

Determination of the technical and economic optimum in piglet production under a semi-technified system

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ABSTRACT

Objective: To estimate the optimal technical and economic levels for semi-technified piglet production based on the number of farrowings.

Design/Methodology/Approach: A linear additive statistical model was applied to the parameters, while a nonlinear cubic model was employed for the variables, using field data collected in 2023 from a semi-technified farm located in Temascaltepec, State of Mexico. The dependent variable was the number of piglets, and the independent variable was the number of farrowings.

Results: At the technical optimum, the number of farrowings was 2.54, corresponding to a maximum piglet production of 10.4749 and a net cash gain of \$2,974.9. At the economic optimum, the number of farrowings was 2.43, equivalent to a production of 10.4731 piglets and a net cash gain of \$3,298.1.

Limitations/Implications: In this type of analysis, the technical optimum is closely aligned with the economic optimum.

Findings/Conclusions: The point of maximum piglet production at weaning did not necessarily correspond to the point of maximum net cash gain at sale.

Keywords: Piglets, births, technical optimum, economic optimum, money profit.

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INTRODUCTION

Mexico is characterized by a wide diversity of pig production systems, which, based on their primary characteristics, are classified into three categories: technified, semi-technified, and backyard or self-sufficiency (extensive) systems (INTAGRI, 2019; SENASICA, 2021). The technified system represents approximately 46% of the national swine inventory, the semi-technified system 20%, and the backyard system 34%. In terms of pork production, the technified system contributes 55%, the semi-technified 20%, while the remaining production, which typically does not enter formal marketing channels, originates from the backyard sector (Hernández *et al.*, 2020a).

In the southern region of the State of Mexico particularly in the municipalities of Luvianos, Tejupilco, Temascaltepec, Zacazonapan, Texcaltitlán, among others backyard



or extensive pig farming predominates, accounting for 63.6% of production, with herds ranging from five to 50 pigs per production unit (PU). Within these systems, piglet production per farrowing remains the most critical productive variable of concern for pig farmers, who continuously seek to improve outcomes provided that the input-output ratio specifically, the efficiency of variable input utilization during piglet production achieves greater technical and economic efficiency. Conversely, the semi-intensive or semi-technified system represents the remaining 36.4% of production in this region, whereas the technified system remains scarce due to the absence of conditions necessary for its proper development (Hernández *et al.*, 2020b).

Undoubtedly, optimizing both the number and weight of piglets per farrowing, along with achieving the optimal number of farrowings per sow, requires strategic management beginning well before farrowing. This involves effective herd management and high-quality nutrition from mating through gestation. However, it is widely recognized that one of the key factors leading to productive imbalance within the herd is the weaning-to-estrus interval (WEI), which significantly influences the percentage of repeated services (PRS), increasing it up to 15%. Prolongation of the WEI and an elevated PRS contribute to a rise in non-productive days (NPD), ultimately decreasing the number of farrowings per sow per year (FSY) and reducing the number of live-born piglets (LBP) per litter. This combination of reproductive inefficiencies including extended WEI, higher PRS, and increased NPD along with the premature culling of young females, adversely affects production costs within pig production systems (PPS) (Ordaz *et al.*, 2014). In this context, and considering the farm's production conditions, it becomes relevant to determine the number of farrowings that maximizes piglet production, and to identify the production point at which achieving the highest number of farrowings does not necessarily translate into the greatest monetary profit. Therefore, the aim of this research was to determine the technical and economic optimum levels of piglet production based on the number of farrowings in a semi-technified system. The underlying hypothesis posits that maximum piglet production does not inherently guarantee the highest sales profitability.

MATERIALS AND METHODS

Study Site: The field data were obtained from a full-cycle farm classified as semi-technified, dedicated to live pig production between April and June 2023. The farm is located in a locality within the municipality of Temascaltepec, State of Mexico.

Biological Material: At the time of data collection, the farm maintained a population of 123 hybrid sows, consisting of 50% Yorkshire and 50% Landrace genetics, along with boars carrying 50% Pietrain and 50% Duroc genetics.

Data Analysis: The dataset encompassed records from seven farrowings per sow over an approximate five-year period. The data collected for each sow were analyzed through correlation using the Ordinary Least Squares (OLS) statistical model, as described by Gujarati and Porter (2010):

$$L = \beta_0 + \beta_1 P + \beta_2 P^2 + \beta_3 P^3 + e$$

Where L =piglets weaned per female per year; β_i , for $i=1, 2, 3$, were the parameters of the model; P =Number of farrowings, and e =Statistical, stochastic, or random error. The statistical significance of the estimated model was obtained through the calculated F, the calculated t-values (tc) (Student's t-test), the adjusted R-squared, and the predicted R-squared (Wooldridge, 2010). For the economic significance of the model, the sign of the coefficients β_2 and β_3 was considered, based on the necessary economic logic to define the concavity of the production function curve (Doll and Orazem, 1984; Rebollar *et al.*, 2022).

The statistical model established that the optimal number of piglets is a function of the sow's optimal average number of farrowings. This model enabled the estimation of the optimal average number of weaned piglets associated with the maximum number of farrowings on the referenced farm. Two optimization levels were derived from this model.

The Technical Optimum Level (TOL) was determined by applying the first derivative of the estimated production function and equating it to zero (marginal product, MP) (Rebollar *et al.*, 2014), expressed as $dL/dP=0$, where the variable to be solved was the number of farrowings.

The Economic Optimum Level (EOL) (Rebollar *et al.*, 2014) was calculated by equating the MP to the price ratio between the input (farrowing cost) and the output (weaned piglet price), represented as (farrowing price/piglet price), according to the equation: $dL/dP=FP/PP$. Upon determining the value of P (number of farrowings) corresponding to both the TOL and the EOL, the total cost (TC), total revenue (TR), and profit (G) were subsequently calculated for each optimization level. According to Rebollar *et al.* (2014), the total cost (TC) was calculated using the equation $TC=PpP$, where Pp represents the average farrowing cost and P denotes the optimal number of farrowings. The Pp value corresponded to the estimated cost per sow at farrowing, as reported by the farm owner, and was established at \$7,500. Total revenue (TR) was determined using the equation $TR=PL$, where TR is the total revenue, Pl represents the average price per weaned piglet valued at \$1,000 as of October 2023 and L refers to the optimal number of weaned piglets per farrowing. Profit (G) was calculated using the formula $G=TR-TC$, where G represents the monetary profit. The results from the statistical model were generated using the PROC REG procedure of SAS (Statistical Analysis System) in its online version (SAS, 2021). Additionally, the predicted R-squared value was obtained through the PRESS (Prediction Sum of Squares) statement within the PROC REG procedure of SAS.

RESULTS AND DISCUSSION

The estimated production function, which explained the number of piglets (dependent variable L) as a function of the number of farrowings (independent variable P) of the sows, is presented in Table 1.

Based on the results of the Fc statistic, the model was statistically significant, as the Fc value was 32.42 (ANOVA, $P<0.05$) under the default 95% confidence level provided by the model output. With this level of confidence, the null hypothesis stating that any β coefficient is equal to zero is rejected. Additionally, empirical evidence suggests that an Fc value of 2.0 or higher, depending on the degrees of freedom, is already sufficient to assign

Table 1. Results of the statistical model of weaned piglets on a semi-technified farm, October 2023.

Variable	Estimated parameter	SE	t-c	Significance
Intercept	9.31286	0.26770	34.79	P<0.05
P	1.03472	0.27009	3.83	P<0.05
P ²	-0.27452	0.07596	-3.61	P<0.05
P ³	0.01861	0.00627	2.97	P<0.05

Source: own elaboration with results from the SAS output. SE: Standard error. Tc: calculated t-value.

statistical significance to a model (Wooldridge, 2010; Rebollar *et al.*, 2008). The adjusted coefficient of determination (ACD) was 0.9402, or 94.02%, indicating that 94% of the total variation in the number of piglets per farrowing (dependent variable) was explained by the number of farrowings (independent variable P). In this context, each β parameter estimate exceeds twice its standard error (SE) (Table 1), supporting the statistical significance of these estimates. Moreover, the predicted coefficient of determination (PCD) was 0.46, reflecting an acceptable predictive power of the regression model (Wooldridge, 2010; Gujarati and Porter, 2010). According to microeconomic production theory (Doll and Orazem, 1984; Rebollar *et al.*, 2022), the signs of the P² and P³ coefficients were as expected, confirming the presence of a concave production function with diminishing marginal returns in the short term (MRST), which allows for the determination of optimization levels. The coefficient of the β_0 estimator, valued at 9.3, lacks economic interpretation (Doll and Orazem, 1984), as it is not feasible to conceptualize piglet production when the number of farrowings (P) is zero. The value of 1.03 suggests that for each additional farrowing achieved by the sows, piglet production is expected to increase by 1.03 piglets. As outlined by Rebollar *et al.* (2011), the technical optimum level (TOL) does not involve product or input prices, as its primary objective is to identify the level of maximum physical production the peak of the production function curve. At this point, as supported by production theory (Doll and Orazem, 1984), production reaches its maximum, and no additional amount of the input variable will yield higher output than that achieved at the TOL. Consequently, the values corresponding to both the TOL and the economic optimum level (EOL), derived from the estimated production function, are presented in Table 2.

Table 2. Cost, revenue, and profit at the TOL and EOL in piglet production on a semi-technified farm, 2023.

Concept	TOL	EOL
X, given in number of births per female	2.54	2.43
P, number of piglets per sow	10.4749	10.4731
TR, \$	7,500.0	7,175.0
IT, \$	10,474.9	10,473.1
P, \$	2,974.9	3,298.1

Economic Optimum Level (EOL). TOL: Toluca. Source: Prepared by the authors based on results output, October 2023.

Thus, the technical optimum level (TOL) of the estimated cubic production function corresponds to a value of the dependent variable L (piglets) of 10.4749 average piglets per farrowing, which is similar to the 10.65 reported by García *et al.* (2011), 10.4 average piglets per sow by Ordaz *et al.* (2013), 9.6 confirmed by Gruhot *et al.* (2017), and 9.8 piglets by Ordaz *et al.* (2019). The production optimum (technical efficiency), or the highest point on the production function curve, is thus associated with a P value (number of farrowings) of 2.54, consistent with the findings of Ordaz *et al.* (2013) and García *et al.* (2014), who reported an average of 3.4 farrowings per sow.

At the economic optimum level (EOL), according to microeconomic production theory (Rebollar *et al.*, 2022), the prices of both the variable input and the product are relevant, as the goal is always to achieve economic efficiency. In the EOL, the producer is not interested in reaching maximum production, but rather in determining the monetary profit, which does not necessarily coincide with the point of maximum total output. Here, a P value of 2.43 corresponds to the EOL of the estimated cubic production function for piglets. Notably, this P value is lower than the P value at the TOL (P=2.54). This finding demonstrates that the TOL occurs before the EOL in relation to L, which aligns with microeconomic production theory (Rebollar *et al.*, 2022). Additionally, the L value at the EOL (10.4731) is lower than that at the TOL (10.4749), which is also consistent with microeconomic theory (Doll and Orazem, 1984; Portillo *et al.*, 2015). At the TOL, the producer's focus is on achieving the maximum level of physical production. Under microeconomic production theory (Rebollar *et al.*, 2022), prices of the product and input are not relevant at this optimum; however, it remains important to estimate the total cost (TC), total revenue (TR), and profit (P) in monetary terms corresponding to the TOL. According to microeconomic production theory (Portillo *et al.*, 2015), in a classic production function graph, the EOL is always located below the TOL. At the EOL, the prices of both the variable input and the product are considered, as this optimum reflects the fact that maximum production does not necessarily imply maximum monetary profit. This insight is especially important for any producer aiming to maximize monetary profit in the production process. In this study, the monetary profit at the EOL (\$3,298.1) was higher than at the point of maximum piglet production (\$2,974.9). This demonstrates that maximum production does not necessarily lead to maximum monetary gain. In fact, in this research, the highest piglet production did not correspond to the highest profit, thereby confirming both the general objective and the hypothesis of the study.

CONCLUSIONS

The number of farrowings corresponding to the technical optimum level (TOL) was higher than that of the economic optimum level (EOL). The number of piglets associated with the TOL exceeded that of the EOL; however, the monetary profit achieved at the EOL was greater than at the TOL. This demonstrates that maximum production does not necessarily result in maximum monetary profit. Any pig producer operating under similar production conditions as those described in this study may benefit from these findings to improve the economic profitability of piglet production.

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