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Subsidies Reform and the Efficiency of Dairy Farms in Iran: A Comprehensive Evaluation

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Abstract

Subsidies reform in Iran started in 2010 after the implementation of the Targeted Subsidies Plan. Increasing the efficiency and productivity of production units through price realization was a main objective of this policy. However, the resulting spike in input and output prices challenged the achievement of the policy goals. The main purpose of this article is to compare the efficiency of the dairy farms in Iran before and after the Targeted Subsidies Plan was implemented. We used a sample of longitudinal data over the years 1990, 1993, 2000, 2007, 2013, 2016, and 2019 covering 11 regions in 18 provinces and applied stochastic frontier analysis by imposing the monotonicity condition to evaluate efficiency and productivity of the farms. The estimation results show that the unrestricted production frontier is not monotonic in energy and labor. Therefore, imposing a monotonicity condition reduces estimation bias which is critical for policymaking. Unbiased estimation of productive efficiency resulting from imposing the monotonicity condition ranges from 0.72 to 0.86, depending on the region. Results also show a 17% reduction in the production efficiency of the examined dairy farms after the subsidy reform plan which is against the policy goals. The regional differences in the efficiency of intensive dairy farming indicate the need for the more regionally specific supplementary policy, in terms of support schemes and subsidy reforms.

Highlights

- In this study, dairy farm efficiency in major milk production areas in Iran between 1990 and 2019 is investigated and compared before and after the subsidies reform.
- A well-behaved production function, among satisfying other assumptions, should be monotonic in all inputs.
- Dairy farms are producing at the second stage of the production.
- The results show that improving production efficiency and using the potential capacities of this sector can help fulfill the Production Leap Policy.
- The production efficiency of the dairy farm has decreased after the subsidy reform.

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1. Introduction

Subsidies in Iran in their current form began in the 1960s. A review of statistics on subsidies for basic goods and services over the past few decades shows that the volume of subsidies has been on the rise (Shahaei et al., 2016). Government budgetary payments to support milk producers include subsidies to production inputs, energy, and affordable insurance and financing. Investigating support policies of dairy production in Iran, Hosseini and Iravani (2012) reported various types of government support for milk producers among which energy subsidies had the highest share (71%), followed by production input subsidy (17%) and affordable financing (7.8%) considering the average value of subsidies in all Development Plans.

Distribution of sizable amounts of subsidies in Iran's economy has been counter effective mainly because such policies has caused severe price distortion and disrupted market mechanisms (Tashkini, 2014). At the end of 2010, the government gradually removed subsidies and reformed prices on food and energy carriers. The plan was to redistribute the additional revenue earned from liberalized prices to low-income families and producers with the goal of minimizing price deviations, increasing the purchasing power of consumers, and expanding social equality. One of the goals of implementing this plan was to increase efficiency and productivity in production units through market price realization (Sobhanian et al., 2018).

Meanwhile, given the realities of Iran's political and economic situation such as the international sanctions, reliance on oil revenues, and low productivity levels, governments over the last decade have been propounding the concepts of resilient economy, production growth, and production leap to solve these issues. However, the only way to realize these ideas in agriculture is to increase production efficiency due to limited critical resources such as water and arable land.

The coexistence of these two policy goals, i.e., subsidy reform and production growth, has implications on in Iran's economy, and specifically, the agricultural sector. More importantly, achieving these goals in dairy industry, begs the question about the status of milk production and input efficiency in this sector. We mainly focus on whether the production efficiency of dairy farms differed before and after the Targeted Subsidies plan? What is the difference in milk production efficiency between different regions? How milk production could be compared in Iran and other countries of the world? To what extent can improving milk production efficiency be effective in fulfilling the production leap policy? Despite the importance of answering these questions in adopting appropriate policies to grow the dairy sector in line with economic development in Iran and to promote domestic production, no study has so far assessed milk production efficiency in this country. Therefore, this study aims to investigate dairy farm efficiency in major milk production areas in Iran between 1990 and 2019 based on data availability.

Although the demand for dairy products, especially milk, is increasing in Iran as a result of population growth and economic development, the annual consumption of milk per capita is less than 80 kilograms on average, half of its recommended level (Fatemi-Amin & Mortezaie, 2013). This low level of consumption can partly be attributed to low production and/or relatively high cost of the production of milk in the country. Thus, the current gap in consumption could be met in the short term by increasing the level of inputs or by improving the efficiency at a given level of technology. Since Iran's livestock industry is mainly constrained by the cost of feed and fodder, the most reasonable approach is to increase production efficiency. Higher efficiency could, in turn, lead to higher profitability and comparative advantage for dairy farms.

A reliable measure of efficiency is essential for policymakers to develop programs that boost milk production. Decision-making processes, including production procedures, are economically efficient only when the achievements are maximized through allocating restricted resources to competing activities. Efficiency is more important when production is limited by scarce resources. Improving efficiency and productivity is a common solution to the current challenges in the agricultural sector due to the increasing population and the demand for agricultural products, price sensitivity in food markets, and critically limited access to water and land.

As we mentioned before, despite the need for improving milk production efficiency, Iran's economy has undergone a major transformation after implementing the Targeted Subsidies Plan in 2010 which has led to an increase in the general level of prices in the country. Therefore, evaluating the production efficiency of milk in different regions and comparing it before and after the implementation of subsidy reform can help policymakers increase the effectiveness of the policy toward its goals and identify possibly needed corrections.

Conceptually, it is largely recognized that producers' decision-making in terms of production resource allocation in the agricultural sector is affected by subsidies (Sckokai & Moro, 2009). Many studies investigated subsidies and farm efficiency linkage from theoretical and empirical points of view (Hadley, 2006; Sckokai & Moro, 2009; Latruffe et al., 2017; Minviel & Latruffe, 2017). However, these studies are more focused on European countries and encompassed the various Common Agricultural Policy (CAP) reforms. Although in developing countries such as Iran, protection policies are more in the form of subsidy payments, studies in this field are less visible in these countries. Also, much of the current literature on subsidies and production efficacy linkage pays particular attention to energy subsidy reform (Barkhordar et al., 2018; Lin & Jiang, 2011). Furthermore, these studies focus mostly on macroeconomic variables and the industrial sector.

To the best knowledge of authors, no prior study has examined regional differences in milk production efficiency before and after subsidy reforms in Iran. The present study bridges the gap by comparing the dairy farms' productive efficiency in different years and provinces before and after the subsidies reform plan. Another contribution of this paper is the imposing monotonicity condition. The monotonicity condition is important in estimating the efficiency and accuracy of the results (Wang, 2002) that has not been investigated in the previous studies to the best of our knowledge. Therefore, this study sheds light on the production efficiency of the dairy farm by imposing the monotonicity condition on longitudinal data of dairy farms in Iran. We found that estimated coefficients before imposing the monotonicity condition are biased. After imposing the monotonicity condition, the relative efficiency across provinces shows that the production efficiency in dairy farms can be improved.

To better understand the conditions of milk production in Iran, it is better to describe the production status and performance of this product in the country compared to the world which is discussed in the following by using FAO statistics on milk production and yield. The total world milk production with an upward trend has increased from 350 million tonnes in 1970 to 680 million tonnes in 2018 (about 90 percent growth), over the last 50 years (see Figure 1). Meanwhile, global per capita milk production experienced a declining trend up to 1997 and reached 93.2 kg per person, then increased in 2018 to 110.5 kg per person. Also, the average yield of milk production in the world has increased about 45 percent, reaching 2577.2 kg per cow in 2018 (see Figure 1). The United States, Denmark, Spain, Estonia, and the Republic of Korea gain high yields (about 9000 kg per cow) in milk production.

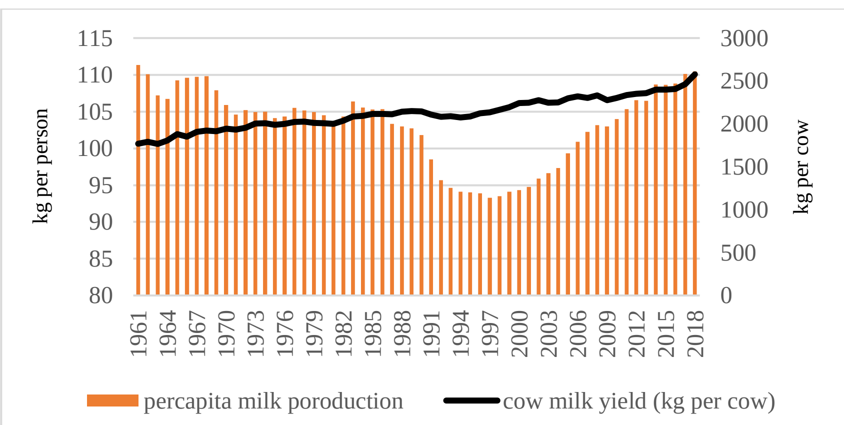

Figure 1. Global per capita milk production and cow milk yield

More detailed examination of data show that despite high levels of milk production in countries such as the United States, Brazil, Russian Federation, Turkey, United Kingdom, and the Netherlands, production growth has been negligble. On the other hand, countries like Azarbaijan, Turkmenistan, Ukraine, India, Republic of Korea, Newzealand, Algeria, Pakistan, and Iran experienced a significant growth, more than double in some cases. Statistics show that developing countries have the main share of world milk production growth as a result of an increasing number of livestock and dairy farms rather than a rise in productivity gains. The reason is that milk production is one of the main activities for smallholders in developing countries. Small dairy farmscontribute to household subsistence, nourishment, and food security by providing a return in a short time and adequate revenue for small-scale producers. As opposed, in developed countries the trend is toward the intensification and industrial production of milk.

Milk production, with a long tradition, is one of the main agricultural products in Iran. Today, it is produced in almost all the provinces. However, Isfahan, Tehran, Alborz, Qom, Fars, Razavi Khorasan, and Yazd supply more than 85 percent of the total milk production in Iran. The size of most dairy farms ranges between 20 to 150 heads. Farms with pure breed and cross breed livestock show highest milk performance recording, respectively. Iran’s dairy sector is centrally controlled and the price of milk and main dairy products are determined by the government. According to FAO statistics, milk production in Iran sharply increased from 1584.5 in 1980 to 8107 million tonnes in 2014, declined due to economic structural reforms in 2015 and finally reached 6929.212 million tonnes in 2018 (see Figure 2). In the meantime, milk yield had an upward trend, with some fluctuations, reaching to 3669 from its lowest level of 850.5 kg per cow in 1980 (see Figure 2).

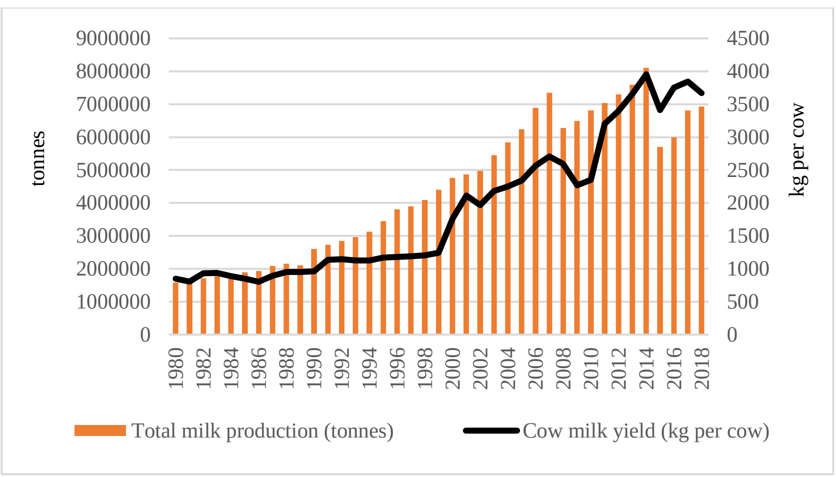

Figure 2. Milk production and yield in Iran

These statistics show that the increase in Iran’s milk production was mainly due to the increasing number of cows rather than the productivity gain. Also, despite the yield growth of more than 4 times, it is far from the global standards in this industry. So, there is still a long way to go to achieve optimal performance. Another issue of the dairy sector in Iran is its high dependence on feed imports which is against milk and dairy self-sufficiency policy. More than 80 percent of corn and soybean for livestock feeding are imported which could transfer the fluctuations of global feed markets into the domestic feed market; negatively affect the profit of dairy farmers; and increase the cost of milk production. The government modifies the fluctuations, reduces the production cost, and supports dairy farmers and consumers by implementing an exchange rate subsidies policy for feed.

We organized the rest of this paper as the following: Section II reviews the empirical literature investigating the production efficiency especially in dairy farm. Section III describes the data, model specification, and empirical methodology. Section IV represents the empirical results. Finally, Section V provides conclusions and policy implications.

2. A Review of the Related Literature

To properly measure the efficiency, an estimation of the production function, defined as the maximum output possible with a given level of inputs, is critical. In his seminal paper, Farrell (1957) proposed the frontier function that any observed level of inputs and output below the frontier production is associated with technical inefficiency. Since then, several parametric and nonparametric methods have been introduced to measure efficiency.

In nonparametric methods, including Data Envelope Analysis (DEA) and Free Disposal Hull (FDH), mathematical programming is used to evaluate efficiency without taking into account any statistical distribution (Mulwa et al., 2009; Emrouznejad & Podinovski, 2004; Aigner et al., 1977). In parametric methods, however, the mathematical relationship between inputs and outputs is used to specify stochastic or deterministic production functions (Coelliet et al., 2005; Kumbhakar & Lovell, 2003). The stochastic frontier approach (SFA) is a parametric method, commonly used to analyze the technical efficiency of agricultural products including dairy firms (Jiang & Sharp, 2014; Dourandish et al., 2013; Furesi et al., 2013). In this method, the maximum output is calculated for a given level of inputs (Coelli et al., 2005). Thus, the relative efficiency can be calculated and compared across producers because all of them can't reach production at the frontier level (Henningsen & Henning, 2009).

Assessing theoretical conditions of compatibility and flexibility, and proper specification is critical in estimating frontier functions. Yet, specifying a production, costs, or utility function while satisfying the second-order conditions under economic theory, including monotonicity and concavity, is another challenging task (Diewert & Wales, 1989; Wang, 2002; Arreola et al., 2020).

The monotonicity condition implies that the production function is increasing in all inputs. Therefore, the reasonable decision in case of the decrease in output when inputs are increasing is reducing the level of inputs (Henningsen & Henning, 2009). In other words, the marginal production for all inputs and therefore the cost elasticity of inputs should be positive.

There is extensive research on the estimation and analysis of productivity in the agricultural industry, including milk production (Alem, 2021; Dakpo et al., 2021; Skevas et al., 2018; Paltasingh & Goyari, 2018; Shahraki et al., 2016; Dourandish et al., 2013; Mukherjee et al., 2013). For instance, Bravo-Ureta et al. (2008) applied SFA to estimate the production frontier for the dairy industry of three South American countries, using unbalanced panel data. They found the average technical efficiency of 87, 84.9, and 81.1 percent for Uruguay, Chile, and Argentina, respectively. They concluded that there is room to improve milk production, given the current level of inputs. Derks et al. (2014) also used SFA to examine the impact of veterinary herd health management programs on milk production efficiency. They, however, did not find any statistically significant difference between the productivity of participants and non-participant farmers. In another research, Alem (2021), the dynamic parametric approach to estimate the performance of Norwegian dairy farms was adopted. They applied unbalanced farm-level panel data for the period 2000–2018 and the results showed a mean technical efficiency was 0.92 for the studied region.

Most of the models used to investigate the productive efficiency of firms in earlier studies do not satisfy monotonicity (Barnett, 2002; Belotti & Ferrara, 2019). Edwards and Terrell (2004) show that imposing monotonicity and concavity conditions leads to forecasting the accuracy of cost frontiers and estimated elasticities. Few empirical studies took the monotonicity condition into account (e.g. Belotti & Ferrara, 2019; Arreola et al., 2020; Mugera et al., 2010; Bokusheva & Hochman, 2006; O'Donnell & Coelli, 2005). Estimation results and policy recommendations are only reliable when necessary conditions, including monotonicity, are imposed and bias is reduced (Mugera et al., 2010). For instance, Belotti and Ferrara (2019) introduced a useful method for the estimation of semiparametric stochastic frontier models with imposing monotonicity conditions. This study developed an iterative estimation algorithm based on nonlinear least squares and the results showed that the new algorithm had a very good performance. Also, Arreola et al. (2020) developed a monotonic and concave nonparametric Bayesian estimator for production frontiers. They investigated a cross-section of Japan's concrete industry with the proposed method. The results demonstrate that the estimations are aligned well with economic theory and can be used for the larger data set.

The literature on the productivity in Iran focuses mostly on non-parametric methods, analyzing a single region using cross-section data (Molaei & Sani, 2017; Eshraghi & Kazemi, 2014; Amini et al., 2012; Mehrjou et al., 2011; Rafiei et al., 2011; Torkamani & Shoushtarian, 2007). To the best of our knowledge, Ahmadzadeh (2016) is the only study that implemented a production frontier approach with monotonicity condition in estimating the efficiency of fish, and there is no other study to impose such restriction in efficiency estimation in the country.

3. The Study Model

A production function should be monotonically positive in all inputs or the estimated coefficients are not theoretically compatible nor empirically interpretable (Mas-Colell et al., 1995). The monotonicity condition is imposed on the model in the non-parametric DEA approach, but not in the stochastic frontier modeling approach.

The production frontier function is estimated as deterministic or stochastic. While the output is assumed fixed in the deterministic estimation, the impact of stochastic factors like weather conditions and measurement error is included in stochastic models (Belotti & Ilardi, 2012). The general form of a stochastic frontier for a cross-section data is as follows:

$$y = f(x_i,\beta).exp\{\varepsilon_i\} \quad (1)$$

in which y is the level of the output, x_i is the level of inputs, and β is the vector of coefficients to be estimated. The error term $\varepsilon_i = \vartheta_i - u_i$ has two components. The inefficiency term, u_i, with the truncated normal distribution, controls for managerial factors and measures the distance between the observed production levels from the estimated frontier level in a given level of inputs. The stochastic term, $\vartheta_i \sim N(0,\sigma_\vartheta^2)$, measures the stochastic disturbances that are out of the management's control (Battese, 1992).

If we assume that the estimated frontier production is monotonically increasing in all inputs, the technical efficiency parameter is $\gamma = \frac{\sigma_u^2}{\sigma^2} = \frac{\sigma_u^2}{\sigma_u^2+\sigma_\vartheta^2}$ and the variance of the error term is $\sigma^2 = \sigma_u^2 + \sigma_\vartheta^2$ (Battese & Corra, 1977). In this case, the output is not decreasing, or at least remains constant, when the level of an input increases. In other words, the monotonicity condition requires $\frac{\partial f(x_i,\beta)}{\partial x_i} \geq 0$, i.e. a positive marginal production for all inputs. Otherwise, the estimated coefficients are biased because the technical inefficiency reflects the production decrease due to the overconsumption of inputs in the third region of the production function.

To impose the monotonicity condition, we follow Henningsen and Henning's (2009) three-stage procedure. In the first stage, we estimate an unrestricted Translog production frontier as follows:

$$lny_{kt} = f(x_i,\beta) = \beta_0 + \sum_{i=1}^{m} \beta_i lnx_{kti} + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \beta_{ij} lnx_{kti} lnx_{ktj} \quad (2)$$

in which y_{kt} is the quantity of total milk produced in the k^{th} region and x_{kti} is the level of i^{th} input used in the same region at time t(k=1… 11 and m=1,…,5). We include the quantity of five inputs that are three different feed (concentrate, green chop, and dried fodder), labor, and energy. To impose homogeneity, we normalized all inputs relative to energy. The coefficients, $\hat{\beta}$, and the covariance matrix, $\hat{\Sigma}_\beta$ are saved to be used in the next stage.

In the second stage, we estimate the restricted parameters, $\hat{\beta}^0$ using a minimum distance estimation method as

$$\hat{\beta}^0 = argmin(\hat{\beta}^0 - \hat{\beta})\Sigma_\beta^{-1}(\hat{\beta}^0 - \hat{\beta}) \quad (3)$$

$$s.t.\, f_i(x,\hat{\beta}^0) \geq 0, \forall i,x$$

where $f_i(x,\beta) = MP_i = \frac{y_{kt}}{x_i}(\beta_i + \sum_{j=1}^{n} \beta_{ij} lnx_j) \geq 0$ implies that to have monotonicity, the marginal product needs to be greater than, or equal to zero. In the last stage, we estimate the efficiency of firms and factors that affect the inefficiency, using a consistent frontier production as follows:

$$lny = \alpha_0 + \alpha_1 ln\tilde{y} - u^0 + \vartheta^0 \quad (4)$$

in which $\tilde{y} = f\left(x,\hat{\beta}^0\right)$ implies that we use the restricted parameters from the previous stage as independent variables and $(u^0 - \vartheta^0)$ is the error term. Finally, we calculate the adjusted coefficients using the following relations

$$\hat{\hat{\beta}}_0^0 = \hat{\alpha}_0 + \hat{\alpha}_1\hat{\beta}_0^0 \quad (5)$$
$$\hat{\hat{\beta}}_i^0 = \hat{\alpha}_1\hat{\beta}_i^0 \ \forall i > 0$$
$$\hat{\hat{\beta}}_{ij}^0 = \hat{\alpha}_1\hat{\beta}_{ij}^0 \ \forall i,j$$

where $\hat{\beta}^0$s are restricted parameters calculated in the second stage, $\hat{\alpha}$s are the coefficients from the last stage, and *i* and *j* denote different inputs. Using the coefficients in equation (4) we can get the production efficiency under the monotonicity condition.

We used the available data from commercial dairy farms in 11 regions that include 18 provinces for the years 1990, 1993, 2000, 2007, 2013, 2016, and 2019. All the provinces included in our sample had a share of at least 2 percent of the total raw milk production in Iran. Table 1 compares the quantity and share of milk production for our sample in three different years. Since some of the larger provinces were divided into smaller provinces during the past decades, we group them into regions. Thus, each region consists of the original province and the smaller ones that formed later. The first and the third regions (i.e. Isfahan and Tehran, Qom, and Karaj provinces) have been the major dairy producers, consistently more than 48 percent of total production since 1990 in Iran.

3.1 Data

We used the available data from commercial dairy farms in 11 regions that include 18 provinces for the years 1990, 1993, 2000, 2007, 2013, 2016, and 2019. All the provinces included in our sample had a share of at least 2 percent of the total raw milk production in Iran. Table 1 compares the quantity and share of milk production for our sample in three different years. Since some of the larger provinces were divided into smaller provinces during the past decades, we group them into regions. Thus, each region consists of the original province and the smaller ones that formed later. The first and the third regions (i.e. Isfahan and Tehran, Qom, and Karaj provinces) have been the major dairy producers, consistently more than 48 percent of total production since 1990 in Iran.

Table 1. Milk Production in Iran by Selected Provinces

Regions	Provinces	1990		2000		2016		2019	
		Quantity	Share	Quantity	Share	Quantity	Share	Quantity	Share
1	Isfahan	819.9	15.23	1624	13.37	9403	23.01	9731	19.4
2	East Azerbaijan	325.6	6.05	413	3.40	828	2.03	1192	2.38
	Ardabil	N/A[b]	0	383	3.15	524	1.28	654	1.30
3	Tehran	1966.5	36.53	4110	33.83	6658	16.29	11057	22.10
	Qom	N/A	0	177	1.48	1041	2.55	994	19.87
	Alborz	N/A	0	N/A	0	2567	6.28	2449	4.89
4	North Khorasan	N/A	0	N/A	0	199	0.49	170	0.33
	Razavi Khorasan	818.2	15.20	2283	18.79	4006	9.80	4088	8.17
	South Khorasan	N/A	0	N/A	0	302	0.74	482	0.96
5	Zanjan	192.6	3.58	208	1.71	655	1.60	549	1.09
	Qazvin	N/A	0	361	2.97	2492	6.10	4414	8.82
6	Semnan	65.1	1.21	136	1.12	1188	2.91	1133	2.26
7	Fars	124.1	2.31	416	3.42	3020	7.39	4510	9.01
8	Kerman	89.1	1.66	201	1.65	815	1.99	722	1.44
9	Mazandaran	210.2	3.90	401	3.30	767	1.88	684	1.36
	Golestan	N/A	0	198	1.63	483	1.18	470	0.93
10	Markazi	137.2	2.55	195	1.61	659	1.61	1067	2.13
11	Yazd	78.4	1.46	322	2.65	1754	4.29	1695	3.38
Other Provinces		556.3	10.33	721	5.93	3506	8.58	3976	7.95
Total		5383.2	100	12149	100	40867	100	50014	100

[a] *measured as (100 tons)*
[b] *the original province was later divided into two or three smaller provinces in this region.*
Source: *Statistical Center of Iran*

4. Empirical Results

Table 2 shows the results of estimating equation 5, where most coefficients are significant. However, as we discussed before, monotonicity is a necessary condition for the validity of any interpretation of efficiency coefficients. To investigate the monotonicity condition, we calculated the marginal production of all inputs.

Table 2. Unrestricted Estimation of a Translog Production Frontier for Dairy Farms in Iran

Parameter	Coefficient	Parameter	Coefficient
Constant	2.73*** (0.91)	Concentrate×Labor	-0.27* (013)
Concentrate	2.28** (0.83)	Concentrate×Green chop	0.04 (0.15)
Labor	-1.84*** (0.44)	Concentrate×Dried fodder	0.38*** (0.03)
Green chop	-0.04 (0.36)	Concentrate×Energy	-0.22 (0.04)
Dried fodder	1.17** (0.40)	Labor × Green chop	-0.12 (0.07)
Energy	-0.57 (0.51)	Labor × Dried fodder	-0.11* (0.05)
Concentrate (squared)	0.06 (0.34)	Labor ×Energy	0.22 (0.10)
Labor (squared)	0.27** (0.08)	Green chop× Dried fodder	-0.19*** (0.05)
Green chop (squared)	0.22 (0.13)	Green chop× Energy	0.1 (0.05)
Dried fodder (squared)	0.02 (0.13)	Dried fodder×Energy	0.05 (0.02)
Energy (squared)	0.02 (0.01)		
Technical Efficiency (γ)	1.00*** (0.027)	The variance of the Error Term (σ^2)	0.12*** (0.022)
Log-likelihood = 8.74			

Note Standard errors in parenthesis. *, **, and *** denote significant at 10%, 5%, and, 1%, respectively. The coefficients for Dried fodder are calculated using the homogeneity condition.

As Table 3 shows, the marginal product for concentrate, green chop, and dried fodder is positive for all observations. However, labor and energy mostly have negative marginal products. These results indicate that higher output is achievable by reducing labor and energy which is against the monotonicity condition and implies a bias in the estimation of the production function.

Table 3. Marginal Products of Inputs

Input	Marginal Product
Concentrate	1.003
Labor	-0.650
Energy	-0.044
Green chop	0.609
Dried fodder	2.216

Source: *Authors' calculation*

To address this estimation bias, we used the minimum distance estimation in the second step, as shown in equation (2), and calculated the adjusted coefficients. Table 4 shows the results of the second step. All the coefficients change and, in some cases, the change is as large as two standard errors of the coefficients at the first stage.

Table 4. Results of the Minimum Distance Estimation

Parameter	Coefficient	Parameter	Coefficient
Constant	-0.33	Concentrate×Labor	-0.054
Concentrate	0.88	Concentrate×Green chop	-0.043
Labor	-0.40	Concentrate×Dried fodder	0.210
Green chop	0.13	Concentrate×Energy	-0.073
Dried fodder	-0.16	Labor×Green chop	-0.025
Energy	0.55	Labor×Dried fodder	0.077
Concentrate (squared)	-0.04	Labor×Energy	-0.075
Labor (squared)	0.077	Green chop×Dried fodder	-0.085
Green chop (squared)	0.096	Green chop × Energy	0.03
Dried fodder (squared)	-0.019	Dried fodder× Energy	-0.183
Energy (squared)	0.303		

Source: *Authors' calculation*

Then, we used the adjusted coefficients to compute the predicted level of milk production, $\tilde{y}$. The values of $\tilde{y}$ are then used to estimate equation (3) which results in

$$lny = -0.437 + 0.95ln\tilde{y}$$

SE. (0.17) (0.021)

Finally, we modified the coefficients of the production frontier based on the relations specified in (4) as shown in Table 5.

Table 5. Coefficients of the Stochastic Frontier after Imposing Monotonicity Condition

Parameter	Coefficient	Parameter	Coefficient
Constant	-0.758	Concentrate×Labor	-0.052
Concentrate	0.84	Concentrate×Green chop	-0.040
Labor	-0.39	Concentrate×Dried fodder	0.201
Green chop	-0.162	Concentrate×Energy	-0.065
Dried fodder	0.533	Labor×Green chop	-0.024
Energy	0.179	Labor×Dried fodder	-0.062
Concentrate (squared)	-0.044	Labor×Energy	0.061
Labor (squared)	0.074	Green chop×Dried fodder	-0.081
Green chop (squared)	0.092	Green chop× Energy	0.053
Dried fodder (squared)	-0.018	Dried fodder× Energy	-0.049
Energy (squared)	0.049		

Source: *Authors' calculation*

Now that we adjusted the coefficients and imposed the monotonicity condition, the productive efficiency across the time and regions can be calculated. The average efficiency of commercial dairy farms for the study periods is shown in Table 6. The first row shows the efficiency estimates after imposing the monotonicity. The difference between adjusted and unadjusted estimates implies the estimation bias of 1.5 to 15.4 percent, depending on the year. In general, failing to impose monotonicity leads to lower estimates of the relative productivity for all the years in our study, except for 2000, which is mainly due to the overconsumption of inputs rather than the inefficiency of the farms.

The average estimate of 0.83 in 2016 implies that the efficiency of dairy farms can be improved by 17 percent through better production practices.

Table 6. Average Efficiency of Dairy Farms in Iran (selected regions)

Average Efficiency	1990	1993	2000	2007	2013	2016	2019
Adjusted Coefficients	0.7301	0.8230	0.8487	0.8276	0.6812	0.8390	0.7213
Unadjusted Coefficients	0.6282	0.8103	0.8616	0.7929	0.6173	0.7095	0.6538

Source: *Authors' calculation*

The amount of dairy farm efficiency increased by 10% between 1990 and 2016. Also, the results presented in Table 6 show that in 2013, the amount of dairy farm efficiency has reduced significantly (by17%) after The Politics of Subsidy

Reform in Iran compared with previous periods. Although it was compensated to some extent in 2016, the amount of dairy farm efficiency in 2016 was still less than that in 2000. This can be due to market instability and high risks of input supply and selling products by producers. In the milk production process, feedstuff composition will have a significant impact on production efficiency.

We also estimated the productive efficiency of dairy farms located in 11 regions in Iran. Comparing the adjusted and unadjusted efficiency coefficients imply that failing to account for the monotonicity condition leads to an estimation bias of 2 to 16.5 percent, depending on the region. The first column of estimates in Table 7 shows that using the adjusted coefficients the average efficiency varies between 72 to 86 percent. Farms in region 5 are the most efficient, followed by regions 4, 9, and 2, and farms in region 10 are the least efficient ones.

Table 7. Average Efficiency of Dairy Farms in Iran (study period)

Regions	Provinces	Average Efficiency	
		Adjusted Coefficients	Unadjusted Coefficients
1	Isfahan	0.7311	0.6510
2	East Azerbaijan Ardabil	0.8107	0.7570
3	Tehran Qom Alborz	0.7698	0.6607
4	North Khorasan Razavi Khorasan South Khorasan	0.8455	0.8656
5	Zanjan Qazvin	0.8685	0.8534
6	Semnan	0.7718	0.7530
7	Fars	0.7625	0.6572
8	Kerman	0.7261	0.6441
9	Mazandaran Golestan	0.8163	0.8401
10	Markazi	0.7237	0.6851
11	Yazd	0.7775	0.7993

Source: *Authors' calculation*

Based on the available data on the characteristics of Region 5 (Zanjan and Qazvin provinces), we can point to the high milk yield per feedstuff consumption. The mean concentrate feeding for a milk yield of one kg was 0.071 units in this area which was the lowest amount compared with those in all other areas. Also, the average herd size in this area increased during the period under investigation and by 2017, more than 50% of dairy farms in this area will have more than 250 head of cattle, mainly Holsteins. According to meteorological statistics, this region has a mean annual temperature of 15 ° C (with a minimum of 7° C and a maximum of 22° C), which is a suitable temperature for Holsteins. Also, based on Table 7, despite producing approximately 50% of Iran's milk, regions 1 and 3, with production efficiencies of 0.73 and 0.76, have lower efficiency levels compared to other regions, respectively.

5. Concluding Remarks

Improving the productive efficiency of dairy farms is essential to address the increasing demand for milk and other dairy products in Iran. To effectively measure the efficiency of firms, unbiased estimation of the production function is a critical step. According to microeconomic theory, a well-behaved production function, among satisfying other assumptions, should be monotonic in all inputs. We estimate a production frontier and impose a monotonicity condition to measure the efficiency of commercial dairy farms in 11 selected regions of Iran. The estimated production elasticities for different regions show the average for all inputs, except for the concentrate in regions 2, 5, 9, and 11 in the year 2016, is less than unity throughout the study years. Therefore, considering the theory of the production functions, we can conclude that dairy farms are producing at the second stage.

The estimation results show that the unrestricted production frontier is not monotonic in energy and labor. We used a three-step method proposed by Henningsen and Henning (2009) to adjust the coefficients and calculate the unbiased efficiency estimates. Our empirical results confirm that imposing a monotonicity condition reduces estimation bias which is critical for policymaking. In line with Ahmadzadeh (2016), ignoring the monotonicity concept can cause biases in the interpretation of results.

The results of this study also show that the amount of dairy farm efficiency has reduced after the Politics of Subsidy Reform in Iran. The 17% decrease in the production efficiency compared with the period before the Politics of Subsidy Reform shows the negative impact of structural changes in Iran's economy and the resulting instability on milk production efficiency. On the other hand, milk supply, like many agricultural supplies, is dynamic (Howard & Shumway, 1988). Hence, managerial decisions in the current period will affect production in later periods. Therefore, the effect of economic changes and the consequent market instability on milk production efficiency cannot be expected to be immediately mitigated. These results show that under the new economic conditions, producers need more support for managing market risk, input supply, and selling products, and if policymakers seek to fulfill the Production Leap Policy, they should address the problems and requirements of efficient production more seriously. In other words, a comparison of milk production efficiency in different regions of Iran and other countries shows that improving production efficiency and using the potential capacities of this sector can help fulfill the Production Leap Policy.

After imposing the monotonicity condition, the productive efficiency ranges from 0.72 to 0.86, depending on the region. Thus, an improvement of 14 to 28 percent is possible without changing the current technology. Since the production technology and dairy breeds are almost the same in commercial dairy farms in Iran, extension efforts to transfer successful practices and experiences from the most efficient regions to the less efficient ones could improve production efficiency in the latter. This can reduce feedstuff intake by 20% at the current production level with minimum cost and in a relatively short time. This is a significant figure in the current situation of milk production in Iran where the demand for feedstuff is mainly met by imports (above 85%) and major milk-producing regions (regions 1 and 3) have low levels of efficiency compared with other regions. Hence, improving the efficiency of these regions can improve the production efficiency of the country and optimize feed intake. Therefore, these regions should be given priority to increasing milk production in Iran. The difference in production efficiency between different regions can be due to climatic differences, especially the temperature and sensitivity of dairy cattle to heat temperature stress. The effect of this variable on milk production efficiency was not investigated in this study due to the limited data on seasonal or annual milk production. However, improvements in dairy breeds according to ecological conditions can increase milk production.

Also, a comparison of milk production statistics in Iran and other countries shows a great difference between the current average milk production in Iran and the optimal level of milk production. In other words, the production of milk per cow can be increased by three times. To do so, structural changes and new technologies such as smart agriculture should be made and value chain performance should be improved in this industry, taking advantage of the experiences of successful countries in the world. In general, given the limitations of foodstuff production and the status of production efficiency in Iran compared with that in other countries, the success of the Production Leap Policy largely depends on improving the efficiency of this sector.

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The authors declare no conflict of interest.

References

Ahmadzadeh, M. (2016). *Inefficiency and production risk of trout fish in Fars province*. MS Thesis, Shiraz University. (In Farsi).

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21-37.

Alem, H. (2021). The role of technical efficiency achieving sustainable development: A dynamic analysis of Norwegian dairy farms. *Journal of Sustainability*, 13(4), 1841.

Amini, S. H., Yazdani, A. R., Chizari, A. H., & Broujeni, P. A. (2012). Measuring the efficiency of industrial dairy cattle breeding farms using data envelopment analysis: A case study in southern Tehran province, Iran. *Journal of Agri Econ Research*, 4(13),105-120. (In Farsi).

Arreola, J. L. P., Johnson, A. L., Chen, X. C., & Morita, H. (2020). Estimating stochastic production frontiers: A one-stage multivariate semiparametric Bayesian concave regression method. *European Journal of Operational Research*, 287(2), 699-711.

Bakhshoodeh, M. (2013). Proxy means tests for targeting subsidies scheme in Iran. *Iranian Journal of Economic Studies*, 2(2), 25-46. (In Farsi).

Barkhordar, Z. A., Fakouriyan, S., & Sheykhha, S. (2018). The role of energy subsidy reform in energy efficiency enhancement: Lessons learnt and future potential for Iranian industries. *Journal of Cleaner Production*, 197, 542-550.

Barnett, W. A. (2002). Tastes and technology: Curvature is not sufficient for regularity. *Journal of Econometrics*, 108(1), 199-202.

Batiese, G. E. (1992). Frontier production functions and technical efficiency: A survey of empirical applications in agricultural economics. *Agricultural Economics*, *7*(3-4), 185-208.

Battese, G. E., & Corra, G. S. (1977). Estimation of a production frontier model: With application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*, 21(3), 169-179.

Belotti, F., & Ferrara, G. (2019). Imposing monotonicity in stochastic frontier models: An iterative nonlinear least squares procedure. *Centre for Economics and International Studies (CEIS) Working Paper*, 462.

Belotti, F., & Ilardi, G. (2012). Consistent estimation of the 'true' fixed-effects stochastic frontier model. *Centre for Economics and International Studies (CEIS) Working Paper*, 231.

Bokusheva, R., & Hockmann, H. (2006). Production risk and technical inefficiency in Russian agriculture. *European Review of Agricultural Economics*, 33(1), 93-118.

Bravo-Ureta, B. E., Moreira, V. H., Arzubi, A. A., Schilder, E. D., Álvarez, J., & Molina, C. (2008). Technological change and technical efficiency for dairy farms in three countries of South America. *Chilean J. Agric. Res*, 68, 360-367.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Dakpo, K. H., Latruffe, L., Desjeux, Y., & Jeanneaux, P. (2021). Modeling heterogeneous technologies in the presence of sample selection: The case of dairy farms and the adoption of agri-environmental schemes in France. *Agricultural Economics*.

Derks, M., Hogeveen, H., Kooistra, S. R., van Werven, T., & Tauer, L. W. (2014). Efficiency of dairy farms participating and not participating in veterinary herd health management programs. *Preventive Veterinary Medicine*, 117(3-4), 478-486.

Diewert, W. E., & Wales, T. J. (1989). Flexible functional forms and global curvature conditions. *National Bureau of Economic Research (NBER)*, 55(1), 43-68.

Dourandish A., Nikoukar A., Hosseinzadeh M., & Lavshabi, A. (2013). Estimating multi-output technical efficiency for the dairy farms of the northern Khorasan province (applying stochastic production and stochastic distance frontiers). *Journal of Agricultural Economics and Development*, 27(2), 114-122. (In Farsi).

Edwards, D., & Terrell, D. (2004). Does theory matter: Assessing the impact of monotonicity and concavity constraints on forecasting accuracy. *Midwest Econometrics Group*.

Emrouznejad, A., & Podinovski, V. (2004). Data envelopment analysis and performance management: Proceedings of the 4th international conference on DEA, September 2004. *Birmingham, UK*, 417.

Eshraghi F., & Kazemi, F. (2014). Evaluating economic and technical efficiency of dairy farms in Gorgan county. *Journal of Ruminant Research*, 2(1), 195-211. (In Farsi).

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General)*, 120(3), 253-281.

Fatemi-Amin, S. R., & Mortezaie, A. (2013). *Food supply chain strategic plan*. Tehran, JDSB Press. (In Farsi).

Furesi, R., Madau, F. A., & Pulina, P. (2013). Technical efficiency in the sheep dairy industry: An application on the Sardinian (Italy) sector. *Agricultural and Food Economics*, 1(1), 1-11.

Hadley, D. (2006). Patterns in technical efficiency and technical change at the farm-level in England and Wales, 1982–2002. *Journal of Agricultural Economics*, 57, 81-100.

Henningsen, A., & Henning, C. H. (2009). Imposing regional monotonicity on translog stochastic production frontiers with a simple three-step procedure. *Journal of Productivity Analysis*, 32(3), 217-229.

Hosseini, S. S., & Iravani, S. (2012). Evaluating support policies of milk producers in Iran: 1368-87. *Agricultural Economics*, 5(3), 1-24.

Howard, W. H., & Shumway, C. R. (1988). Dynamic adjustment in the US dairy industry. *American Journal of Agricultural Economics*, 70(4), 837-847.

Jiang, N., & Sharp, B. (2014). Cost efficiency of dairy farming in New Zealand: A stochastic frontier analysis. *Agricultural and Resource Economics Review*, 43(3), 406-418.

Kumbhakar, S. C., & Lovell, C. K. (2003). *Stochastic frontier analysis*. Cambridge University Press.

Latruffe, L., Bravo-Ureta, B. E., Carpentier, A., Desjeux, Y., & Moreira, V. H., (2017). Subsidies and technical efficiency in agriculture: Evidence from European dairy farms. *American Journal of Agricultural Economics*, 99(3), 783-799.

Lin, B., & Jiang, Z. (2011). Estimates of energy subsidies in China and impact of energy subsidy reform. *Energy Economics*, 33(2), 273-283.

Mas-Colell, A., Whinston, M. D., & Green, J. R. (1995). *Microeconomic theory (Vol. 1)*. New York: Oxford University Press.

Mehrjou, E., Moghadasi, R., Mirsalehpour, M., & Mehrjoo, N. (2011). Study of technical performance of diary cattles cooperative companies in Kohgiluyeh and Boyer-Ahmad province. *Co-Operation and Agriculture*, 22(6), 21-41. (In Farsi).

Minviel, J. J., & Latruffe, L. (2017). Effect of public subsidies on farm technical efficiency: A meta-analysis of empirical results. *Applied Economics*, 49(2), 213-226.

Molaei, M., & Sani, F. (2017). Evaluating the impact of environmental pollutants on technical efficiencies of dairy farms using stochastic frontier analysis. *Iranian Journal of Agricultural Economics and Development Research*, 48(1), 35-42. (In Farsi).

Mugera, A., Langemeier, M., & Featherstone, A. (2010). *Do theoretical restrictions matter for the translog stochastic production function? evidence from the kansas farm sector (No. 61582)*. Agricultural and Applied Economics Association.

Mukherjee, D., Bravo-Ureta, B. E., & De Vries, A. (2013). Dairy productivity and climatic conditions: Econometric evidence from South-eastern United States. *Australian Journal of Agricultural and Resource Economics*, 57(1), 123-140.

Mulwa, R., Emrouznejad, A., & Muhammad, L. (2009). Economic efficiency of smallholder maize producers in Western Kenya: A DEA meta-frontier analysis. *International Journal of Operational Research*, 4(3), 250-267.

O'Donnell, C. J., & Coelli, T. J. (2005). A Bayesian approach to imposing curvature on distance functions. *Journal of Econometrics*, 126(2), 493-523.

Paltasingh, K. R., & Goyari, P. (2018). Impact of farmer education on farm productivity under varying technologies: Case of paddy growers in India. *Agricultural and Food Economics*, 6(1), 1-19.

Rafiei, H., Heidari-Khormizi, S. R., & Ganjkhanlou, M. (2011). Measuring total factor productivity and calculating efficiency and return to scale in industrial dairy farms: Case study, Gilan province. *Journal of Agricultural Economics Research*, 3(4), 117-132. (In Farsi).

Rahiminia, H., Akbari Moghada, B., & Monjazeb, M. R. (2015). The impact of fuel subsidy targeting in Iran using a CGE model. *Iranian Journal of Economic Studies*, 4(1), 53-79. (In Farsi).

Sckokai, P., & Moro, D. (2009). Modelling the impact of the CAP single farm payment on farm investment and output. *European Review of Agricultural Economics*, 36(3), 395-423.

Shahaei, B., DanaeiFard, H., & Azar, A. (2016). Explaining statis and change in Iran, subsidy policy: Advocacy coalition framework. *Quarterly Journal of Public Organzations Management*, 5(1), 67-88. (In Farsi).

Shahraki, J., Pahlavani, M., & Ohadi, N. (2016). Measurement of technical efficiency and production risk in Zabol dairy farms, Iran. *International Journal of Agricultural Management and Development (IJAMAD)*, 6(1047-2017-1699), 439-448.

Skevas, I., Emvalomatis, G., & Brümmer, B. (2018). Heterogeneity of long-run technical efficiency of German dairy farms: A Bayesian approach. *Journal of Agricultural Economics*, 69(1), 58-75.

Sobhanian, S. M. H., Aghajani-Memar, E., & Aboohamzeh, D. (2018). Analysis of macro factors affecting the process of social capital accumulation in Iran. *Majlis & Rahbord*, 25(94), 5-38. (In Farsi).

Sobhanian, S. M. H., Haghani, M. E., & Abouhamzeh, D. (2018). Analysis of macro factors affecting the process of social capital accumulation in Iran. *Majlis and Rahbord*, 25(94), 5-38.

Tashkini, A. (2014). Effects of targeting subsidies on agricultural sector in Iran. *Economic Modelling*, 8(25), 35-52. (In Farsi).

Torkamani, J., & Shoushtarian, A. (2007). Economic analysis of production and determining technical efficiency of dairy farms: Case study in Fars province. *Development and Productivity*, 2, 29-48. (In Farsi).

Wang, H. J. (2002). Heteroscedasticity and non-monotonic efficiency effects of a stochastic frontier model. *Journal of Productivity Analysis*, 18(3), 241-253.