

Seasonal Subfertility in Pigs: The Effect of Elevated Service Numbers on the Expression of the Syndrome

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Abstract: The seasonal subfertility syndrome was studied on the basis of determining whether the elevated numbers of Services induced by sows returning to estrus have an impact on the numbers of sows impregnated in the reduced fertility period of July-August-September. Numbers of sows mated (Services) and sows that farrowed (Pregnancies) were collected from 5 pig farms located in three different regions of mainland Greece. A total of 2303 sows were involved in 6809 matings and 5606 farrowings grouped in monthly observations over a period of 12 months. The collected data was analyzed in respect of the Services-Pregnancies relation and the potential effect of farm and season on this relation. The thorough statistical analysis provided the proof for a close, non-linear relation between Services and Pregnancies ($R^2 = 0.96$, $p < 0.01$). There was no farm effect established on the Services-Pregnancies relation. The effect of a season-specific factor was found to generate an inverse relation between pregnancies and services in the months of July, August and September ($R^2 = 0.97$, $p < 0.01$) suggesting that the increased amount of services potentially consists of one of the factors that explain the decreased pregnancy levels. Excessive numbers of Services were then shown unable to relate to numbers of Pregnancies when the season-specific factor was ignored. It was therefore, concluded that elevated numbers of Services, which are, themselves, caused by unsuccessful matings of sows returning to estrus in the period of July-August-September, enhance the expression of reduced fertility and constitute an element of the seasonal subfertility syndrome.

Key words: Pigs, seasonal subfertility, services, pregnancies, syndrome, pregnancies

INTRODUCTION

Seasonal subfertility is an unquestionable problem in pig reproduction with as many causal factors as expressions. It is considered as a fraction of the heat stress condition in pigs but it is neither a heat only problem, nor is it the entire representation of the effect of hot weather on a pig herd. Heat stress affects all the pig population by means of malfunction of various physiological mechanisms and diminished productivity. Seasonal subfertility may be expressed from May to September (therefore seasonal and not only summer) by a series of reproductive occurrences at various degrees in each herd (therefore subfertility and not infertility).

The seasonal subfertility syndrome is constituted by low results in almost all reproductive parameters of a pig herd. Reduced ovulation rates and embryonic mortality are the triggering factors (Claus and Weiler, 1985) leading to early disruption of pregnancy (Tast *et al.*, 2002).

Regular or delayed return to estrus and abortion) are also reflected to low conception and farrowing rates (Hurtgen and Leman, 1980; Love, 1981; Hancock, 1988; Almond and Bilkei, 2005). Hormonal changes regulated by the melatonin pathway may also be expressed as delayed onset of estrus in gilts and post-farrowing sows (Hurtgen *et al.*, 1980) and subsequent silent and undetected estrus (Stork, 1979) affecting successful fertilization.

Furthermore, even when pregnancy is established, low litter sizes are recorded as a result of induced malfunction of the female reproductive system (Almond and Bilkei, 2006).

On the male's side, reduced libido and semen qualitative and quantitative parameters may occur when boars are subjected to high ambient temperatures, direct sunlight and reducing photoperiod (Colenbrander and Kemp, 1990; Park and Yi, 2002; Smital, 2008) contributing to seasonally limited reproductive output of pig herds.

On the basis of physiology of the female pig, what is generally accepted is that seasonal changes in environment are perceived mainly by the ability of the pig to recognise seasonal changes in photoperiod. This information is mediated through changes in the activity of the pineal gland to secrete melatonin. Stimulation of melatonin receptors located in the hypothalamus has a significant role for the release of GnRH and subsequent gonadotrophin release from the pituitary (Peltoniemi and Virolainen, 2006). Moving into gestation, heat-induced low levels of blastocyst-synthesized luteotrophic oestrogens at day 12 of pregnancy and high levels of luteolytic prostaglandins between days 12 and 16 of pregnancy consist the hormonal path (Wetteman and Bazer, 1985) leading to heat-stress-imposed decrease in progesterone, causing return to oestrus and reduced reproductive output (Tast *et al.*, 2002).

The mechanisms by which the environmental conditions influence pig reproduction have long been studied and debated in research, where the results appoint the effect to a number of factors varying from genetic predetermination through "seasonality genes" (Skinner *et al.*, 1999) hormonal and physiological regulations (Love *et al.*, 1993) to plain stressors such as low level of feeding and management of the livestock (Love, 1978; Hennessy and Williamson, 1984).

What the controversy shows is that the interrelations between environment and physiology produce a phenomenon with such a complexity that the seasonal subfertility syndrome is yet a problem unsolved. Furthermore, the reduced reproductive output of pig herds introduces additional pressure in controlling reproduction by increasing the number of services over the critical period of hot weather, as problematic sows recycle in the services' routine. This leads to a gradual uplift in the number of services performed, over-usage of boars and stockman-power and intensifies the expression of subfertility by reduced semen quality and quantity (Du Mesnil *et al.*, 1978) and by low stock-people productivity when excessive demands in working hours occur (English *et al.*, 1992).

In order to clarify the likelihood of sows returning to estrus, stressing the conditions of reduced fertility and if yes, to which extent this effect is evident, the present work takes a focused look at this particular aspect of seasonal subfertility in pigs.

MATERIALS AND METHODS

Five pig farms located in three different regions of mainland Greece were included in the present study. A confined system is used in all farms for housing the pigs.

A total of 2303 F1 hybrid (LW x Landrace) sows were involved in 6809 matings and 5606 farrowings over a period of 12 months.

Farm 1: Farm 1 is a 550 sows unit, located in south-western Greece. Dry sows are housed mainly in crates, with a small number housed in boxes. There are 8 boars in the farm, used in Artificial Insemination (A.I.) and occasionally in natural services. Two services are always applied per each estrus.

Farm 2: In Farm 2, which is established in northern Greece, the reproductive population consists of 175 sows and 9 boars. Natural service is the only practice and two services are performed from two different boars in each estrus. Dry sows are housed in crates and post-weaning sows are grouped in boxes.

Farm 3: Located in south-western Greece, Farm 3 houses 158 sows and 10 boars, performing natural services, which is the only reproductive practice applied. All sows are housed in crates, visiting the boar's box only for fertilization.

Farm 4: Farm 4 is the last south-western Greek farm in the experimentation, housing 520 sows and 6 boars, in crates and boxes, respectively. A.I. is again the most applied method in reproduction, whereas few natural services are also taking place. In this latter case, two different boars are used/estrus.

Farm 5: A large farm in central Greece is the last unit included in the present study. The pig population is divided into two different establishments of 600 sows and 300 sows, respectively. Twelve boars are used for the matings in both farms and A.I. is the main practice. Each sow in estrus is served twice, not necessarily with semen from the same boar. In the few cases where natural service is preferred, the sow is moved to the boar pen for 2 matings. Although, the 2 establishments are under the same managerial and zootechnical practices, due to the separation of the sow population, the second establishment of 300 sows will herein be referred to as Farm 6.

- All farms apply similar practice, as far as the recordings of the reproductive phenomena are concerned
- Successful fertilization is confirmed by the non-return-to-estrus method in the first 45 days post service and thereafter disruption of pregnancy was reported as abortion
- Farrowings take place under similar housing conditions in farrowing pens with slatted floors

Statistical methods: We use a balanced panel data set of pig data from the previously mentioned 6 farms over a period of 12 months. The examination period of twelve months does not apply within a calendar year, but dates from December to November, in order to randomize the position of the quarter of the 3 months (July, August and September) in the 12-month period.

In overall the sample consists of 72 farm-month observations. The parameters recorded were:

- Number of sows mated (Services)
- Number of non pregnant sows before day 45 of gestation
- Number of non pregnant sows after day 45 of gestation

The calculated parameters for statistical analysis purposes were:

- Number of sows mated minus the total of non pregnant sows. This variable is termed as Pregnancies and consists of the dependent variable of the analysis
- Number of sows mated. This variable is termed as Services and consists of the independent variable of the analysis

Statistical analysis is performed by the use of Microfit 4.0 Windows version, statistical package.

In order to be more confident about the non-normality inference, we perform the Jarque-Berra test.

To better conform to the normality assumption, we take a logarithmic transformation of both variables and of the percentage change of the variables. However, when a variable X_t is expressed in logarithms, percentage changes over time are expressed as follows:

$$\ln \frac{X_t}{X_{t-1}} = \ln X_t - \ln X_{t-1} = D \ln X_t$$

It is quite conceivable that we cannot take simple percentage changes and then take their logarithms because percentage changes usually include negative values.

After performing the logarithmic transformations, the final variable set of the present study includes the Pregnancies and Services variables expressed in levels and in logarithms, as well as their logarithmic percentage change. These variables are used to estimate the following regressions:

$$PREG_{i,t} = \alpha_{i,0} + \alpha_{i,1} SER_{i,t} + u_{i,t} \quad (1)$$

$$\ln PREG_{i,t} = \beta_{i,0} + \beta_{i,1} \ln SER_{i,t} + \epsilon_{i,t} \quad (2)$$

$$D \ln PREG_{i,t} = \gamma_{i,0} + \gamma_{i,1} D \ln SER_{i,t} + \epsilon_{i,t} \quad (3)$$

Where:

- PREG = Denotes pregnancies
- SER = Denotes services
- ln = Denotes the natural logarithm of the variable
- Dln = Denotes the logarithmic percentage change
- I = Denotes the farm of data origin
- t = Denotes the month
- $u_{i,t}$, $\epsilon_{i,t}$ and $\epsilon_{i,t}$ = Assumed to be zero-mean, normally distributed error or disturbance terms i.e., $u_{i,t} \sim N(0, \sigma)$

Estimated regression t-statistics are corrected for conditional heteroskedasticity using White (1980) consistent covariance matrix. Our measure of explanatory power is the coefficient of determination (R^2) which shows the degree to which changes in the explanatory variable (Services) explain changes in the dependent variable (Pregnancies). However, we report the adjusted values of R^2 because they are more appropriate for explanatory-power comparisons across different models.

To test for the linearity assumption we follow 2 paths. First we re-estimate the 3 regression models augmented by an additional variable being the square of the model-specific independent variable. If the additional squared variables are found to be significant, then the relation between pregnancies and services is potentially non-linear. Second, we perform the Wald test setting the restriction that the coefficients of the squared variables equal zero. If the Wald test is insignificant the additional explanatory variables can be omitted implying a linear relation between pregnancies and services. However, if the Wald test is found to be significant the additional variables need to be included in the model indicating potential non-linearities in the relation between the two basic variables. A thorough exposition of the Wald test is provided in Pagan and Hall (1983).

An interesting research question concerns whether the farm of data origin has any observable effects on the relation between pregnancies and services. To answer this question we employ six intercept dummies which account for each one of the six farms examined in the context of the present study. To examine whether the farm of data-origin has an impact on the results (heterogeneity across farms) we calculate six intercept dummies (F1-F6) which take the value of 1 if the variable values are originated from the respective farm and zero otherwise. Since, our concern lies only with the effects of

heterogeneity we avoid including slope dummies. The 6 vector dummies used in the analysis are orthogonal (i.e., $F_1 + F_2 + F_3 + F_4 + F_5 + F_6 = 1$ and $F_1 * F_2 * F_3 * F_4 * F_5 * F_6 = 0$). Therefore, multiplication of their summation with the intercept term does not violate the initial regression model. The form of the regression models will now be

$$PREG_{i,t} = \alpha_0 * \sum_{j=1}^6 F_j + \alpha_{i,t} SER_{i,t} + u_{i,t} \quad (4)$$

Where:

F_j = The dummy variable accounting for farm j ($j = 1, 2, \dots, 6$) and $\sum_{j=1}^6 F_j = 1$

A similar transformation is also conducted to the logarithmic models. In the case where any one of the dummies is found to be significant, then the specific conditions applying to the, respective farm bear important fertility implications.

An additional set of analysis concerns the question as to whether the effect of services on fertility is less profound during the quarter of July to September. This problem is dealt by augmenting the initial models by a seasonal Slope Dummy (SD) which takes the value of 1 in months July, August and September and 0 in all other months. In particular, the augmented form of the models is as follows:

$$PREG_{i,t} = \alpha_{i,0} + \alpha_{i,1} SER_{i,t} + \alpha_{i,2} SD * SER_{i,t} + u_{i,t} \quad (5)$$

Of course, the 2 logarithmic models are being similarly transformed. The sign and the magnitude of the slope coefficient $\alpha_{i,1}$ reveal the direction and the significance of a seasonal fertility effect during the quarter from July-September.

The potential low performance of the model raises the question of model misspecification especially in the case of omitted explanatory variables. To answer this question we perform Ramsey's RESET test which examines the functional form of the regression model by calculating the squares of the fitted values (Pagan and Hall, 1983). The testable null hypothesis states that the model is not well specified and the alternative hypothesis states that the model is well specified. Significant values of the F-test support the null hypothesis and indicate that the model is potentially misspecified. The performance of the test results in an F-test value of 3.11 and a, respective p-value of 0.08 indicating that the null of model misspecification is rejected either at the 1 or at the 5% level of significance. Therefore, despite the low performance in terms of

explanatory power, the model is well specified and all the conclusions drawn about the inverse seasonal effect in the pregnancies-services relation are fully justified.

In a final attempt, we test for potential non-linearity in the relation between Services and Pregnancies. The intuition is to test whether the extremely increased number of services has an inverse effect than what is expected, namely it results in a decreasing number of pregnancies. To perform this analysis, the variables are ranked according to the number of Services and are divided into three groups. Group 1 (LOW) contains all observations that correspond to the lowest 30% of the number of Services. Group 2 (MEDIUM) contains all observations that correspond to the medium 40% of the number of Services. Finally, Group 3 (HIGH) contains all observations that correspond to the highest 30% of the number of services. If the values of the adjusted R^2 deviate significantly across the three groups, then 3 is evidence of a potential non-linear relation between pregnancies and services.

RESULTS AND DISCUSSION

Results: Table 1 tabulates some summary descriptive statistics of the panel farm-month values of the two variables and Fig. 1 portrays the Services and Pregnancies levels for the total of the farms and over the 12-month experimentation period.

The results of Table 1 offer a first indication of non-normality in the data. In particular, the mean values of both variables deviate significantly from the respective median values. Moreover, the values of skewness and kurtosis reveal that the distributions of both variables are right skewed and platykurtic. Finally, the minimum and maximum values of both variables, along with their high standard deviations reveal significant cross-sectional differences across the six farms which potentially are owed to the large differences in the size of the farms.

The results of the Jarque-Bera test provide somehow mixed evidence of non-normality. The values of the test for the Pregnancies and Services variables are 6.26 and 7.21, respectively while the corresponding (p-values) are

Table 1: Summary descriptive statistics of farm results

	Pregnancies	Services
Mean	77.72	94.57
Median	72.50	96.50
Maximum	160.00	180.00
Minimum	22.00	24.00
SD	41.83	50.95
Skewness	0.22	0.06
Kurtosis	1.62	1.46
Jarque-bera test	6.26	7.21
Probability	0.04	0.03

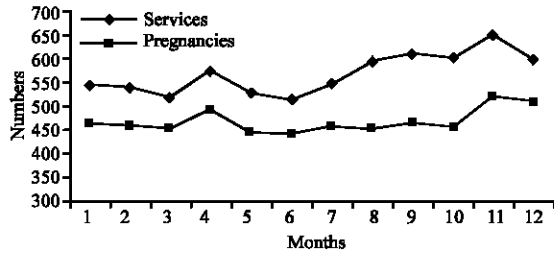


Fig. 1: Number of services and pergnancies (sum of all farms) in a 12-month period. (1: Dec., 2: Jan., 3: Feb., 4: March, 5: Apr., 6: May, 7: June, 8: July, 9: Aug., 10: Sep., 11: Oct., 12: Nov)

Table 2: Regression analysis of pregnancies on services

	Intercept	Services	Adj. R ²
Model 1 (Levels)	1.79(1.43)	0.80*(35.40)	0.96
Model 2 (Ln)	0.05(0.70)	0.95*(56.05)	0.97
Model 3 (DLn)	0.00(-0.05)	0.95*(63.06)	0.97

Numbers are rounded to two decimal points. Regression t-statistics are shown in parentheses. The superscript * indicates significance at the 1% level

0.04 and 0.03, respectively, implying that the normality assumption could be accepted at the 5% level of significance. Figure 1 shows that it can be very informative to investigate fertility through the simultaneous examination of Services and Pregnancies numbers. The course of their values over the 12-month period indicates that the 2 parameters covariate during the first 7 months (December to June) and then gradually deviate in the quarter July-August-September, to converge again after October. This observation points that the source of any abnormality in the values distribution or the relation of Services and Pregnancies lies in this quarter.

Following, we report the results of running the three basic regression models using a number of estimation techniques which include the addition of dummy variables and the grouping of the data set. In all cases, regression t-statistics are adjusted for heteroskedasticity. Table 2 reports the results of a regression of pregnancies on services only. Model 1 expresses variables in levels; Model 2 employs the natural logarithm of the variables and Model 3 uses the monthly logarithmic changes of the variables.

The results reported in Table 2 display that the number of Services, either in levels or in logs, has a high explanatory power for Pregnancies. The values of the adjusted R² depict that only a small portion of the variability in pregnancies is explained by factors other than services. Moreover, the values of the t-statistics are extremely high and significant at the 1% level indicating that services consist of a highly important variable in explaining pregnancies. Similar results are observed when the model estimation accounts for the logarithmic

percentage changes in both dependent and independent variables (Model 3). Interestingly, the near-zero intercept and the approximately unity slope coefficient, point towards a direct linear relation between monthly changes in pregnancies and monthly changes in services, which appears to be approximately dichotomous.

The results of performing the Wald test setting the restriction that the coefficients of the squared variables equal zero are exhibited in Table 3.

The results in Table 3 show that the linearity hypothesis is rejected at the 10% level of significance when the models include variables in levels and logarithms and at the 5% level when the model includes variables expressed in logarithmic percentage changes. Clearly, these results do not comprise a sound indication of non-linearity in the relation between pregnancies and services. However, nor do they fully support the existence of a direct relation between pregnancies and services which would conclude that any increase in the amount of services unambiguously leads to an increase in the number of pregnancies.

The impact of farm specific factors: The farms involved in the present study vary in size and are located in different parts of the mainland of Greece. Therefore, the significance of any of the calculated farm-dummies would conclude that farm size and location bear implications for the pregnancies-services relation.

The results of regressing pregnancies on services and on the 6 intercept dummies are shown in Table 4.

Interestingly, almost none of the dummies is found to be significant, even at the 10% level, irrespective of the estimation model used. The only exception refers to Farm 2, which is found significant at the 10% level in the case of Model 1. However, when moving to the other 2 Models the result falters, indicating that it is at best transitory. On the other hand, the services variable is found significant at the 1% level and consists of the only variable which exhibits solid explanatory power for pregnancies. Moreover, as compares to the results of Table 2, the values of the adjusted R² display no variation except in the case of Model 3 where we observe a marginal drop from 97-96%.

In overall, what can be drawn from the results of Table 4 is that the specific features of the farm of data origin (i.e., size, location etc.) include no observable factors which could possibly affect the relation between pregnancies and services.

The impact of seasonality: The quarter of July-September is considered to be a period of reduced fertility. To check whether the observed increased amount of services could

Table 3: Testing for linearity between pregnancies and services

	Intercept	Services	Squared services	Adj. R ²	Wald test
Model 1 (Levels)	8.16(2.51)	0.62*(6.16)	0.00***(1.85)	0.96	3.43*** (0.06)
Model 2 (Ln)	1.33(1.84)	0.33(0.95)	0.07***(1.77)	0.97	3.12*** (0.08)
Model 3 (DLn)	0.01(0.50)	0.87*(12.76)	-0.13**(-2.20)	0.84	4.83** (0.03)

Numbers are rounded to 2 decimal points. Regression t-statistics are shown in parentheses. The Wald test uses a chi-square (χ^2) test to check whether the squared services variable is significant. The corresponding p-values of the test are shown in brackets. The superscripts *, ** and *** indicate significance at the 1, 5 and 10% levels, respectively

Table 4: Farm-specific effect in pregnancies-services relation

	Services	Farm1	Farm2	Farm3	Farm4	Farm5	Farm6	Adj. R ²
Model 1 (Levels)	0.81*(41.18)	3.60(1.20)	5.16***(1.72)	3.68(1.25)	-1.42(-0.47)	-4.92(-1.58)	1.69(0.54)	0.96(0.96)
Model 2 (Ln)	0.95*(49.69)	0.03(0.39)	0.09(0.97)	0.05(0.55)	0.00(0.00)	-0.04(-0.41)	0.01(0.15)	0.97(0.97)
Model 3 (DLn)	0.95*(41.39)	-0.02(-0.37)	0.01(0.11)	0.00(-0.09)	0.02(0.31)	-0.01(-0.18)	0.00(0.09)	0.96(0.96)

Numbers are rounded to two decimal points. Regression t-statistics are shown in parentheses. The superscripts *, ** and *** indicate significance at the 1, 5 and 10% levels, respectively

Table 5: Seasonal effects in the pregnancies-services relation

	Intercept	Services	Seasonal slope dummy	Adj. R ²
Model 1 (Levels)	1.44(1.17)	0.83*(53.56)	-0.09*(-3.25)	0.97
Model 2 (Ln)	0.03(0.40)	0.96*(57.49)	-0.02*(-2.73)	0.97
Model 3 (DLn)	0.00(0.35)	0.97*(17.38)	-0.57**(-2.30)	0.85

Notes: Numbers are rounded to two decimal points. Regression t-statistics are shown in parentheses. The superscripts *, ** and *** indicate significance at the 1, 5 and 10% levels, respectively

potentially help overcoming periods of subfertility, or if the opposite is true, we introduce a seasonal slope dummy in the models which takes the value of 1 for the quarter from July-September and 0 for the remaining quarters. The intuition is that the slope dummy isolates the specific quarter incremental effects and shows the direction and magnitude of the examined relation within the quarter under investigation.

Table 5 tabulates the results of running the three regression models of pregnancies on services and on the seasonal slope dummy. It clearly appears that the services variable, expressed in any of the three forms (levels, Ln and DLn) is no less significant as compared to our previous results. Interestingly, the seasonal dummy is found negative and significant in all three models implying an inverse relation between pregnancies and services in the months of July, August and September. Therefore, given that within this quarter the farrowing rates are at low levels, it is reasonable to assume that the reproduction activity is more intense. However, our results document the ineffectiveness of intensive reproduction and conclude that the increased amount of services potentially consists of one of the factors that explain the decreased pregnancy levels.

Surprisingly enough it is Model 3 which exhibits the worst performance of all. The value of the adjusted R² drops to 85% and the seasonal dummy is found significant only at the 5% level. Of course, Model 3 employs variables expressed in percentage changes and bears different implications than the other two models. In particular, Model 3 reveals that the seasonal effect is less

profound, when interest lies with the relation between the pace of change in services and the pace of change in pregnancies. In other words, the results of Model 3 imply that the percentage of decrease in the number of pregnancies is not fully explained by the percentage of increase in the number of services. Instead, there may be other factors, not included in the model, which explain the residual portion of the variability in the percentage change of pregnancies. Since, this finding is only evident during July, August and September, it leads to the assumption that the effects of all the genetic, physiological and environmental factors that constitute the seasonal subfertility syndrome are also present.

Explaining the form of the pregnancies-services relation:

The results reported so far bear some implications on the form of the pregnancies-services relation. A primary set of tests has provided some evidence of a non linear relation. Another set of tests has revealed a robust seasonal inverse relation. In an attempt to investigate the cause of these two findings we rank our observations according to the size of the services variable and form three groups: One including the observations which correspond to the lowest 30% of the number of Services and is termed as Group 1 (LOW); another one including the observations that correspond to the medium 40% of the number of Services and is termed as Group 2 (MEDIUM); finally, a third one which includes all observations that correspond to the highest 30% of the number of Services and is termed as Group 3 (HIGH).

The results of the regression analysis for each one of the three groups are shown in Table 6. A focal point of discussion concerns the sign and significance of the services variable. It appears that irrespective of group and model of estimation this variable is positive and significant at the 1% level, magnifying its importance as an explanatory variable for pregnancies. However, the most interesting result concerns the evolution of the adjusted R² across the 3 groups of observations. In

Table 6: Regression analysis of groups formed according to the number of services

	Intercept	Services	Adj. R ²
Group 1: Low services			
Model 1 (Levels)	7.47(2.20)	0.66*(6.68)	0.56
Model 2 (Ln)	0.61(1.75)	0.79*(8.09)	0.61
Model 3 (DLn)	-0.07(-39.57)	0.87*(87.87)	0.92
Group 2: Medium services			
Model 1(Levels)	1.93(0.60)	0.80*(16.81)	0.87
Model 2(Ln)	0.05(0.25)	0.94*(18.26)	0.88
Model 3(DLn)	-0.02(-0.87)	0.99*(42.22)	0.98
Group 3: High services			
Model 1 (Levels)	-44.38(-1.99)	1.10*(8.21)	0.61
Model 2 (Ln)	-2.15(-2.13)	1.39*(7.01)	0.56
Model 3 (DLn)	0.14(5.29)	0.75*(14.76)	0.82

Numbers are rounded to two decimal points. Regression t-statistics are shown in parentheses. The superscript * indicates significance at the 1% level

particular, for each one of the three estimated models the value of the adjusted R² increases when moving from the low-services group to the medium-services group and decreases when moving further to the high-services group. The observable implication of this finding is that the explanatory power of services for pregnancies is contingent upon the number of services and exhibits an inverse U-shaped form.

In terms of model performance, superiority lies with Model 3. In all three groups it outperforms the other 2 models by delivering the higher values of adjusted R². Moreover, when focusing on the medium group results, we observe that the explanatory power of the model is approximately 100% indicating that percentage changes in services fully explain percentage changes in pregnancies. Further inspection reveals that the model plots an almost perfect linear relation (zero intercept and unity slope) between percentage changes in services and in pregnancies. It thus appears that the failure of the primary tests to verify a direct linear services-pregnancies relation for the full sample is owed to the extremely low and extremely high services observations which potentially induce the non-linearity effects.

In overall, the results of this path of analysis support that increasing the number of services does not necessarily guarantee increased farrowing rates. Our findings indicate that a mediocre reproduction activity enhances farrowing performance. This result also offers the grounds to generalize the seasonal effects observed in the pregnancies-services relation. In particular, if during the months of farrowing depression, mating becomes intensive, the observed inverse pregnancies-services relation is an extremely high services effect, added to the effect of the season in question.

General discussion: The thorough examination of the results confirms the perception of the seasonal subfertility syndrome as an unquestionable phenomenon, but with

such a complexity that, in many cases, simple figures and rates fail to express.

The presentation of the recorded values of the numbers of sows inseminated monthly and the numbers of the sows that farrowed shows that normal distribution can only be marginally assumed, due to excessive values in both cases of Services and Pregnancies which introduce a bias in the distribution of the values over the 12-month period. In the case of services, managerial strategies of each stock can affect the numbers of services to apply to market demands. In the case of pregnancies, although the monthly-recorded values should covariate with the number of services, this is only the case in the period when seasonal subfertility is not evident. From June onwards, a discrepancy between the numbers of Services and Pregnancies is growing, applying again to covariance assumptions after October and thus, providing evidence that the pig is a short day-length breeder (Love *et al.*, 1993).

What is striking, though, is the fact that the discrepancy is not produced by low numbers of Pregnancies, but by increased numbers of Services.

However, in the regression analysis of the values, the Services-Pregnancies relation gives a high correlation index ($R^2 = 0.96$, $p < 0.01$) which demonstrates that the number of Services explains almost all the variability in Pregnancies. This trend is confirmed after the logarithmic transformation of the data, showing the strong Services-Pregnancies relation.

In order to exclude the farm effect on the Services-Pregnancies relation, the farm dummies provide low statistical analysis indices, underlining the fact that productive farms, irrespective of size, with average level of managerial and zootechnical practices like the farms involved in the present study, are consistent in the pursuit of numbers of Pregnancies as close as possible to the numbers of Services, maximizing conception/farrowing rates and litter size in sows and gilts (Hughes and Hemsworth, 1994) but this is not always achieved in the quarter of seasonal subfertility. In this case, the farm effect is only evident where high level of management is practiced. Indeed, in well-managed farms of the climatic zone of North-western Germany, even climatic factors have no substantial effects on sow fertility (Lahrmann and Gardner, 1997). On the other hand, the farm effect has been found significant on other reproductive parameters such as litter size and piglet mortality (Kharouf *et al.*, 1991a) and the lengths of gestation, lactation, weaning to conception interval and sow reproductive life (Kharouf *et al.*, 1991b) in Greek pig farms.

The explanation of the deviation among Services and Pregnancies values over the potential seasonal subfertility period is attempted in two different approaches.

Initially, the season dummies isolate the majority of the high Service values, which coincide with the potential seasonal subfertility period. The regression analysis results ($R^2 = 0.96$, $p < 0.01$) show that, not only is the seasonal subfertility effect evident (declination of Pregnancies from Services) but there is negative relation between Services and Pregnancies in the period which is critical for the expression of seasonal subfertility. The first fraction of the explanation of the results is in absolute agreement with the majority of the relevant literature recently reviewed by Peltoniemi and Virolainen (2006). The fact that, although the performed Services increase, the Pregnancies remain persistently low, suggests that there exists an aspect in the phenomenon of seasonal subfertility which is not expressed in the examination of conception and farrowing rates as percentages only. It takes the investigation of the values of Services and Pregnancies together to demonstrate that the conditions of the potential seasonal subfertility period deteriorate by the expression of the phenomenon itself. This means that the more sows are not successfully impregnated the more sows participate in subsequent services. However, the number of the Pregnancies remains low. What is striking is that as soon as the environmental stressors are withdrawn after October, the Services routine, along with the successful services (Pregnancies) returns to normal. Added to that, the same trend for declination is not evident when the Service numbers also peak in March. Moreover, if it is attributed to overuse of boars which is known to affect semen quality and quantity, this is only significant in long-term frequent collection schemes (Schilling and Vengust, 1987; Pruneda *et al.*, 2005). It is therefore, suggested that it is more substantial for a quarter rather than one month and it must be regarded as an added expression of seasonal subfertility conditions.

Indeed, when the data is classified in 3 levels according to the numbers of services (Low, Medium and High) the Services-Pregnancies relation is only established in the medium-level values ($R^2 = 0.87$, 0.88 0.98 for Models 1, 2, 3, respectively, $p < 0.01$). When less or more Services are performed, irrespective of season, their number lacks in explanatory power upon the numbers of Pregnancies. This finding confirms the previous assumption that excessive numbers of Services are only meaningful upon Pregnancies during the quarter of July-August-September which coincides with the subfertility season.

CONCLUSION

The thorough statistical analysis and interpretation of the data confirm the assumption that the reproductive performance of pig herds is a complex phenomenon which lacks in normality and difficult to explain with plain figures and rates.

In a 12-month-round period, when the effect of farm and season are neglected, there is an obvious strong relation between the numbers of sows mated (Services) and the sows impregnated (Pregnancies) which, however, is not linear.

The farm-effect failed to express any implications on the pregnancies-services relation.

On the contrary, there is an evident seasonal effect in the quarter July-August-September, causing a season-specific negative relation between Services and Pregnancies. This implies that, in contrast with the rest of the months, during this period, as the number of Services rise, the number of Pregnancies deviates. What is more, there are other than the examined factors present, giving strong evidence for the manifestation of the multiplex seasonal subfertility syndrome.

Since all the causal factors of the decreased fertility in this period are generally assumed to constitute the seasonal subfertility syndrome, it is only reasonable to recognize, based on the present study, that, apart from the genetic, physiological and environmental aspects, the elevated numbers of services which are, themselves, generated by reduced fertility, enhance the expression of the seasonal subfertility syndrome.

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REFERENCES

- Almond, P. and G. Bilkei, 2006. Short communication: Effects of a gonadotropin application on seasonal subfertility in pigs. *Deutsche Tierärztliche Wochenschrift*, 113 (5): 201-202. PMID: 16821564. <http://www.ncbi.nlm.nih.gov/pubmed/16821564>.
- Almond, P.K. and G. Bilkei, 2005. Seasonal infertility in large pig production units in an Eastern-European climate. *Aust. Vet. J.*, 83 (6): 344-346. PMID: 15986910. <http://www.ncbi.nlm.nih.gov/pubmed/15986910>.

- Claus, R. and U. Weiler, 1985. Influence of Light and Photoperiodicity on Pig Prolificacy. *Journal of Reproduction Fertility Supplement*. In: Foxcroft, G.R., D.J.A. Cole and B.J. Weir (Eds.). *The J. Reprod. Fertil. Ltd. Essex, U.K.*, 33: 185-197. ISBN: 0 906545 10 2. PMID: 3910824.
- Colenbrander, B. and B. Kemp, 1990. Factors influencing Semen Quality in Pigs. *Journal of Reproduction and Fertility Supplement*. In: Foxcroft, G.R., D.J.A. Cole and B.J. Weir (Eds.). *The J. Reprod. Fertil. Ltd. Essex, U.K.*, 40: 105-115. ISBN: 0-906545-18-8. PMID: 219 2031.
- Du Mesnil de Buisson, F., M. Paquignon and M. Courot, 1978. Boar sperm production: Use in artificial insemination: A review. *Livest. Prod. Sci.*, 5 (3): 293-302. DOI: 10.1016/0301-6226(78)90057-X.
- English, P.R., G. Burgess, R. Segundo and J. Dunne, 1992. Motivation of Stockpeople. In: *Stockmanship: Improving the care of Pigs and other Livestock*. 1st Edn. Farming Press, Ipswich U.K., pp: 146-164. ISBN: 0-85236-236-6.
- Hancock, R.D., 1988. Clinical observations on seasonal infertility in sows in Cornwall. *Vet. Rec.*, 123 (16): 413-416. PMID: 3201668.
- Hennessy, D.P. and P.E. Williamson, 1984. Stress and summer infertility in pigs. *Aust. Vet. J.*, 67 (1): 212-215. PMID: 6497805.
- Hughes, P.E. and P.H. Hensworth, 1994. Management and Artificial Insemination. In: *Principles of Pig Science*, Cole, Wiseman and Varley (Eds.). Nottingham University Press. Nottingham, U.K., pp: 253-276. ISBN: 1-897676-22-0.
- Hurtgen, J.P., A.D. Leman and B. Crabo, 1980. Seasonal influence on estrous activity in sows and gilts. *J. Am. Vet. Med. Assoc.*, 176 (2): 119-123. PMID: 7353985.
- Hurtgen, J.P. and A.D. Leman, 1980. Seasonal influence on the fertility of sows and gilts. *J. Am. Vet. Med. Assoc.*, 177 (7): 631-635. PMID: 7440358.
- Kharouf, A.T., S.G. Deligiorgis and E. Rogdakis, 1991a. Sow Reproductive characteristics in intensive pig farming and the factors affecting them: I. Litter size and piglet mortality. *Animal science review. Official J. Hellenic Soc. Anim. Prod.*, 13: 5-24.
- Kharouf, A.T., S.G. Deligiorgis and E. Rogdakis, 1991b. Sow Reproductive characteristics in intensive pig farming and the factors affecting them: II. Gestation and lactation length, length of sows reproductive life, farrowings interval, weaning to conception and weaning to culling interval. *Anim. Sci. Rev. Official J. Hellenic Soc. Anim. Prod.*, 13: 25-45.
- Lahrmann, K. and I.A. Gardner, 1997. Epidemiological studies regarding the summer infertility syndrome of sows in confinement housing. *Deutsche Tierärztliche Wochenschrift*, 104 (9): 383-386. PMID: 9410729.
- Love, R.J., 1978. Definition of a seasonal infertility problem in pigs. *Vet. Rec.*, 11; 103 (20): 443-446. PMID: 749312. <http://www.ncbi.nlm.nih.gov/pubmed/749312>.
- Love, R.J., 1981. Seasonal infertility in pigs. *Vet. Rec.*, 31;109 (18): 407-409. PMID: 7340074. <http://www.ncbi.nlm.nih.gov/pubmed/7340074>.
- Love, R.J., G. Evans and C. Klupiec, 1993. Seasonal Effects on Fertility in Gilts and Sows. *Journal of Reproduction and Fertility Supplement*. In: Foxcroft, G.R., M.G. Hunter and C. Dobersk (Eds.). *The J. Reproduc. Fertility Ltd. Essex, U.K.*, 48: 191-206. ISBN: 0-906545-27-7. PMID: 8145204. <http://www.ncbi.nlm.nih.gov/pubmed/8145204>.
- Pagan, A.R. and A.D. Hall, 1983. Diagnostic tests as residual analysis. *Economet. Rev.*, 2 (2): 159-218. DOI: 10.1080/07311768308800039.
- Park, C.S. and Y.J. Yi, 2002. Comparison of semen characteristics, sperm freezability and testosterone concentration between Duroc and Yorkshire boars during seasons. *Anim. Reprod. Sci.*, 73 (1-2): 53-61. DOI:10.1016/S0378-4320(02)00129-X. PMID: 12220818.
- Peltoniemi, O.A. and J.V. Virolainen, 2006. Seasonality of Reproduction in Gilts and Sows. *Control of pig reproduction VII: Proceedings of the 7th International Conference on Pig Reproduction, Society of Reproduction and Fertility Supplement*. In: Ashworth, C.J. and R.R. Kraeling (Eds.). Nottingham University Press. Nottingham, U.K., 62: 205-218. ISBN: 13: 9781904761334 . PMID: 16866319.
- Pruneda, A. and E. Pinart, M. Briz, S. Sancho, N. Garcia-Gil, E. Badia, E. Kádár, J. Bassols, E. Bussalleu, M. Yeste and S. Bonet, 2005. Effects of a high semen-collection frequency on the quality of sperm from ejaculates and from six epididymal regions in boars. *Theriogenology*, 63 (8): 219-223. PMID: 15826685. DOI: 10.1016/j.theriogenology.2004.10.009.
- Schilling, E. and M. Vengust, 1987. Frequency of semen collection in boars and quality of ejaculates as evaluated by the osmotic resistance of acrosomal membranes. *Anim. Reprod. Sci.*, 12 (4): 283-290. DOI: 10.1016/0378-4320(87)90099-6.
- Skinner, T.M., N.L. Lopez-Corrales, S.I. anderson, M. Yerle and A.L. Archibald, 1999. Physical mapping of porcine seasonality gene. *Anim. Biotechnol.*, 10 (3): 143-146. PMID: 10721429.

- Smital, J., 2008. Effects influencing boar semen. *Animal Reproduction Science* (in Press). PMID: 18367351.
- Stork, M.G., 1979. Seasonal reproductive inefficiency in large pig breeding units in Britain. *Vet. Rec.*, 20: 104 (3): 49-52. PMID: 433107.
- Tast, A., O.A. Peltoniemi, J.V. Virolainen and R.J. Love, 2002. Early disruption of pregnancy as a manifestation of seasonal infertility in pigs. *Anim. Reprod. Sci.*, 74 (1-2): 75-86. DOI: 10.1016/S0378-4320(02)00167-7. PMID: 12379377.
- Wettemann, R.P. and F.W. Bazer, 1985. Influence of Environmental Temperature on Prolificacy of Pigs. *Journal of Reproduction and Fertility Supplement*. In: Foxcroft, G.R., J.A. Cole and B.J. Weir (Eds.). *The J. Reprod. Fertil. Ltd. Essex, U.K.*, 33: 199-208. ISBN: 09-06545-10-2. PMID: 3910825.
- White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, 48: 817-838. <http://www.jstor.org/pss/1912934>.