The functional relationship between non-renewable energy use and milk yield in Iran

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Abstract

Data from a face to face questionnaire survey were conducted to contribute to the development of a method for investigating the relationship between energy inputs and yield of milk production in the Tehran Province of Iran and study on NRE and RE. The results revealed that total non-renewable energy of 9997 MJ cow^{-1} was expended in a period of 365 days; while fossil fuels and electricity were the main energy consuming inputs. Moreover, in specifying a functional relationship the Cobb–Douglas production function was selected as the best function due to its better performance in statistical significance and expected signs of parameters. It was found that fossil fuels energy contributed to the milk yield significantly; while the use of machinery and electricity were inconsistent. The marginal physical productivity (MPP) was applied to investigate the effect of energy use on milk yield. It was concluded that milk production had more sensitivity on fuels energy; hence an additional use of 1 MJ from the fossil fuels energy would lead to increase in yield by 0.18 kg cow^{-1}. The controlled use of NRE inputs and expansion of applying more renewable energy (RE) sources as an alternative to fossil fuels is recommended.

Key words: Non-renewable energy, Cobb–Douglas, electricity, Fossil fuels, Input energy.

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1. Introduction

In agriculture, we record a constantly growing consumption of raw materials and fossil energy due to the intensification and mechanization of production technologies. So far, insufficient knowledge is available about the energy efficiency of production technologies in livestock keeping, their share in the total energy consumption of a farm and how yield is influenced by energy inputs flow in a production process (Kraatz et al., 2006).

At the present time, the productivity and profitability of agricultural productions depend upon energy consumption (Tabatabaeefar et al., 2009). Efficient use of energy in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, preservation of fossil resources, and air pollution reduction (Mohammadi et al., 2008).

Today dairy farming and dairy farm milk collection posts are huge energy consumers, because of several operations such as milking machines, water heaters, milk coolers, vacuum pumps, lighting, etc. (Rodrigues et al., 2011). Nowadays, production systems, especially agricultural production, rely heavily on the consumption of non-renewable energy sources as fossil fuels. The non-renewable energy category is an important indicator of the sustainability of food production systems, given that it comes from finite resources which will eventually be exhausted beyond the level that can be economically extracted (Nguyen et al., 2010). In spite of positive effects as increased risks and reduced risks, consumption of fossil energy would result in negative environmental impacts through emission of CO_2 and other combustion gases (Refsgaard et al., 1998; Nguyen et al., 2008). Reaching a balance between available resources and the increased demands is an issue of interest for the public, politicians, and scientists. Moreover, global warming and decreasing available fossil fuels due to the increasing price of fossil- based energy are the aspects increase the interest to manage efficient use of non-renewable energy and alternative energy resources (Dahlquist et al., 2011).

The province of Tehran plays an important role in the national production of milk representing approximately 30% of total output. On the other hand, within Iran, Tehran province accounts for over 13% of the total number of dairy farms. The milk yield for the first three months of the year 2010 was announced as 265,501 tons from the 1,897 dairy farm units in Tehran Province (Anonymous, 2010b). It was reported that the average milk yield per cow (average Holstein cow weight was 635 kg) was about 27 kg day^{-1}.

Energy input-output analysis of agricultural systems has been considered by many authors (Ozkan et al., 2004; Canakci et al., 2005; Beheshti Tabar et al., 2010). This is usually made to evaluate the energy use pattern of inputs and outputs to find how efficiently the energy is utilized. Meanwhile, very few studies have been conducted on energy use pattern analysis of livestock keeping especially on dairy farming (Kaknaroglu, 2010; Meul et al., 2007; Moitzi et al., 2010; Cederberg and Mattsson; 2000). Meul et al. (2007) determined the energy use and energy use efficiency of specialized dairy, arable and pig farms during different time periods in Flanders. Later, Koknaroglu (2010) conducted a study on cultural energy analyses of dairy cows fed different concentrate levels. The cultural energy included energy expended on feed preparation, feeding, inspection, veterinary care, waste removal, milking, electricity and water. In addition, Moitzi et al. (2010) investigated the energy requirement (fuel and electricity) for two Austrian dairy farms and discussed the energy demand of feed stuff (forage and concentrate) production system.

In recent years several researches have been conducted on econometric analysis of inputs and outputs of agricultural production systems. Sensitivity analysis of the model parameters has also been employed to verify how a given model depends on its input factors. Against this background, any investigation of the relationship between energy inputs and milk yield is suggested to consider. Sensitivity analysis allows finding the consistent and inconsistent inputs to milk yield, reducing extra energy costs and approval of modern management techniques. These methods have been used in several case studies in agriculture (Singh et al. 2004; Mobtaker et al., 2010; Pishgar Komleh et al., 2011a; Mousavi-Avval et al., 2011a; Mousavi-Avval et al., 2011c). Regardless of an extensive use of econometric analysis in agriculture, an almost complete survey on previous studies showed that related research to livestock keeping have been rarely considered.

Due to the importance of non-renewable energy (NRE) and renewable energy (RE) use in modern agriculture, this paper presents a study carried out to investigate the input-output energy use pattern relevant to renewable and non-renewable energy forms and analyse mathematical functional relationship between milk yield and various non-renewable energy inputs viz. fossil fuels (diesel fuel, gas, gasoline and kerosene), electricity and machinery of dairy farming in Tehran Province of Iran.

2. Materials and method

Tehran Province is located within 35°34' and 35°50' north latitude and 51°02' and 51° 36' east longitude (Anonymous, 2010a). The province was announced to produce 265,501 tons milk in the first three months of 2010 production period (Anonymous, 2010b); this is a specific percentage of dairy production in Iran. Hence because of that eventually high share on the total dairy production, the province of Teheran was used in this study. More detailed information about studied farms and cows are given in Table 1. Data were collected from 47 dairy farms by using a face to face questionnaire in June and July 2011. The required sample size was determined using simple random sampling method as below (Cochran, 1977).

$$n=\frac{N\times s^2\times t^2}{(N-1)\,d^2+(s^2\times t^2)}$$

where n is the required sample size, N is the number of dairy farms producers in target population, s is the standard deviation, t is the t value at 95% confidence limit (1.96), and d is the acceptable error. The permissible error in the sample size was defined to be 5% for 95% confidence.

Some assumptions were compulsory due to have a much more precise computation such as the period for which energy consumption was estimated for. A lactation period of a cow is 305 days and cows are dry about 60 days. Therefore, operations following milking and before a cow start lactating were not regarded in this study.

Non-renewable energy inputs in milk production were machinery, fossil fuels and electricity; while renewable energy sources consisted of feed intake, human labour and water. The output was considered as milk yield. It is important to note here that the renewable energy use calculation is not a part of this analysis scope but they were considered in order to have a sophisticated conclusion part. The energy coefficient equivalents presented in Table 2, were applied to calculate the energy input amounts. This was calculated by multiplying different energy coefficients (Table 2) with their amount of resource use. However, the machinery energy input was estimated by considering the energy which was used to produce the machines and their economic life time using the following equation. It is essential to state that the expended time of each machine per head of cow was considered to calculate the energy used for each machine per head of cow. (Mousavi Avval et al., 2011b; Pishgar et al., 2011b):

$$ME=\frac{G\times M_P\times t}{T}$$

where ME is the machinery energy per cow (MJ cow^{-1}); G is the material mass used for manufacturing (kg); M_P the production energy of material in a year (MJ kg^{-1}), t is the time that machine used per cow (h cow^{-1}), and T is the economic life time of machine (h). This energy indicates the energy use during manufacturing process of machinery.

Water energy consumption referred to the amount of energy expended to supply water needs from wells for cows and dairy farms was divided into two categories: direct energy (DE) and indirect energy (IDE). To measure the DE use the following formula was used as follows (Kitani, 1999):

$$DE=\frac{Q\,\rho\,g\,h}{10^6\,\eta_1\,\eta_2}$$

Where Q is referred to discharge flow rate per cow in the target period (365 days) (m^3 cow^{-1}), ρ is the density of water (kg m^3), g acceleration due to gravity (m s^{-2}), h is the net head between the upper and the lower water levels (in m) and η_1 and η_2 are pump efficiency (0.7-0.9) and overall efficiency of conveyance and application in electrical motors (0.18-0.2), respectively. Subsequently, DE represents the energy consumption of water (in MJ cow^{-1}).

Pointing out that output is a function of inputs, production function can be expressed as:

$$Y=f\,(X_{it})$$

where Y is output (milk yield) level, X_{it} is a vector of input variables that affect output such as electricity, fossil fuel and machinery and t is a time subscript.

In order to estimate this relationship, a mathematical function needs to be modeled. For this purpose, several functions were tried, and the Cobb–Douglas production function was applied since it yielded best estimates among the others in terms of statistical significance and expected signs of parameters. The Cobb–Douglas production function is expressed in general as following form (Hatirli et al., 2005);

$$\ln Y_i=\sum_{j=1}^{n}\alpha_j \ln(X_{ij})+e_i \quad i=1,2,\ldots,47$$

where Y_i denotes the yield of the ith farmer, X_{ij} the vector of inputs used in the production process, α_j represent coefficients of inputs which are estimated from the model and e_i is the error term. With assumption that the dependent variable Y was taken as milk yield (the main product of dairy farms) and was specified as a function of electricity, fossil fuels and machinery energy, Eq.(5) can be expanded to Eq.(6);

$$\ln Y_i=\alpha_1 \ln(X_1)+\alpha_2 \ln(X_2)+\alpha_3 \ln(X_3)+e_i$$

where X_1 is fuel energy, X_2 is labor energy, X_3 machinery energy all in MJ cow^{-1}.

Since the marginal product governs the law of production, the marginal physical productivity (MPP) technique, based on the response coefficients of the inputs, was used to determine the sensitivity of a particular energy input on production. The MPP of a fact indicates the change in the output with a unit change in the factor input in question, keeping all other factors constant at their geometric mean level. Negative value of MPP states that it is better to keep it in surplus rather than using it as a fixed resource (Singh et al., 2004). The MPP of the various inputs was computed using the αj of the various energy inputs as;

$$MPP_{xj} = \frac{GM(Y)}{GM(X_{ij})} \times \alpha_{ij}$$

where MPP_{xj} is marginal physical productivity of jth input, α_{ij} regression coefficient of jth input, $GM(Y)$ geometric mean of milk yield and $GM(X_{ij})$ geometric mean of jth input energy. A positive value of MPP of any factor indicates that production is increasing with an increase in input. A negative value of MPP of any factor input indicates that additional units of inputs are contributing negatively to production, i.e. less production with more input.

In validating the econometric models, autocorrelation was applied by using Durbin-Watson test (Singh et al. 2004). Return to scale was calculated by adding the elasticities ($\sum \alpha_{ij}$) derived in the form of regression coefficients in the Cobb-Douglas production function. Return to scale stresses the proportionate change in output due to an equi-proportionate change in all the inputs (Singh et al., 2004). Equations 9–11 were estimated using the Ordinary Least Square (OLS) technique. The whole calculations were carried out using the Microsoft Excel 2010 and SPSS 19.0 software programs.

3. Results and discussion

3.1. Analysis of energy input-output in dairy farming

The collected data from 47 dairy farms in Tehran Province were analysed and the results are mentioned as following; considering the point that the data were collected in 2010 production period by a face to face questionnaire method. The whole dairy farms had 3 times milking a day and the analysis was carried out in 365 days of lactation and drying period of a cow.

Table 3 shows the renewable and non-renewable energy input equivalents with the amounts of output and their energy equivalents, as well. The total non-renewable energy input was required as 9997 MJ cow^{-1}. The average milk yield was determined to be 8 ton cow^{-1} in 365 days of milking period and its corresponding energy was 57,744.3 MJ cow^{-1}. The total energy use (renewable and non-renewable) was calculated to be 49368 MJ cow^{-1}. In literature, Koknaroglu (2010) calculated the total cultural energy expended in dairy farming including cultural energy expended for feed, operations, transportation and machinery and equipment as 19,700 MJ cow^{-1}. As Meul et al. (2007) reported the total energy input was 36,372 MJ ha^{-1} (with assumption of this study conditions it is about 40000 MJ cow^{-1}) for dairy farms in 2000-2010 in Flanders. Furthermore, renewable and non-renewable energy quantities were 39371 and 9997 MJ cow^{-1}, respectively in our study.

The results also revealed that among non-renewable energy sources, fossil fuels with 7824 MJ cow^{-1} (78%) is significantly utilized during milk production processes and the second rank belongs to electricity with 17% portion. Similar results were reported in literature that the diesel fuel and electricity are between the first two energy consuming inputs (Meul et al., 2007; Moitzi et al., 2010).

To sum it up, this analysis illustrated that efforts to improve the overall energetic efficiency should be focused on electricity usage and fuel consumption. However, almost all of the dairy farming equipment are operated on electricity but farm managers can save on electricity use by maintaining the electrical motors to perform better, substituting old motors with saving energy ones and implementing machines in low consuming hours of a day. As far as electricity production is mainly dependent on fossil fuels which both are the non-renewable energy sources, using more renewable energy sources such as solar energy, biofuels and wind power is suggested to have a sustainable production system. Apart from using renewable sources, improving tractor operating performance and replacement of obsolete machines is recommended.

3.2. Econometric model estimation between non-renewable energy inputs and milk yield

The Cobb-Douglas production function was specified in order to investigate the relationship between energy inputs and milk yield. Milk was assumed to be a function of electricity, fossil fuel and machinery energy. It is worth pointing out that elasticity and impact are exactly alike (Mohammadi and Omid, 2010a). Durbin-Watson was found to be 2.3 for Eq. (6) which implies that there was no autocorrelation at the 5% significance level in the estimated model.

Table 1: Characteristics of dairy farms and cows of studied area

Breed of cows	Holstein
Average No. of cows per farms (head)	129
Lactation period	305
drying period (days)	60
Average milk yield (kg day^{-1} cow^{-1})	26.5
No. of lactations (times per day)	3
Average feed intake of lactating cow (kg day^{-1} cow^{-1}) (DM*)	19
Average feed intake of dry cow (kg day^{-1} cow^{-1}) (DM)	35

*Dry matter

Table 2: Energy coefficients of non-renewable and renewable energy inputs and output

Inputs(unit)	Energy coefficient (MJ unit^{-1})	Reference
A. Inputs		
Tractor and self-propelled(kg a*)	9-10	(Kitani, 1999)
Stationary equipment (kg a*)	8-10	(Kitani, 1999)
Implement and machinery(kg a*)	6-8	(Kitani, 1999)
Fossil fuels		
(a) Diesel(l)	47.8	(Kitani, 1999)
(b) Gasoline(l)	46.3	(Kitani, 1999)
(c) Kerosene(l)	36.7	(Kitani, 1999)
(d) Natural gas(m^3)	49.5	(Kitani, 1999)
Electricity(kWh)	11.93	(Ozkan et al., 2004)
Human labour (h)	1.96	(Kitani, 1999)
Feed		
(a) Concentrate(kg)	6.3	(Muel, 2007)
(b) Silage (kg)	2.2	(Wells, 2001)
(c) Alfalfa (kg)	1.5	(Sainz, 2003)
Water (m^3)	1.02	(Mohammadi, 2010b)
B. Outputs		
(a) Milk(kg)	7.14	(Coley et al., 1998)
(b) Cow manure(kg Dry matter)	0.3	(Singh & Mittal, 1992)

Table 3**:** Non-renewable and renewable energy inputs and energy output equivalents (MJ cow^{-1})

Item	Total energy equivalent (MJ cow^{-1})
A. Inputs	
Fossil fuels	7,824
Electricity	1698
Machinery	475
Total non-renewable energy	9997
Human labour	406
Feed	38,704
Water	261
Total renewable energy	39,371
B. Output	
Milk	57744.3
Cow manure	572

Table 4: Econometric estimation and sensitivity analysis of milk production

Independent variable	Coefficient	t-Ratio	MPP
Model 1: $lnY_i=\alpha_1 ln(X_1)+\alpha_2 ln(X_2)+\alpha_3 ln(X_3)+e_i$			
Constant	8.7	12.6^a	
Fossil fuels	0.18	2.4^b	0.18
Electricity	-0.15	-2	-0.18
Machinery	-0.03	-0.7	-0.04
Fossil fuels	0.18	2.4^b	0.18
Electricity	-0.15	-2	-0.18
Machinery	-0.03	-0.7	-0.04
Return to scale	0		

^{a} significant at 1% level, ^{b} significant at 5% level

The R^2 (coefficient of determination) was as 0.87 for this linear regression model indicating the relationship between input and output parameters. Estimated coefficients indicated that the impact of fossil fuels could be assessed positive on milk yield. Fossil fuels had the highest impact (0.18) indicating that by increase in the energy obtained from fossil fuels input, the amount of yield improves in present condition. With respect to the assessed results, increasing 10% in the energy of fossil fuel led to 1.8% increase in milk output. Electricity and machinery found inconsistent with improving the yield of milk. The regression results of Eq. (6) (Table 4) revealed that fossil fuels energy is contributed to productivity at 5% level.

Due to lack of research into relationship between energy inputs and yield in dairy farming systems, the results are compared with crop production systems. No study was found on econometric analysis of energy inputs and milk yield during our long research in literature review.

The research also sought to do sensitivity analysis. The results of sensitivity analysis indicate which variables should be identified and measured most carefully to assess the state of the environmental system, and which factors should be managed preferentially (Drechsler, 1998). Within this framework, the sensitivity of NRE inputs was analyzed using the MPP method and partial regression coefficients on output level and the results are provided in Table 4. As can be seen, the MPP value of fuel was found to be 0.18. This indicates that an increase of 1 MJ in this input, would lead to an additional increase in yield by 0.18 kg cow^{-1}. Hence, one should not stop increasing the use of fossil fuels so long as the resource is not fully utilized. The value of return to scale for the model (6) was calculated by gathering the regression coefficients as 0. The less than unity return to scale indicates a decreasing return to scale. This emphasizes the proportionate change in output due to an equi-proportionate change in all the inputs.

Due to lack of literature review, the results were compared with other researches in crop productions. The biggest MPP value was drawn by machinery energy as Mousavi- Avval et al. (2011c) reported. The same result was investigated in canola production (Mousavi-Avval et al., 2011a). Mobtaker et al. (2010) found that an additional unit of human labour and machinery had a positive contribution to barely yield.

4. Conclusion

Data used in this study were collected from 47 dairy farms located in Tehran Province of Iran. The main objective of the present research was to estimate the relationship between non-renewable energy inputs (fossil fuels, electricity and machinery) and milk yield and input sensitivity was analyzed, as well. Moreover, the NRE and RE flows were investigated. The total NRE equivalent was calculated to be 9997 MJ cow^{-1}. The highest rate of energy in the total amount was generated by fossil fuels followed by the kind of energy brought about by electricity. In consequence of econometric analysis fossil fuels had the highest impact on milk yield. Indeed, the high rate of fossil fuel and electricity energy consumption was due to the fact that almost all of the livestock keeping equipment are running with these two power sources. The dependency of milk production on fossil fuels and machinery (fossil fuels utilized in machinery production process) cause impacts on human health and ecosystems and also confronts communities with greenhouse gas emissions crisis. Energy management becomes more important if the energy needed is to be economical, sustainable and productive. The inefficient use of electricity and fossil fuels not only threaten the sustainability of dairy farming and saving costs in Iran, but also this may bring about adverse human health effects. It is recommended to develop the rational and more efficient production systems in livestock keeping, monitor the use of energy inputs which is called energy auditing and employ the recent techniques extensively. Besides, more alternative renewable energy sources should be introduced to farmers and equipment manufacturers such as solar energy, wind energy, biofuels and etc.

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