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Research article

Determinants of meat and milk production of Awassi sheep in Syria: A Cobb-Douglas production function estimation approach

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A R T I C L E I N F O

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A B S T R A C T

Awassi is a fat-tailed sheep breed, and the best breed in Syria is famous. Awassi sheep are Syria's main source of red meat and milk production. In this study, we estimated the influence of various factors on sheep meat and milk production using time-series data from 1961 to 2020. This study employed the Cobb-Douglas production function to analyze the data. The results obtained indicate that Awassi meat production in Syria was positively and significantly influenced by carcass weight ($p < 0.001$) and quantity of slaughtered sheep ($p < 0.001$), with elasticity coefficients of 0.994 and 1.000, respectively. The model results show that raw milk yield and milk animals have a positive and significant influence on milk production at the 0.1 % significance level, with an elasticity coefficient of 0.998. However, climatic factors (precipitation and temperature) have a significant effect and negative influence on milk production at the 1 % and 5 % significance levels, respectively. This result sheds light on the policies and procedures the government should implement to develop sheep production in Syria. Therefore, it can be stated that policymakers should enhance the quality and productivity characterization of sheep through the implementation of breeding programs, improve grazing potential, and protect natural pastures. Furthermore, feed rations should be supported to help breeders overcome the effects of drought and high feed prices.

1. Introduction

Livestock products are important for global food security [1,2]. The livestock sector has been the main source of protein resources for humans since ancient times [3], as its products contribute to 34 % of the protein consumed globally [1]. Sheep farming is an important economic, environmental, and social issue in Mediterranean countries, especially in Middle Eastern countries [4–6]. It is also an important component of the livestock sector because of its important role in achieving food security, reducing poverty among smallholder farmers, and being a main source of revenue for rural people in developing countries [7,8]. Sheep-rearing is also an important source of income for breeders in arid zones [9]. There are multiple benefits for sheep. Sheep produce meat, fiber, milk, and hides. In addition, there is economic impact from the sheep manure, which is used in organic farming [3].

Livestock activities are a major part of the agricultural system in Syria and are an important source of household income [10]. Sheep represent 98 % of the main Syrian livestock sector, which fluctuates according to rainfall [11]. Awassi is a fat-tailed breed which is the only and the best breed that Syria is famous for [11–15], as it represents 90 % of the total number of sheep heads in Syria [11]. Syrian steppe (*Al-Badia*) in the eastern and southeastern regions has a total area of approximately 8.3 million hectares and receives less than 100 mm of annual rainfall [10]. However, it provides the most important source of fodder from natural pastures and rangeland

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Table 1
Descriptive statistics of the variables.

Variable	Mean	St.Dev.	Coef.Var	Minimum	Maximum
SHP	11861003	5070567	42.75	2901000	22865400
RMPQ	463125	179804	38.82	130000	873673
MTPQ	107529	53761	50.00	29300	204567
LMP	8199.4	275.1	3.36	7500.0	8631.0
TEMP	18.328	0.754	4.12	16.710	20.310
PREC	302.95	61.96	20.45	171.85	449.39
CARW	250.1	92.4	36.94	180.0	400.0
QSL	4223398	1570369	37.18	1628000	7262889
RMY	669.3	197.5	29.51	452.0	1327.0
MAN	7565132	3539005	46.78	1130000	15771400
QSIM	343466	481612	140.22	1400	2350568
QSEX	549882	612277	111.35	410	2417933
BP	866105	587140	67.79	101954	3053124

[11,12,16]. Livestock breeders usually provide supplementary feeding during winter. Supplements include straw, barley grain, wheat bran, and cotton seeds [12,16].

Awassi can adapt to a wide range of weather conditions [3,11,17], bear limited food resources, and also is capable of walking long distances [11]. Awassi sheep are the main source of red meat and milk production in Syria, accounting for approximately 78 % of the total red meat production and 30 % of the milk production [13]. A common traditional system used by *Bedouins,* called the extensive system, remains the most important sheep production system in Syria. This system relies mainly on sheep grazing on steppes [9,12]. In marginal farming areas, semi-intensive systems are used for sheep farming [12]. This system also relies on range grazing, but in this case, farmers use restricted range [9]. A new system of breeding called the intensive system uses a model where sheep are raised in closed stables and provided with concentrated feed for more than 10 months a year [9]. Breeders rely on this system when fattening sheep and exporting them to Arab Gulf Countries as a profitable agricultural business [12].

In 2021, the number of sheep in Syria reached approximately 16783185 heads. Syria also produced 703350.57 tonnes of raw milk [18]. Despite the development of red meat in Syria during the last few decades, there is still no self-sufficiency in animal products where the per capita share is below the recommended level [13].

The National Agricultural Policy Center [11] indicates that thousands of sheep are slaughtered in Syria every year, especially on religious and tourist occasions. Sheep exports rank second among Syria's agricultural exports, as their contribution to total agricultural exports during the period 2008–2010 was approximately 5.1 %. Saudi Arabia is the main destination for sheep exports in Syria (67.8 %), due to the great demand for sheep meat [19]. As mentioned previously, the government has focused on the development of the livestock sector. The Syrian government adopted a set of policies that encouraged the private sector to invest in sheep-rearing and fattening. In addition, measures have been implemented to balance supply and demand in the market to maintain prices [11].

A study conducted by Kibona et al. [20] analyzed beef meat production in Tanzania from 1990 to 2019 and found that the key factors that positively influenced beef meat production included beef cattle population, beef cattle yield, and the number of beef cattle slaughtered. The results also suggested that the number of exported beef cattle positively influenced beef meat production. However, farm credits and imported pure-bred beef cattle had a negative and insignificant impact on beef meat output. Jaouad [21] studied red meat supply response (sheep and cattle) and its determinants in Tunisia using data obtained from 1970 to 2006 with the Nerlove model. The results showed a positive impact of the meat price and expected rainfall quantity on the production level. However, the price of grain negatively and insignificantly affected production quantity. Furthermore, Bakucs and Márkus [22] analyzed annual data between 1981 and 2009 using the Vector Error Correction Model to estimate long-run elasticities to highlight farmers' reliance on live pigs for slaughter purchase prices and soya fodder prices in Hungary. According to their findings, there is a relatively high importance of expected pig purchase prices and the price of soya fodder in farmers' production decisions. The study also showed high long-run elasticities of the sow stock with regard to the pork purchase price and soy fodder. Bhattacharya et al. [23] estimated the supply response of milk production in BRIC countries using panel data for the period 1992 to 2010. This study analyzes the impact of price and non-price factors on the milk supply. The empirical results indicate a strong association between milk prices, the number of milking animals, and total milk yield. The study also finds a positive impact of non-price factors (WTO membership and exports) on milking animals.

Given this background, the goal of the present study is to identify the determinants of Awassi sheep meat and milk production in Syria. During our review of previous studies, it was noted to the best of our knowledge that this topic did not receive sufficient importance from researchers in Syria, and the literature is almost devoid of any studies that addressed the factors affecting the production of both meat and milk by Awassi sheep. This paper is organized as follows. Section 1 presents an introduction. Section 2 provides a detailed description of the materials and methods used in this study. Section 3 presents and discusses the results. Section 4 contains the study's limitations, followed by conclusions and policy implications (Section 5).

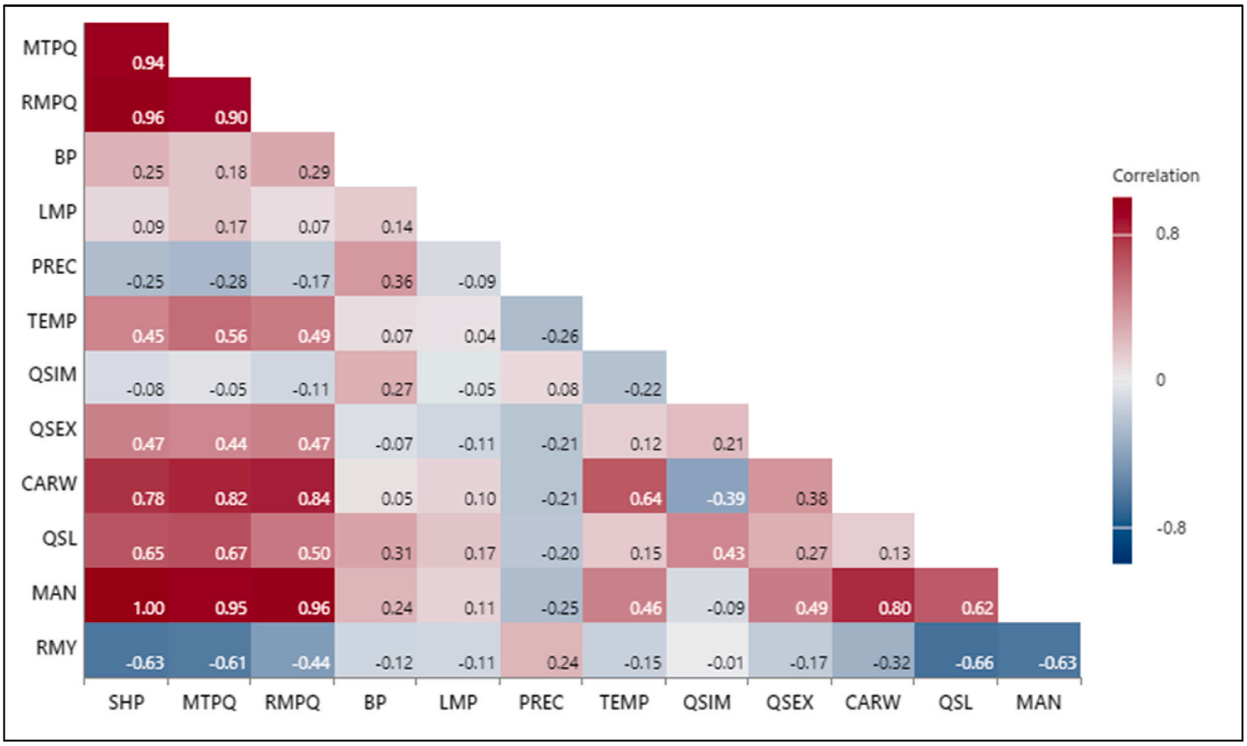

Fig. 1. Pearson correlation heatmap.

2. Materials and methods

2.1. Data and descriptive statistics

The data used in this study are annual time series data from 1961 to 2020. Data on sheep population (heads) (SHP), meat production quantity (tons) (MTPQ), raw milk production quantity (tons) (RMPQ), barley production (tons) (BP), land under meadows and pastures (hectare) (LMP), quantity of sheep imported (heads) (QSIM), quantity of sheep exported (heads) (QSEX), yield/carcass weight (100G/head) (CARW), quantity of slaughtered (heads) (QSL), milk animals (heads) (MAN) and raw milk yield (100G/head) (RMY) are gathered from Food and Agriculture Organization (FAO), while precipitation (mm) (PREC), temperature (C) (TEMP) are extracted from the World Bank [24]. In this study, sheep meat and raw milk production (tons) were the dependent variables, while the other variables were independent. Table 1 presents the descriptive statistics of the data. The trends in all variables from 1961 to 2020 are depicted in Fig. 1 (see the Appendix).

2.2. Model specification

To estimate the factors affecting meat and milk production of Awassi sheep in Syria from 1961 to 2020, this study used the Cobb-Douglas Production Function, which is one of the most commonly used to estimate the input-output relationship [25]. The simplified form of the Cobb–Douglas formula can be written as follows (Equation (1)) [20,26,27]:

$$Q_t = B_1 L_i^{B_2} K_i^{B_2} e^{u_i} \tag{1}$$

where Q = output (meat and raw milk production), L = labor input, K = capital.

This model is nonlinear in the parameters and to convert this function to linear form (Equation (2)), the natural log on both sides of equation (1) is applied:

$$Ln\, Q_t = Ln\, B_1 + B_2\, Ln\, L_i + B_3\, Ln\, K_i + u_i \tag{2}$$

$$= B_0 + B_2\, Ln\, L_i + B_3\, Ln\, K_i + u_i$$

in this study, to analyze the relationship between the dependent and independent variables, the model was specified as follows:

The model estimated for the meat production function is shown in equation (3).

Table 2
Model's estimation results of the factors affecting meat production in Syria.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Ln (BP)	0.001387	0.001156	1.199602	0.2358
Ln (LMP)	−0.014417	0.021804	−0.661214	0.5115
Ln (PREC)	−0.004317	0.003639	−1.186307	0.2410
Ln (TEMP)	−0.017294	0.021528	−0.803324	0.4255
Ln (QSIM)	−0.000670	0.000542	1.509369	0.1374
Ln (QSEX)	0.000695	0.000461	−1.236399	0.2220
Ln (CARW)	0.994029	0.003366	295.3250	0.0000
Ln (QSL)	1.000286	0.001904	525.4152	0.0000
C	−8.994476	0.205043	−43.86623	0.0000
R-squared	0.999942			
Adjusted R-squared	0.999933			
F-statistic	110462.9			
Prob(F-statistic)	0.000000			
Durbin-Watson stat	2.009138			

$$Ln\ (MTPQ_t) = B_0 + B_1\ Ln\ (BP) + B_1\ Ln\ (LMP) + B_1\ Ln\ (PREC) + B_1\ Ln\ (TEMP) + B_1\ Ln\ (QSIM) + B_1\ Ln\ (QSEX) + B_1\ Ln\ (CARW) + B_1\ Ln\ (QSL) + \varepsilon \tag{3}$$

The model estimated for the raw milk production function is shown in equation (4).

$$Ln\ (RMPQ_t) = B_0 + B_1\ Ln\ (BP) + B_1\ Ln\ (LMP) + B_1\ Ln\ (PREC) + B_1\ Ln\ (TEMP) + B_1\ Ln\ (QSIM) + B_1\ Ln\ (QSEX) + B_1\ Ln\ (MAN) + B_1\ Ln\ (RMY) + \varepsilon \tag{4}$$

where: Ln (MTPQ) natural logarithm of meat production quantity; Ln (RMPQ) natural logarithm of raw milk production quantity; Ln (BP) natural logarithm of barley production; Ln (LMP) natural logarithm of land under meadows and pastures; Ln (PREC) natural logarithm of precipitation; Ln (TEMP) natural logarithm of temperature; Ln (QSIM) natural logarithm of quantity of sheep imported; Ln (QSEX) natural logarithm of quantity of sheep exported; Ln (CARW) natural logarithm of carcass weight; Ln (QSL) natural logarithm of quantity of slaughtered; Ln (MAN) natural logarithm of milk animals; Ln (RMY) natural logarithm of raw milk yield. B_0: intercept of the model; $B_{1\text{-}8}$: are the coefficients; ε: error term. Ordinary Least Square (OLS) has been used to estimate the coefficients of the variables.

This model will be subjected to statistical diagnostic tests, namely normality, serial correlation, and heteroskedasticity tests, to ascertain its statistical adequacy. Cumulative sum (CUSUM) and cumulative sum of squared (CUSUMSQ) tests are used to investigate whether the parameters of the model are stable over the study period.

3. Results and discussion

3.1. *The correlation between variables*

Fig. 1 shows a heatmap of the correlation coefficients between all variables used in the study. As shown in Fig. 1, the sheep population has the highest correlation with milk animals, raw milk production quantity, meat production quantity, and carcass weight (r = 1.00, 0.96, 0.94, and 0.78, respectively). Milk animals showed positive correlations with meat production quantity, raw milk production quantity, and carcass weight (r = 0.95, 0.96, and 0.80, respectively). It is also apparent that carcass weight correlated positively with meat production quantity and raw milk production quantity (r = 0.82 and 0.84 respectively). Furthermore, raw milk production quantity and meat production quantity are positively correlated (r = 0.90). Thus, the result showed that the correlation between these variables is more than 0.25, which means that multicollinearity may exist [28]. Multicollinearity is a potential problem in multiple regression analysis [29]. Variance Inflation Factor (VIF) was employed to check for multicollinearity across all variables. If the (VIF) exceeds 10, we can conclude that a collinearity problem exists, and the regression coefficients are poorly estimated [30,31]. The results showed that the (VIF) of each variable was less than 10, except for the sheep population (SHP) variable. Hence, this variable was removed from the estimated models.

3.2. *Results of econometric models*

3.2.1. *Estimated model of meat production function*

The results of the econometric model are reported in Table 2. The results revealed that carcass weight (CARW) and quantity of slaughtered (QSL) have a significant effect on sheep meat production in Syria. Based on the results of this model, other variables have no significant effect on meat production. According to Table 2, carcass weight and quantity of slaughtered had a significant effect at the 0.1 % significance level with positive influence on meat production. The estimated coefficient indicates that if the carcass weight and quantity of slaughtered increase by one percent (1 %), Awassi meat production quantity increases on average by 0.994029 % and 1.000286 % respectively. Similarly, Kibona et al. [20] stated that there is a positive and significant relationship between the beef cattle

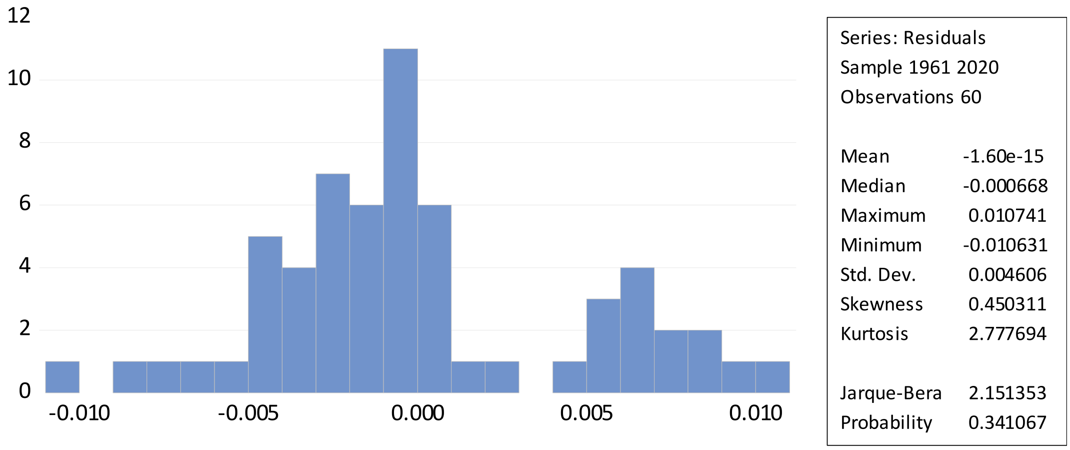

Fig. 2. Jarque–Bera test's results for investigating the normality of meat production.

Table 3
Breusch-Godfrey Serial Correlation LM Test of the meat production model.

F-statistic	1.086755	Prob. F(2,49)	0.3453
Obs*R-squared	2.548400	Prob. Chi-Square(2)	0.2797

Table 4
Heteroskedasticity test of the meat production model.

F-statistic	1.009402	Prob. F (8,51)	0.4408
Obs*R-squared	8.201630	Prob. Chi-Square (8)	0.4140
Scaled explained SS	5.267020	Prob. Chi-Square (8)	0.7287

yield (carcass weight per head), slaughtered beef cattle (heads), and beef meat output in Tanzania. However, the other independent variables did not significantly affect the Awassi meat production quantity. According to Table 2 results, land under meadows and pastures (LMP), precipitation (PREC), temperature (TEMP), and quantity of sheep imported (QSIM) had a negative and insignificant impact on meat production quantity in the model.

This may be because the pastures in Syria are distributed in the *Al-Badia* (in Arabic) region, which is located in the arid and semi-arid regions, and this region is characterized by fluctuations in rainfall and temperatures. Also, in most years, rainfall rates are less than average, in addition to the length of drought periods, which negatively affects pasture productivity [13,32]. The negative effect of precipitation can be attributed to the fact that it improves the conditions for raising sheep (availability of pastures and water), therefore, there is no need to sell the sheep to secure their needs for fodder and water [33]. Syria has suffered from a noticeable rise in temperatures and frequent heat waves in recent years [34]. Many studies have indicated that high temperatures make animals vulnerable to heat stress, which negatively affects growth and the production of meat [35–37]. Castillo et al. [38] reported that there is a negative relationship between temperature and sheep production. Further to these, the quantity of sheep imported (QSIM) is also negative. However, the amount of the effect of this variable is negligible (−0.000670) and may be omitted.

It is observed that the normality test of the meat production model's error terms is reasonable. The Jarque– Bera statistic value is equal to 2.15 which is less than 5.99 ($p > 0.05$) (Fig. 2). This gives evidence to accept the null hypothesis (H_0) that the regression errors are normally distributed.

Breusch-Godfrey LM test is implemented to examine the autocorrelation of the error terms. The null hypothesis (H_0) is, there is no serial correlation [39]. Table 3 shows that the probability of F-statistic was 0.3453 ($p > 0.05$), so we can accept the null hypothesis.

To test for heteroskedasticity, the Breusch-Pagan-Godfrey test is used. As shown in Table 4, the probability of F-statistic was 0.4408 ($p > 0.05$). Therefore, we accept (H_0) (Homoskedasticity), which indicates that heteroscedasticity is not present in the data.

The results from the meat production function presented in Table 2 show that the R-squared and adjusted R-squared values of the model were 0.999942 and 0.999933, respectively, suggesting that the goodness-of-fit between the data and their predicted values was

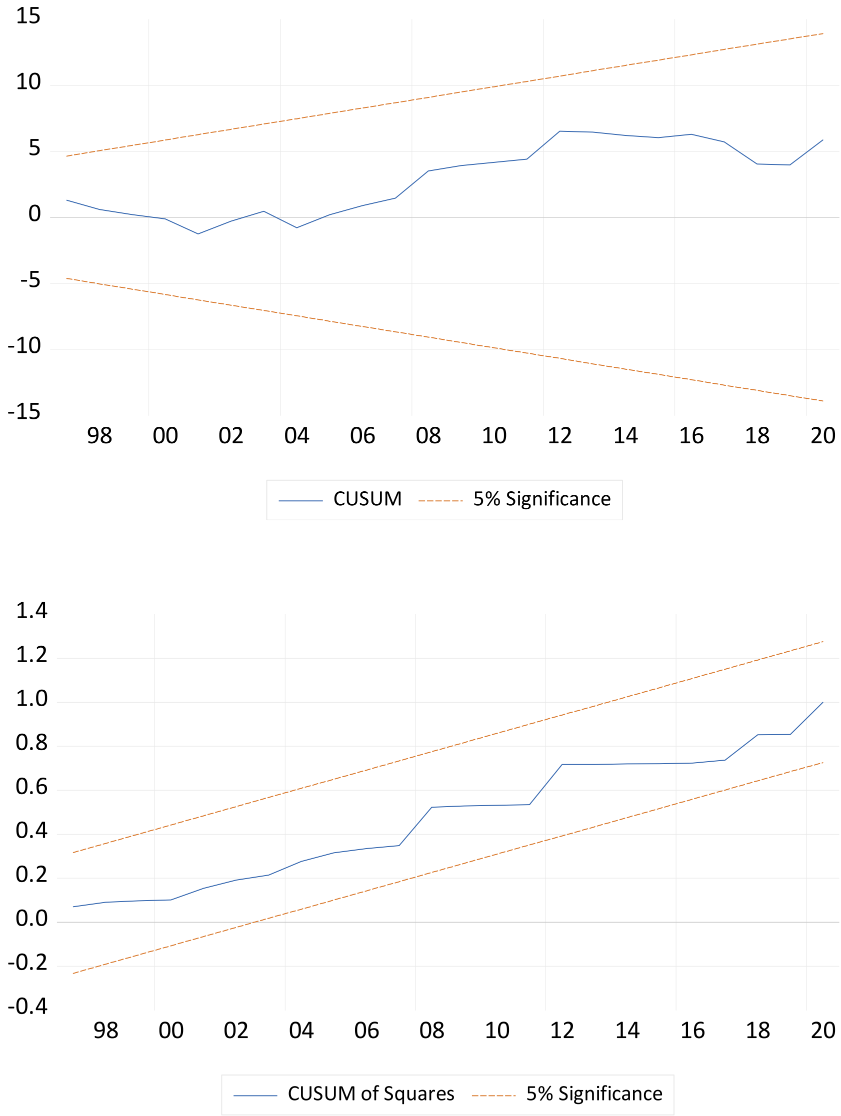

Fig. 3. Stability of meat production function model.

Table 5
Model's estimation results of the factors affecting milk production in Syria.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Ln (BP)	0.001566	0.001028	1.522979	0.1339
Ln (LMP)	0.004757	0.016815	0.282926	0.7784
Ln (PREC)	−0.007822	0.002906	−2.692068	0.0096
Ln (TEMP)	−0.040819	0.016193	−2.520781	0.0149
Ln (QSIM)	2.03E-06	0.000359	0.005663	0.9955
Ln (QSEX)	0.000494	0.000358	1.381462	0.1732
Ln (RMY)	0.998537	0.003993	250.0431	0.0000
Ln (MAN)	0.998905	0.001994	500.9815	0.0000
C	−9.090241	0.161968	−56.12362	0.0000
R-squared	0.999929			
Adjusted R-squared	0.999917			
F-statistic	89210.12			
Prob(F-statistic)	0.000000			
Durbin-Watson stat	2.390850			

Table 6
Breusch-Godfrey Serial Correlation LM test of the milk production model.

F-statistic	1.136259	Prob. F(2,49)	0.3293
Obs*R-squared	2.659341	Prob. Chi-Square(2)	0.2646

Table 7
Heteroskedasticity test of the milk production model.

F-statistic	0.635581	Prob. F (8,51)	0.7441
Obs*R-squared	5.439618	Prob. Chi-Square (8)	0.7097
Scaled explained SS	6.539079	Prob. Chi-Square (8)	0.5871

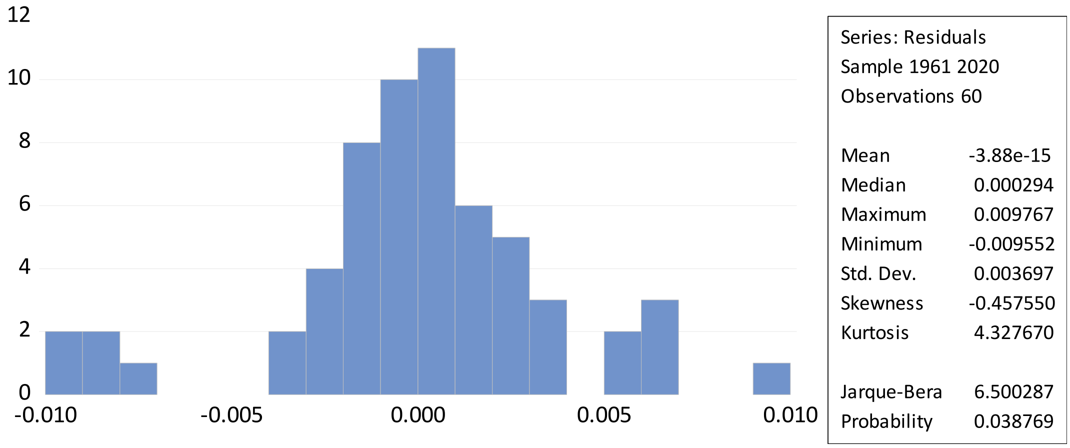

Fig. 4. Jarque–Bera test's results for investigating the normality of milk production.

high [40]. This result is consistent with that of Kibona et al. [20], who also found high R-squared (0.996) and adjusted R-squared (0.995) values. In addition, cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUM squares) plots were employed to test the model's stability (Fig. 3). The tests showed that the model was stable throughout the study period.

3.2.2. Estimated model of milk production function

The relationship between raw milk production in Syria and barley production (BP), land under meadows and pastures (LMP), precipitation (PREC), temperature (TEMP), the number of sheep imported (QSIM), quantity of sheep exported (QSEX), milk animals (MAN), and raw milk yield were also examined. The results of the model are presented in Table 5. As illustrated, changes in precipitation, temperature, raw milk yield, and milk animals affect the quantity of raw milk produced. However, the other independent variables did not significantly affect raw milk production. The effects of precipitation, temperature, raw milk yield, and milk animals were −0.007822, −0.040819, 0.998537, and 0.998905, respectively. The positive effect indicates that if the raw milk yield and milk animals increase by one percent (1 %), raw milk production increases on average by 0.998537 % and 0.998905 % respectively.

The results have shown that there is a negative and significant correlation between the climatic variables (precipitation and temperature) and raw milk production. This suggests that at a one percent (1 %) increase in temperature, raw milk production decreases by −0.040819 %. According to Gowane et al. [3] and Biswal et al. [41], there is a high negative relationship between milk production and temperature. Exposure to high ambient temperatures reduces productivity and welfare of animals. Heat stress caused by high temperatures also increases the mortality rate and reduces feed intake, leading to a decrease in growth rates and milk production [42].

Precipitation has a minor adverse impact on milk production. A one percent (1 %) increase in precipitation reduced milk production by −0.007822 %. This negative impact is due to the fluctuating and irregular nature of rainfall in the *Al-Badia* region, where sheep farming is concentrated. Thornton et al. [36] argue that increased rainfall variability and seasonal runoff changes negatively

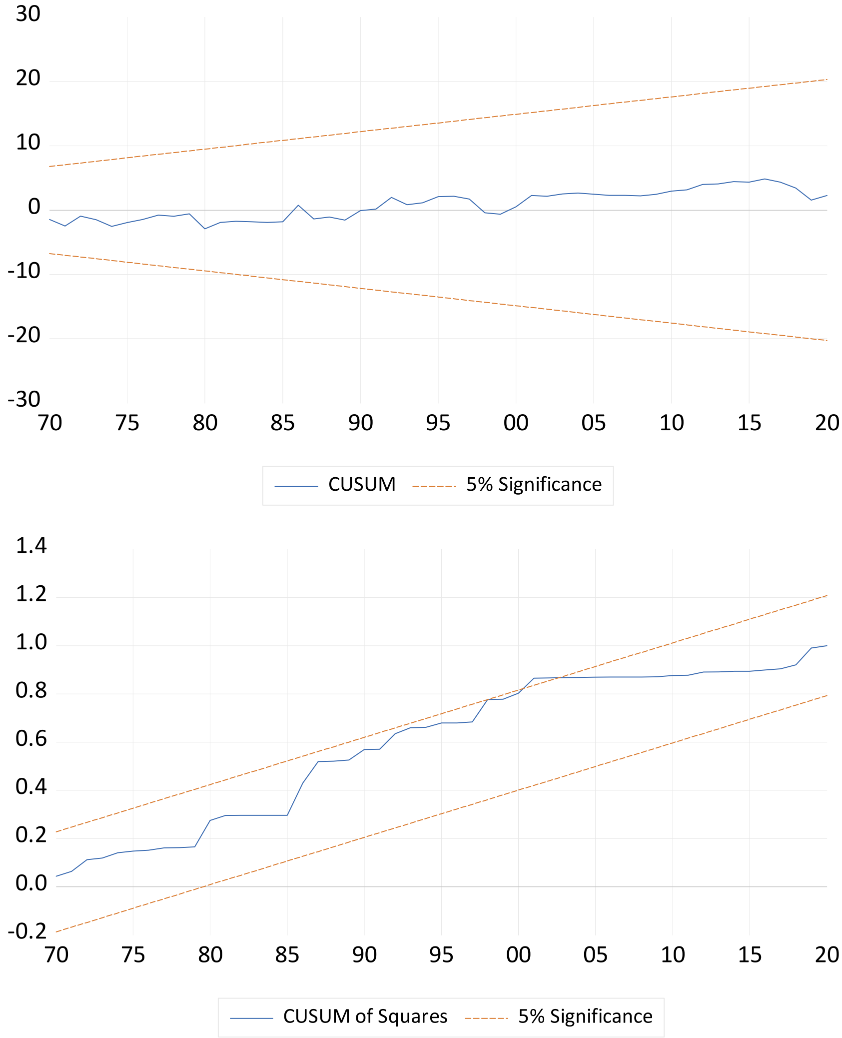

Fig. 5. Stability of milk production function model.

affect water supply, water quality, and flood risk, thus mitigating the beneficial effects of increased precipitation.

The diagnostic test results indicate that the model is free of any serial correlation error term and heteroscedasticity. Since the *p*-values of the Breusch-Godfrey Serial Correlation LM and Breusch-Pagan-Godfrey test are above 5 % (Tables 6 and 7). The Jarque–Bera test or normality value is 6.50 with a *p*-value of 0.038769 (Fig. 4). We reject the null hypothesis that the regression errors are normally distributed. This result does not affect the accuracy of the model; Hill et al. [40] pointed out that the normal distribution of the residuals in linear regression models estimated by the OLS method is only a sufficient condition and is an optional assumption.

The stability of the milk production model was evaluated. Fig. 5 shows that the model is stable because both the CUSUM and CUSUM of squares are within the boundary lines. This demonstrates that the coefficients predicted by the model were stable.

4. Study limitation

This study aimed to identify the factors affecting meat and milk production in Awassi sheep in Syria. Theoretically, the supply of meat and milk is a function of the price. Breeders' decisions regarding the quantity of meat and milk produced also depend on expected prices [23]. There is a lack of data on prices. Price data for sheep meat and milk were available only for the period (1991–2012, 2015–2017) and (1993, 2003–2012, 2015–2017) respectively. Therefore, we could not examine the effects of price on meat and milk production. There is a lack of empirical work or literature on some independent variables affecting meat and milk production (e.g., medication cost and relative humidity). In addition, data availability for these variables was limited.

5. Conclusions and policy implications

Sheep farming plays an important role in the Syrian economy as it provides protein for local consumption, provides job opportunities, and contributes to increased farm income, especially in *Al-Badia*. Additionally, it is an important export commodity [19]. The estimation results of this study revealed that Awassi meat production in Syria is positively influenced by carcass weight and quantity of slaughtered sheep. The results also showed that raw milk yield and milk animals had a positive impact on the quantity of milk produced, whereas climate factors (precipitation and temperature) negatively influenced sheep milk production. This result sheds light on the policies and procedures that the government should implement to develop sheep production in Syria. Therefore, genetic improvement of Awassi sheep through breeding programs and crossing with other strains will help enhance meat, milk, and/or wool production. More efforts should be focused on increasing the prolificacy and growth rate. Considering that natural pastures in the *Al-Badia* region are among the most important sources of grazing, special actions should be implemented by the government to improve the grazing potential and protect natural pastures. Furthermore, in dry seasons, support should be provided to enable breeders to maintain their herds by increasing feed rations or providing loans to breeders for purchasing feed.

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Additional information

No additional information is available for this paper.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Naji Khames AlFraj: Writing – review & editing, Writing – original draft, Software, Resources, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

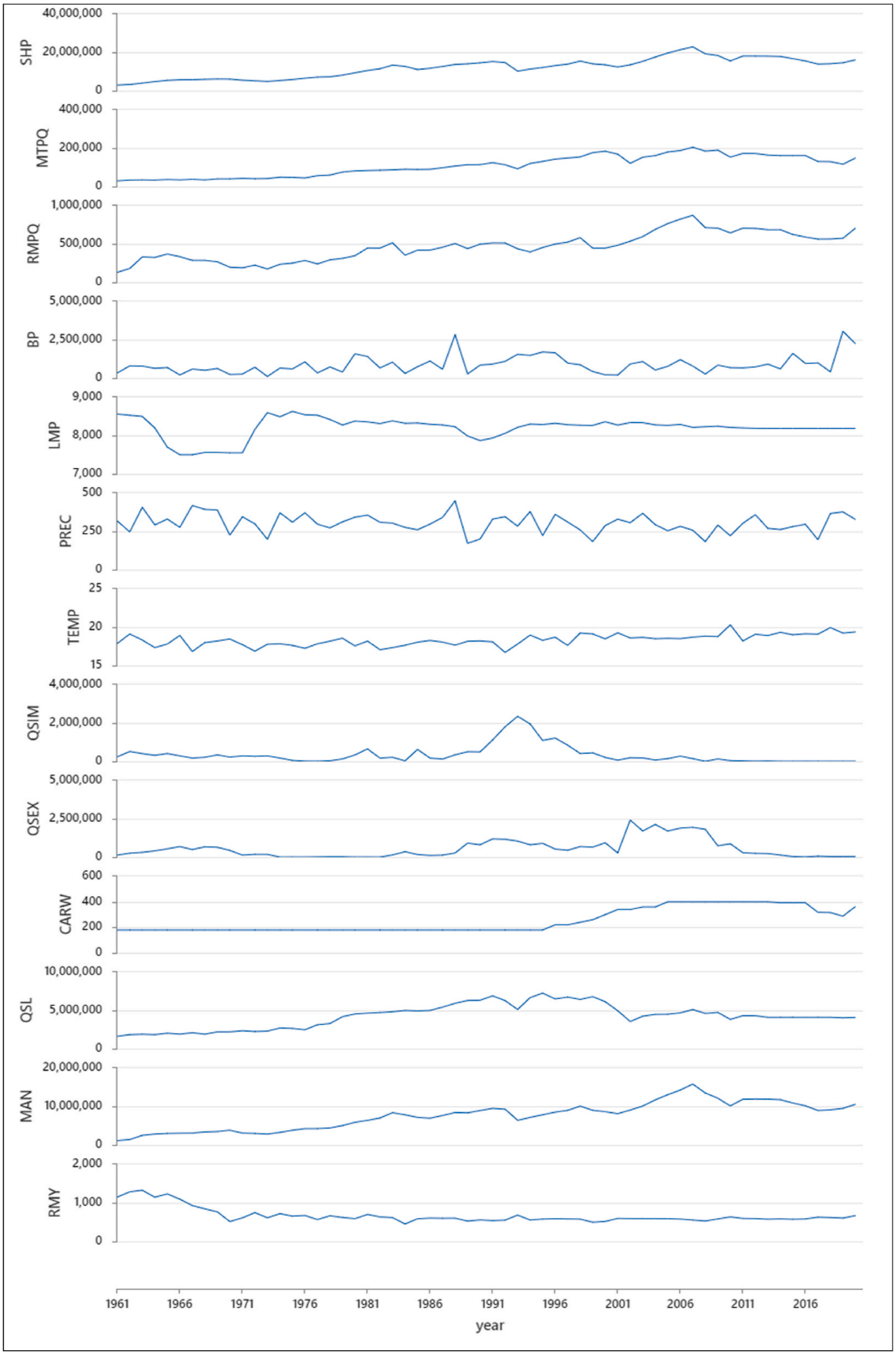

Fig. 1. The trend in all variables from 1961 to 2020.

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