE	AGE^2	AFF
NBT	***	NS	***	***	-
NSB	***	***	***	NS	-
NBA	***	*	***	***	-
NBW	***	***	***	***	-
FIT	***	***	***	***	-
AFF	***	*	-	-	-

LPL	***	***	-	-	***
LNL	***	**	-	-	***
LTP	***	***	-	-	NS
LTT365	***	***	-	-	***

* P<0.05; ** P<0.01; *** P<0.001; NS: not significant

NBT = total number of pigs born per litter; NSB = number of stillborn; NBA = number of pigs born alive; NBW = number of pigs weaned per litter; FIT = farrowing interval; AFF = age at first farrowing; LPL = length of productive life; LNL = lifetime number of litters; LTP = lifetime pig production; LTP365 = lifetime efficiency; HY = herd-year; S = season.

Table 3

Estimated variance components (± standard error) and proportions of variance (± standard error) of reproductive and longevity traits in Bísaro pigs.

Trait	Variance components			Proportions of variance		
	σ_a^2	σ_{pe}^2	σ_e^2	h^2	pe^2	CV_a
NBT	0.082±0.036	0.560±0.049	5.371±0.056	0.014±0.006	0.093±0.008	0.031
NSB	0.005±0.003	0.017±0.005	0.741±0.008	0.007±0.004	0.022±0.006	0.177
NBA	0.077±0.033	0.511±0.044	4.645±0.049	0.015±0.006	0.098±0.008	0.031
NBW	0.045±0.023	0.272±0.003	4.069±0.043	0.010±0.005	0.062±0.008	0.028
FIT	2.365±6.570	0.000±0.000	1294.800±17.614	0.002±0.005	0.000±0.000	0.271
AFF	1740.110±163.852	-	3239.600±115.741	0.349±0.028	-	0.109
LPL	9748.480±3046.400	-	97824.900±2965.290	0.091±0.028	-	0.135
LNL	0.254±0.065	-	1.834±0.059	0.121±0.030	-	0.197
LTP	16.746±4.218	-	124.082±3.904	0.119±0.029	-	0.215

LTP365	0.628±0.215	-	7.463±0.218	0.078±0.026	-	0.081

σ_a^2 = additive genetic variance; σ_{pe}^2 = permanent environmental variance; σ_e^2 = error variance; h^2 = heritability; pe^2 = permanent non-genetic proportion of phenotypic variation; CV_a = additive genetic coefficient of variation.

NBT = total number of pigs born per litter; NSB = number of stillborn; NBA = number of pigs born alive; NBW = number of pigs weaned per litter; FIT = farrowing interval; AFF = age at first farrowing; LPL = length of productive life; LNL = lifetime number of litters; LTP = lifetime pig production; LTP365 = lifetime efficiency.

Table 4

Estimated genetic (above diagonal) and phenotypic correlations (below diagonal), and respective standard errors, between litter size traits in Bísaro pigs.

Trait	NBT	NSB	NBA	NBW
NBT		0.352±0.323	0.968±0.024	0.974±0.110
NSB	0.361±0.005		0.107±0.368	-0.010±0.402
NBA	0.934±0.001	0.005±0.006		0.945±0.068
NBW	0.623±0.004	-0.126±0.006	0.717±0.003	

NBT = total number of pigs born per litter; NSB = number of stillborn; NBA = number of pigs born alive; NBW = number of pigs weaned per litter.

Table 5

Estimated genetic (above diagonal) and phenotypic correlations (below diagonal), and respective standard errors, between longevity and lifetime production traits in Bísaro pigs.

Trait	LPL	LNL	LTP	LTP365
LPL		0.929±0.003	0.948±0.037	0.811±0.155

LNL	0.873±0.004		0.969±0.014	0.920±0.098
LTP	0.818±0.005	0.946±0.002		0.899±0.076
LTP365	0.266±0.014	0.506±0.011	0.677±0.008	

LPL = length of productive life; LNL = lifetime number of litters; LTP = lifetime pig production; LTP365 = lifetime efficiency.

Figure 1

Mean estimated breeding values (EBV) and standard deviations for litter size traits (NBT = total number of pigs born per litter; NSB = number of stillborn; NBA = number of pigs born alive; NBW = number of pigs weaned per litter) by year of birth, from 1995 to 2015.

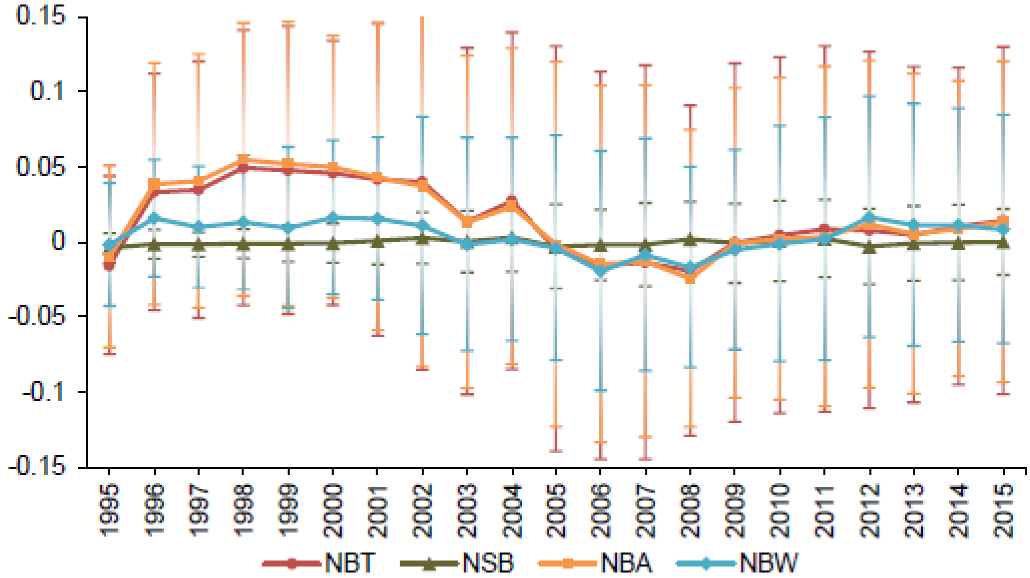

Figure 2

Mean estimated breeding values (EBV) and standard deviations for age at first farrowing (AFF) and length of productive life (LPL) by year of birth, from 1995 to 2015