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Impacts of Production Capacity, FCR, and Capacity Utilization on Broiler Production Costs in different climatic regions of Iran

Mohammad Amin GholamAzad[1], Amir Hossein Chizari[1]*, and Vahideh Ansari[1]

Abstract

Population growth in developing countries, along with the rise of food insecurity and increasing pressure on limited resources, has increased the demand for affordable protein sources, particularly chicken meat. However, the rise in production expenses and economic fluctuations has created serious challenges for the cost of broiler production. In this context, identifying the determinants of the cost of broiler production is of great importance. This study investigates the effects of production capacity, feed conversion ratio (FCR), capacity utilization, and climatic conditions on the cost of broiler production in Iran. The dataset was obtained from the National Statistical Center of Iran and includes information on 4,643 broiler farms located in major producing provinces in 2015 and 2020. After data cleaning and outlier removal, variables including production capacity, climate, FCR, capacity utilization, end-of-period chicken ratio, ownership structure, energy consumption, and hatching frequency were analyzed using a cross-sectional model for 2020 and a pooled regression model for 2015 and 2020, with robust regression estimation. The results showed that production capacity, capacity utilization, end-of-period chicken ratio, and hatching frequency had negative and significant effects on the cost of broiler production, whereas FCR and energy consumption increased it. The findings also indicated that the cost of broiler production was significantly lower in humid regions than in arid, semi-arid, and moderate regions. Therefore, it is recommended that productivity evaluation should rely on performance-based indicators rather than nominal capacity alone. Moreover, support policies should be designed based on climatic conditions, effective capacity utilization, FCR improvement, flock survival, and energy management in broiler production units.

Keywords: Economies of Scale, FCR, Iran Poultry Industry, Interaction Terms, Robust regression.

Introduction

The livestock and poultry sector, as a key pillar of Iranian agriculture, accounts for approximately 31 percent of the sector's value added and 4.5 percent of national GDP (Statistical Center of Iran,

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[1] Department of Agricultural Economics, Faculty of Agriculture, University of Tehran, Karaj, Alborz, Islamic Republic of Iran.
* Corresponding author; e-mail: chizari8000@ut.ac.ir

2020). In addition, 25 to 30 percent of agricultural workers are directly employed in this sector, highlighting its role in employment generation, particularly in rural areas. From a food-security perspective, livestock products provide more than 45% of the country's protein needs, with chicken meat playing a major role because of its relatively affordable price (FAO, 2021). The sector also contributes to non-oil exports, as products such as frozen chicken meat, eggs, and dairy products account for a significant share of Iran's agricultural trade balance (Hosseini et al., 2022). Therefore, improving productivity and optimizing resource management in this sector can contribute to economic growth, market stabilization, and strengthened food security (Sarwar, 2025).

The rising cost of broiler production has become a critical challenge for Iran's poultry industry, affecting profitability, production continuity, food security, consumer welfare, and support-policy burdens (Mohammadi-Nasrabadi et al., 2023). This pressure is largely driven by dependence on imported feed ingredients, particularly corn and soybean meal, which exposes production costs to exchange-rate volatility and global market shocks (Bigzadeh et al., 2021); although feed and day-old chicks are established cost components (Qaderzadeh and Alizadeh, 2021), recent market instability and the sharp increase in soybean meal prices require updated farm-level reassessment (Shabanzadeh-Khoshrody et al., 2022; Liu et al., 2025; Gren et al., 2024; State Livestock Affairs Logistics Company, 2023). Beyond input-price volatility, broiler unit costs are shaped by biological efficiency, capacity-related factors, management practices, feed-use efficiency, economies of scale, capacity utilization, climatic constraints, FCR, and energy-related climate pressures (Machmuddin et al., 2024; Duffy, 2009; Khan et al., 2022; Marmelstein et al., 2024; Prakash et al., 2020; Ramukhithi et al., 2023; Adaszyńska-Skwirzyńska et al., 2025; Safi et al., 2022; Ukita et al., 2025; Tavares de Oliveira et al., 2025; Yusuf et al., 2016; Biswal et al., 2022). However, despite the commercialization, capital intensity, expansion, and spatial heterogeneity of Iran's broiler industry (Moghaddisi and Yousefi, 2011; Pishbahar et al., 2015; Ministry of Agricultural Jihad, 2020; Statistical Center of Iran, 2020; Ministry of Agriculture Jihad, 2020), the joint effects of production capacity, FCR, capacity utilization, and climate remain underexplored; therefore, this study examines these factors jointly across Iran's climatic regions.

Previous studies have examined broiler production costs through external shocks, input composition, feed efficiency, scale, climate, and farm management. Value-chain research shows that COVID-19, supply-chain disruptions, input-market volatility, and reliance on imported feed increased cost pressures and exposed poultry-chain vulnerabilities (Belarmino et al., 2023; Rad et al., 2021; Ijaz et al., 2021; Aslam et al., 2020), yet it provides limited farm-level evidence on cost differences across producers. Cost-composition studies identify feed, day-old chicks, and labor as major cost components (Mansour and Al-Sabai, 2020; Kamrozaman et al., 2021), but often overlook the dynamic roles of technical efficiency, production capacity, and capacity utilization. Efficiency and scale studies show that higher FCR raises feed use and production costs (Prakash et al., 2020; Willems et al., 2013), while small and medium farms face higher costs and managerial constraints, and larger farms may benefit from economies of scale (Ali et al., 2015; Chiekezie et al., 2022; Mohammadi, 2023; Shin et al., 2015; Al-Fawaz and Mafraq, 2013; Najafi et al., 2012). However, these studies rarely distinguish nominal production capacity from effective capacity utilization. Climatic evidence also indicates that temperature, humidity, rainfall variability, stocking density, and electricity use affect productivity, mortality, energy demand, and economic performance (Oke et al., 2024; Osuji et al., 2024; Gholami et al., 2020; Liang and Costello, 2024). Overall, the literature remains fragmented; therefore, this study jointly examines production capacity, FCR, effective capacity utilization, and climatic conditions within a farm-level cost framework across Iran's major broiler-producing provinces.

Therefore, this study aims to estimate the farm-level determinants of broiler production costs in Iran, with particular emphasis on production capacity, feed conversion ratio (FCR), capacity utilization, and climatic conditions. Unlike previous studies that have mostly examined input costs, scale, efficiency, or climate separately, this research analyzes these factors jointly to explain variations in the cost of producing one kilogram of live broiler chicken across different climatic regions. For this purpose, farm-level data from the Statistical Center of Iran for 2015 and 2020 are used, covering broiler farms in 17 major producing provinces. The study applies robust regression models to provide updated empirical evidence on how scale, production efficiency, and regional climatic heterogeneity shape broiler production costs in Iran.

Materials and Methods

Data Source and Study Design

This study is an applied quantitative study based on farm-level secondary data from broiler farms in 17 major producing provinces of Iran. The data were obtained from the Statistical Center of Iran for the census years 2015 and 2020. These years were selected because they provide the available national farm-level datasets and allow comparison of the cost structure of broiler production at two points in time. The final dataset included 4,643 broiler farms, consisting of 2,171 farms in 2015 and 2,472 farms in 2020. The unit of observation was the individual broiler farm, and the dependent variable was the cost of broiler production per kilogram of live broiler chicken, measured in Rials/kg. The empirical analysis was conducted in two stages. First, two cross-sectional models were estimated using the 2020 data: one including climatic dummies and another replacing them with provincial dummies to capture regional differences. Second, the 2015 and 2020 observations were combined in a two-year aggregated regression model with a 2020 dummy variable. This specification was not treated as a panel model, because the same farms were not followed over time; rather, it was used to compare cost structures between the two census years within a combined cross-sectional framework.

Cost Calculation and Dependent Variable

The dependent variable is the cost of broiler production per kilogram of live broiler chicken (CP_i), measured in Rials/kg. It represents the average economic cost incurred by farm i to produce one kilogram of marketable live broiler output. CP_i was calculated by dividing each farm’s total cost of broiler production by the actual live weight produced at the end of the production period. This unit-cost measure allows comparisons across farms with different capacities, flock sizes, production cycles, and output levels, making it a comparable indicator across provinces, climatic zones, and production scales (UNSIAP, 2018; Beal et al., 2023; Chibanda et al., 2022).

The total cost of broiler production was classified into variable and fixed costs, in line with enterprise-budgeting principles, rather than being divided into direct and indirect costs. Variable costs included day-old chicks (BC_i), feed (FC_i), medicine and supplements (VC_i), energy (EC_i), technical services, and other current production costs (OC_i). Fixed costs included labor costs (LC_i) and the rental cost or imputed rental value of production halls (RC_i). Labor was treated as a fixed cost because workers in broiler farms are commonly paid under monthly or annual employment arrangements, regardless of short-term changes in production volume. These components were included because recent broiler cost studies identify feed, chicks, labor, housing-related expenses, energy, and health-related inputs as major determinants of farm-level cost of broiler production (Beal et al., 2023; Adaszyńska-Skwirzyńska et al., 2025). Input costs were obtained from the farm-level records of the Statistical Center of Iran. When quantities and prices were reported separately, costs were calculated by multiplying quantity by unit price; when only expenditure values were available, the recorded expenditure was used directly. This procedure is consistent with agricultural cost-of-production methods based on farm-reported quantities, prices, and expenditures (UNSIAP, 2018). For owner-operated production halls, the opportunity cost of rent (RC_i) was included when no explicit rental payment was reported, because economic cost analysis should account for both explicit expenses and the implicit opportunity costs of owned production factors (Špička and Dereník, 2021). The imputed rent was estimated based on the prevailing rental value of comparable broiler halls in the same locality and production year, using survey information and local market conditions. This market-based valuation is consistent with cost-of-production approaches for internally supplied resources (Canfax Research Services, 2022). Thus, rented and owner-operated farms were assessed on a comparable economic-cost basis.

The cost of production per kilogram of live broiler chicken was computed using Equation (1):

$$CP_i = \frac{BC_i+FC_i+LC_i+OC_i+RC_i+VC_i+EC_i}{Q_i} \quad (1)$$

Where Q_i denotes the actual live weight of broilers produced by farm i at the end of the production period.

Variables and Expected Signs

The explanatory variables were selected based on the cost-function framework of agricultural production and evidence on broiler production efficiency. The cost of broiler production per kilogram was assumed to be influenced by scale economies, feed-use efficiency, capacity utilization, flock survival, energy intensity, ownership structure, and climatic conditions. Production capacity (CS_i) and its squared term (CS_i^2) were included to capture possible nonlinear scale effects, whereby cost reductions may diminish beyond an efficient scale (Khan et al., 2022; Marmelstein et al., 2024). Feed conversion ratio (FCR_i) was expected to increase the cost of broiler production, as a higher FCR indicates greater feed use per kilogram of live weight and lower feed-use efficiency (Ramukhithi et al., 2023; Marmelstein et al., 2024; Adaszyńska-Skwirzyńska et al., 2025). Capacity utilization (SNC_i), end-of-period chicken survival ($dSQB_i$), and hatching frequency (dNP_i) were expected to reduce the cost of broiler production per kilogram by increasing effective output, improving flock performance, and spreading fixed and semi-fixed costs over a larger production volume (Khan et al., 2022; Van Limbergen et al., 2020; Adaszyńska-Skwirzyńska et al., 2025). Energy intensity ($dENE_i$), measured as energy cost per unit of production hall area, was expected to increase the cost of broiler production because it reflects higher heating, cooling, ventilation, and lighting requirements (Li et al., 2022; Liang and Costello, 2024). Ownership type ($dOWN_i$) was included as a control variable with no predetermined sign, since its effect may operate through management incentives, input access, credit conditions, and accounting practices (Khan et al., 2022; Ramukhithi et al., 2023). Climatic conditions were represented by arid (CL_1), semi-arid (CL_2), and moderate (CL_3) dummy variables, with humid climate as the reference category; positive coefficients were expected because less favorable climates may increase heat stress, mortality risk, water demand, energy use, and ventilation requirements (Oke et al., 2024; Attia et al., 2024). Finally, capacity–climate interaction terms ($CS_i \times CL_j$) were included to test whether the scale effect of capacity differs across climatic zones (Li et al., 2022; Liang and Costello, 2024). In the two-year aggregated model, a dummy variable for 2020 was also included to capture cost differences between the two census years.

Table 1. summarizes the definition, measurement, and expected signs of the explanatory variables used in the models.

Table 1. Definition of explanatory variables and expected signs.

Variable	Symbol	Definition / Measurement	Expected sign
Production capacity	CS_i	Nominal capacity of farm i, measured by number of birds	-
Production capacity squared	CS_i^2	Squared term of production capacity	+
Feed conversion ratio	FCR_i	Feed required to produce one unit of live weight	+
Capacity utilization rate	SNC_i	Ratio of actual production use to nominal capacity adjusted by annual cycles	-
End-of-period chicken survival	$dSQB_i$	Ratio of surviving chickens at the end of the cycle to total chicks placed	-
Hatching frequency	dNP_i	1 if more than five hatching cycles per year; 0 otherwise	-
Energy intensity	$dENE_i$	1 if energy cost per unit area exceeds 1.5 million rials; 0 otherwise	+
Ownership type	$dOWN_i$	1 for individual/private ownership; 0 otherwise	Ambiguous
Arid climate	CL_1	1 if farm is located in an arid region; 0 otherwise	+
Semi-arid climate	CL_2	1 if farm is located in a semi-arid region; 0 otherwise	+
Moderate climate	CL_3	1 if farm is located in a moderate region; 0 otherwise	lower than dry regions
Capacity × climate	$CS_i \times CL_j$	Interaction between production capacity and climate dummies	Conditional
Year dummy	$Year\ 2020_i$	1 for 2020 observations; 0 for 2015 observations	+

Model Specification

The general form of the cost of production function, considering the climate effect for 2020, is defined as equation (2):

$$CP_i = \beta_0 + \beta_1.CS_i + \beta_2.FCR_i + \beta_3.SNC_i + \beta_4(CS_i)^2 + \lambda_1.dNP_i + \lambda_2.dENE_i + \lambda_3.dSQB_i + \lambda_4.dOWN_i + \sum_{j=1}^{3}\gamma_j\,CL_j + \sum_{j=1}^{3}\theta_{ij}(CS_i)(CL_j) + \varepsilon \qquad (2)$$

The coefficients β_1 to β_4 measure the effects of the main continuous production variables. The coefficients λ_1 to λ_4 capture the effects of management and structural dummy variables. The coefficients γ_j measure the cost differences of climatic regions relative to the humid reference category. The coefficients θ_{ij} capture the climate-specific marginal effect of production capacity, and ε is the random error term.

The second model combined the 2015 and 2020 observations in a two-year aggregated regression model. This specification was not treated as a panel model, because the same farms were not followed over time. A dummy variable for 2020 was included to capture the difference in cost structure between the two census years:

$$lnCP_i = \beta_0 + \beta_1.lnCS_i + \beta_2.lnFCR_i + \beta_3.ln\mathrm{SNC}_i + \beta_4(\mathrm{C}S_i)^2 + \sum_{j=1}^{3}\gamma_j CL_j + \lambda_1.\mathrm{dN}P_i + \lambda_2.\mathrm{dEN}E_i + \lambda_3.\mathrm{dSQ}B_i + \lambda_4.\mathrm{dOW}N_i + \alpha_i\mathrm{year2020}_i + \phi_i(\mathrm{C}S_i)(\mathrm{year2020}_i) + \sum_{j=1}^{3}\theta_{ij}(CS_i)(CL_j) \qquad (3)$$

In Equation (4), ϕ_i measures the average difference in production cost between 2020 and 2015, while rho captures whether the capacity effect changed in 2020. The logarithmic form was used for the selected continuous variables in this model to improve comparability and allow proportional interpretation.

The optimal production capacity was derived from the quadratic cost specification by taking the first derivative of Equation (2) with respect to $\mathrm{C}S_i$ and setting it equal to zero. This approach follows the standard interpretation of turning points in quadratic econometric cost functions (Wooldridge, 2010; Duffy, 2009):

$$CS_i{}^* = -\frac{\beta_1 + \sum_{j=1}^{3}\theta_{ij}(CL_j)}{2\beta_4} \qquad (4)$$

All econometric estimations and diagnostic tests were conducted using Stata software, which is widely applied in empirical econometric studies due to its integrated procedures for cross-sectional and Aggregated Regression analysis, robust standard errors, heteroskedasticity testing, multicollinearity diagnostics, and post-estimation analysis (Cameron and Trivedi, 2005; Wooldridge, 2010).

Results and Discussion

Descriptive Statistics and Climate-Based Cost Differences

Table 2 reports the descriptive statistics of the main variables used in the empirical models for 2015 and 2020. The mean production cost increased from 52,717 Rials/kg in 2015 to 87,761 Rials/kg in 2020, indicating a substantial rise in the unit cost of broiler production between the two census years. Mean production quantity also increased from 240 tons to 312 tons, while average production capacity remained relatively stable, decreasing slightly from 31,463 to 30,565 birds. The mean feed conversion ratio declined from 2.08 in 2015 to 1.99 in 2020, whereas the average capacity utilization rate decreased from 0.76 to 0.74. The end-of-period chicken ratio also showed a slight decline, from 0.88 in 2015 to 0.86 in 2020.

Table 2. Descriptive statistics of the main variables used in the study, 2015 and 2020.

Year	Variable	Unit	Min	Max	Mean	Standard Deviation
2015	Production cost	Rial/kg	24,499	106,885	52,717	19,234
	Production quantity	Ton	0	5,344	240	341.50
	Production capacity	Bird	700	513,000	31,463	33,878
	Feed conversion ratio	Ratio	1.50	4.50	2.08	0.06
	Capacity utilization rate	Ratio	0.00	1.20	0.76	0.17
	End-of-period chicken ratio to total chicks placed	Ratio	0.00	1.00	0.88	0.19
2020	Production cost	Rial/kg	52,137	137,480	87,761	21,110
	Production quantity	Ton	5	3,177	312	339
	Production capacity	Bird	2,500	300,000	30,565	31,059
	Feed conversion ratio	Ratio	1.00	4.00	1.99	0.41
	Capacity utilization rate	Ratio	0.05	1.00	0.74	0.14
	End-of-period chicken ratio to total chicks placed	Ratio	0.00	1.00	0.86	0.14

Table 3 presents the average broiler production cost across climatic regions in 2020. The results show clear differences in average production costs among climatic zones. The highest average cost was observed in arid regions, followed by semi-arid and moderate regions, while humid regions recorded the lowest average production cost. To examine whether these differences were statistically significant, Welch's one-way ANOVA was applied. The test confirmed a statistically significant difference in mean production costs across climatic regions, Welch's F(3, 1012.71)= 76.19, $p < 0.001$. This result indicates that the observed variation in average production costs across climatic regions is statistically meaningful rather than random.

Table 3. Calculation of Average Broiler Production Costs in Different Climatic Areas of Iran in 2020.

Climate	Dry	Semi-dry	Moderate	Humid
Cost of production (Rials)	86700	85000	82000	63500

Source: Research findings

Climate-Based Regression Results for 2020

Table 4 reports the results of the climate-based regression model for broiler production cost in 2020. The results show that production cost is affected by a combination of scale, technical efficiency, capacity use, flock performance, energy intensity, and climatic conditions. Feed conversion ratio had a positive and statistically significant coefficient, indicating that farms with lower feed-use efficiency faced higher unit production costs. By contrast, capacity utilization, hatching frequency, and end-of-period chicken survival showed negative and significant effects, suggesting that farms with more effective use of installed capacity, more frequent production cycles, and lower mortality were able to reduce the cost per kilogram of live broiler output. Energy intensity had a positive and significant coefficient, confirming that higher energy cost per unit of production hall area increases production cost, while ownership type was not statistically significant after controlling for technical, managerial, and climatic factors.

The estimated coefficients for production capacity and its squared term indicate a nonlinear relationship between capacity and unit cost. The negative coefficient of capacity shows that increasing production scale reduces average cost, whereas the positive coefficient of the squared term suggests that this cost-reducing effect weakens beyond an efficient scale. Based on the estimated quadratic specification, the minimum-cost capacity was approximately 100,934 birds. This result implies that capacity expansion should not be evaluated only in nominal terms; rather, it should be considered alongside actual utilization, flock survival, feed efficiency, and energy performance. The climate dummy variables were positive and statistically significant relative to the humid reference category, indicating that arid, semi-arid, and moderate regions had higher production costs than humid regions. In addition, the significant capacity–climate interaction terms show that the cost effect of production capacity differs across climatic zones. Overall, the climate-based model suggests that cost control in broiler production depends not only on increasing production scale, but also on improving performance-oriented indicators, particularly FCR, capacity utilization, survival rate, hatching frequency, and energy efficiency.

Table 4. Results from the model estimation of the effect of capacity on the cost of production in different climatic zones.

Variable	Estimated coefficient	Standard error	t-statistic	Significance level (P>|t|)
Feed to meat conversion rate	26034.2	2042.136	12.75	0.0
Capacity utilization rate	-49686.05	8936.745	-5.56	0.0
Capacity	-0.2094813	0.0621584	-3.37	0.001
Capacity Squared	1.04e-06	2.15e-07	4.82	0.0
Ownership method	740.6667	1252.774	0.59	0.554
Energy consumption per unit area	3954.886	1532.899	2.58	0.01
Hatching frequency	-10856.99	1411.507	-7.69	0.0
Ratio of end-of-period chickens to total hatching	-20165.815	1720.242	-11.72	0.0
Arid climate	22400.24	3493.617	6.41	0.0
Semi-arid climate	36910.97	3629.618	10.17	0.0
Moderate climate	19692.89	3555.045	5.54	0.0
Interaction of capacity with arid climate	-0.1313203	0.0465206	-2.82	0.005
Interaction of capacity with semi-arid climate	-0.2267534	0.0577342	-3.93	0.0
Interaction of capacity with moderate climate	-0.1130217	0.0483343	-2.34	0.019
Intercept	64299.44	10308.15	6.24	0.0

Source: Research findings

Diagnostic tests were conducted to assess the reliability of the estimated models. In the climate-based model, the VIF for all variable was under 5, indicating no serious multicollinearity among the main explanatory variables, although the capacity–climate interaction term showed a higher VIF due to its composite structure. The initial White test indicated heteroscedasticity, but after outlier treatment and the use of robust standard errors, the final model produced more reliable coefficient estimates. The Jarque–Bera test also supported the normality of residuals. The model was statistically significant overall, F = 136.28, $p < 0.001$, and explained about 41% of the variation in broiler production cost.

Two-Year Aggregated Regression Results

Table 5 presents the results of the two-year aggregated regression model, in which the 2015 and 2020 observations were combined to examine changes in the cost structure between the two census years. The results are generally consistent with the 2020 cross-sectional findings and show that broiler production cost is jointly affected by feed efficiency, capacity use, production scale, flock performance, energy intensity, climatic conditions, and time-specific changes. The logarithm of feed conversion ratio had a positive and statistically significant coefficient, indicating that lower feed-use efficiency was associated with higher production cost. In contrast, the logarithms of capacity utilization and production capacity were negative and significant, showing that farms with better use of installed capacity and larger production scale tended to operate at lower unit costs. The positive and significant coefficient of the squared capacity term also confirms that the relationship between capacity and cost is nonlinear.

The performance-related variables retained their expected effects in the two-year model. Hatching frequency and the end-of-period chicken ratio had negative and significant coefficients, suggesting that more intensive annual use of production facilities and higher flock survival were associated with lower production costs. Energy intensity, on the other hand, had a positive and significant effect, confirming that higher energy cost per unit of production area increased unit cost. Ownership type remained statistically insignificant, indicating that ownership structure did not independently explain cost variation after controlling for technical, climatic, and production-related factors. The dummy variable for 2020 was positive and highly significant, showing that production costs were considerably higher in 2020 than in 2015, even after controlling for the other explanatory variables. In addition, the climate dummies were positive and significant relative to the humid reference category, indicating that arid, semi-arid, and moderate regions had higher costs than humid regions. The capacity–climate interaction terms suggest that the cost effect of capacity may vary across climatic zones, although this pattern appears weaker in the two-year aggregated model than in the 2020 climate-based model. Overall, the model reinforces the central finding that cost reduction is not driven by scale alone, but also depends on feed efficiency, effective capacity utilization, flock survival, energy performance, and regional climatic conditions.

Table 5. Results from the estimation of the model analyzing the effect of capacity, climate and time on the cost of production in an Aggregated Regression format.

Variable	Estimated coefficient	Standard error	t-statistic	Significance level (P>|t|)
Logarithm of feed to meat conversion rate	0.54389	0.15	3.44	0.0
Logarithm of capacity utilization rate	-0.2572	0.037	-6.77	0.0
Logarithm of capacity	-0.08748	0.016	-5.41	0.001
Capacity Squared	3.28e-12	1.41e-12	2.33	0.02
Ownership method	-0.01	0.013	-0.72	0.554
Energy consumption per unit area	0.033	0.015	2.20	0.02
Hatching frequency	-0.079	0.012	-6.28	0.0
Ratio of end-of-period chickens to total hatching	-0.044	0.013	-3.2	0.0
Dummy variable for 2020	0.56	0.022	24.95	0.00
Arid climate	0.28	4.75e-07	7.79	0.0
Semi-arid climate	0.31	0.036	9.07	0.0
moderate climate	0.17	0.034	5.20	0.0
Interaction of capacity with arid climate	-8.65e-07	0.034	-1.53	0.03
Interaction of capacity with semi-arid climate	-4.73e-07	5.75e-07	-0.93	0.35
Interaction of capacity with moderate climate	-5.61e-08	5.08e-07	-0.1	0.92
Intercept	11.076	4.75e-07	53.42	0.0

Diagnostic tests provide evidence for the reliability of this model: multicollinearity was not a problem (VIF < 4), heteroscedasticity detected for the initial White test after the exclusion of atypical values; besides, residuals were normal according to the Jarque–Bera test. Given the robust standard errors applied, the final model met all classical regression assumptions. Thus, the model showed a strong overall significance ($F = 455.96$, $p < 0.0001$), explained 52% of the total variation in production costs ($R^2 = 0.5204$), and a Root MSE of 0.37558 indicated generally acceptable predictive accuracy.

Discussion

The findings of this study show that broiler production costs in Iran are shaped by the joint effect of scale, input-use efficiency, capacity utilization, flock performance, energy intensity, climatic conditions, and time-specific cost changes. From the perspective of production economics, these results are consistent with the cost-function framework, in which average production cost depends not only on the volume of production but also on how efficiently inputs and fixed production factors are used. The negative effect of production capacity, together with the positive coefficient of its squared term, indicates a nonlinear cost–capacity relationship. This suggests that increasing farm capacity can reduce average cost through economies of scale, but only up to an efficient range; beyond that point, the marginal cost-saving effect of additional capacity becomes weaker. This result is in line with studies showing that larger poultry farms may achieve lower unit costs and higher technical efficiency through better use of labor, feed, housing, energy, and fixed capital (Ali et al., 2015; Shin et al., 2015; Al-Fawaz and Mafraq, 2013; Najafi et al., 2012; Khan et al., 2022; Marmelstein et al., 2024). However, the results also indicate that nominal capacity alone is not a sufficient basis for cost reduction. Capacity expansion becomes economically meaningful only when it is accompanied by effective capacity utilization, stable flock performance, efficient feed use, and appropriate production management.

The positive effect of FCR confirms the central role of feed-use efficiency in broiler production economics. Since feed is the dominant variable input in broiler farming, a higher FCR means that more feed is required to produce each kilogram of live weight, which directly increases average production cost. This finding is consistent with Prakash et al. (2020), Willems et al. (2013), Kamruzzaman et al. (2021), Ramukhithi et al. (2023), and Adaszyńska-Skwirzyńska et al. (2025), who emphasized the importance of feed efficiency in determining broiler productivity and cost performance. At the same time, the negative effects of capacity utilization, end-of-period chicken survival, and hatching frequency show that farms can reduce unit costs by increasing marketable output and spreading fixed and semi-fixed costs over larger effective production volume. This interpretation is consistent with Marmelstein et al. (2024), Challioui et al. (2025), Kumar et al. (2021), Nahimana et al. (2017), and Setiawan and Wijaya (2025), who highlighted the importance of mortality control, flock viability, production scheduling, and operational efficiency in improving poultry farm performance.

Climatic conditions provide another important explanation for regional differences in broiler production costs. The lower cost observed in humid regions, compared with arid, semi-arid, and moderate regions, suggests that environmental conditions affect production costs through both direct and indirect channels. Directly, climate influences energy demand for cooling, ventilation, heating, and environmental control. Indirectly, it affects feed intake, growth performance, mortality risk, disease susceptibility, and biological efficiency. This finding is consistent with Gholami et al. (2020), Oke et al. (2024), Osuji et al. (2024), and Attia et al. (2024), who showed that climatic stress and heat exposure reduce broiler performance and increase management and energy requirements. The significant interaction between production capacity and climate further indicates that the economic return to capacity expansion is not uniform across climatic zones. In other words, larger capacity may generate stronger cost advantages where environmental and energy constraints are better controlled, while in more climate-stressed regions, scale expansion without sufficient environmental-control infrastructure may not produce the same cost-saving effect.

Energy intensity also had a positive effect on production cost, which reinforces the link between climate, housing conditions, and cost efficiency. This result agrees with Liang and Costello (2024) and Du et al. (2022), who showed that energy consumption in animal housing systems depends heavily on ventilation, cooling, heating, and environmental-control requirements. The result should not be interpreted as contradictory to energy-efficiency studies; rather, it complements them by showing that higher energy cost per unit of production area is reflected in higher economic cost at the farm level. Therefore, improving energy efficiency can be considered an operational channel through which climate-related cost pressures may be reduced.

The positive year effect in the two-year aggregated model indicates that production costs were higher in 2020 than in 2015 after controlling for farm-level and climatic factors. This finding suggests that the cost structure of broiler production shifted upward over time, most likely due to broader market and macroeconomic pressures such as exchange-rate depreciation, higher prices of imported feed ingredients, input-supply disruptions, and pandemic-related shocks. This interpretation is consistent with Belarmino et al. (2023), Rad et al. (2021), Ijaz et al. (2021), and Adaszyńska-Skwirzyńska et al. (2025), who reported that disruptions in poultry and meat supply chains intensified production costs and reduced the stability of input markets.

The nonsignificant effect of ownership type indicates that ownership structure alone does not explain production cost differences once technical performance, capacity, energy use, climate, and flock survival are controlled. This result differs from studies such as Tsegaye et al. (2024), where ownership or farm-level organizational characteristics were more closely related to profitability and performance. A possible explanation is that the present study uses a large national farm-level dataset and controls for several technical and climatic cost drivers, which may absorb part of the effect that ownership captures in smaller or more localized studies. Thus, ownership may influence costs indirectly through management quality, access to inputs, credit conditions, or technology adoption, rather than through a direct independent effect.

Overall, the discussion of the findings suggests that cost reduction in Iran’s broiler industry should not be approached only through expansion of nominal capacity. A more effective strategy is to combine scale optimization with improvements in FCR, capacity utilization, flock survival, annual production scheduling, and energy efficiency. The climate-related results also imply that support policies and investment decisions should be sensitive to regional production conditions, particularly in arid and semi-arid areas where environmental-control costs are higher. In this sense, the main contribution of the study is to show that broiler production cost is the outcome of an interaction between scale, technical efficiency, and climatic heterogeneity rather than a function of production capacity alone.

Conclusion

This study concludes that broiler production costs in Iran are determined by the joint influence of scale, feed efficiency, capacity utilization, end-of-period chicken ratio, production frequency, energy intensity, and climatic conditions, rather than by nominal production capacity alone. The findings indicate that higher capacity utilization, a higher end-of-period chicken ratio, and more frequent production cycles reduce unit costs, while higher FCR and energy intensity increase them.

The nonlinear effect of production capacity further shows that scale expansion improves cost efficiency only up to an efficient threshold. Moreover, regional climatic differences significantly shape cost performance, suggesting that productivity assessment and support policies should prioritize performance-based indicators and climate-sensitive planning. Overall, sustainable cost reduction in Iran's broiler industry requires improving feed efficiency, energy management, effective use of existing capacity, and end-of-period production performance before pursuing simple capacity expansion.

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بررسی نقش ظرفیت تولید، نرخ تبدیل خوراک به گوشت و میزان بهره‌برداری از ظرفیت بر قیمت تمام‌شده گوشت‌مرغ در پهنه‌های مختلف اقلیمی در ایران

محمدامین غلام آزاد، امیرحسین چیذری، و وحیده انصاری

چکیده

رشد جمعیت در کشورهای در حال توسعه، همراه با گسترش فقر غذایی و افزایش فشار بر منابع محدود، موجب افزایش چشم‌گیر تقاضا برای منابع پروتئینی ارزان‌قیمت، به‌ویژه گوشت مرغ، شده است. با این حال، روند صعودی هزینه‌های تولید و نوسانات اقتصادی، قیمت تمام‌شده این محصول را با چالش‌های جدی مواجه کرده است. در چنین شرایطی، شناسایی و تحلیل دقیق عوامل مؤثر بر قیمت تمام‌شده از اهمیت بالایی برخوردار است. هدف این پژوهش، بررسی اثر ظرفیت تولید و شرایط اقلیمی بر قیمت تمام‌شده گوشت مرغ در ایران است. داده‌های مورد استفاده مربوط به ۴۶۴۳ واحد مرغداری در استان‌های عمده تولیدکننده، استخراج‌شده از مرکز ملی آمار، می‌باشند. پس از پاک‌سازی و حذف داده‌های پرت، متغیرهایی نظیر ظرفیت تولید، اقلیم، نرخ تبدیل خوراک به گوشت، بهره‌برداری از ظرفیت، نسبت مرغ پایان دوره، شیوه مالکیت، مصرف انرژی و دفعات جوجه‌ریزی در قالب دو مدل — مقطعی (سال ۱۳۹۹) و شبه‌پنل (ترکیب سال‌های ۱۳۹۴ و ۱۳۹۹) — با استفاده از رگرسیون مقاوم مورد تحلیل قرار گرفتند. نتایج نشان داد که ظرفیت تولید، بهره‌برداری از ظرفیت، نسبت مرغ پایان دوره، و دفعات جوجه‌ریزی اثر منفی و معناداری بر قیمت تمام‌شده دارند. همچنین قیمت تمام‌شده در اقلیم مرطوب، به‌طور معناداری کمتر از اقلیم‌های خشک، نیمه‌خشک و معتدل بود. بر این اساس، پیشنهاد می‌شود شاخص‌های عملکردی جایگزین ظرفیت اسمی در ارزیابی بهره‌وری شوند و سیاست‌های حمایتی با رویکرد اقلیم‌محور و متناسب با سطح بهره‌برداری طراحی گردند.