Original Research Paper

ECONOMIC ANALYSIS OF HOUSEHOLD ENERGY CONSUMPTION: THE CASE OF HERDERS IN MONGOLIA

GANCHIMEG G., HAVRLAND B.

Institute of Tropics and Subtropics, Czech University of Life Sciences, Prague, Czech Republic

Abstract

Access to adequate electricity and heating is a key factor in increasing agricultural productivity and improve livelihoods of Mongolian herder households. Currently, the share of herder households with electricity sources accounts for 77.2 per cent of a total of 170.1 thousand herder households. This article reports a study which carried out an economic analysis of the herders´ demand for electricity and heating.

We estimated the herder household's energy consumption based on the energy ladder hypothesis, Engle curves and Almost Ideal Demand System (AIDS) model as demand system analysis. The model specification was based on survey in which the herders were interviewed about their household's electricity and heating conditions, its satisfaction, a herder household's incomes and expenditures, and fuel type that they use.

The results of the study show that the Energy Ladder hypothesis fits to herder households in Mongolia. They use mostly dung, wood, forest and grass waste, and coal with regard to their income and energy source availability. The dung is widely available free of charge, and so it is not selected to a multi-stage budgeting process. The estimated share of energy expenditure shows that energy is becoming a necessity for herders. Total household expenditure is inversely related to the energy expenditure share. Total energy budget elasticities of wood, waste and coal are 1.11, 0.20 and 0.99, respectively.

The main conclusions made on the study results are that the herder's energy consumption is on a very low level and some efficient policy interventions are necessary to improve the standard of living for herder families

Keywords: Economic analysis; electricity and heating; energy ladder; Engel curve; herder household; Mongolia.

INTRODUCTION

Although a number of researchers studied the herder households' income, expenditures, labour productivity, herding regime, education and gender issues, risks, yet few of them have in detail been interested in their energy consumption and provision. The Mongolian herders have a worldwide unique nomadic way of life. Hence they need a special way of supplying adequate and proper energy resources.

Access to adequate energy is a key factor to increase agricultural productivity and improve rural livelihoods. Providing multiple energy sources for cooking and heating as well as enough power for industry and transportation, bio energy (and other renewable energies such as solar, wind and geothermal) can strongly contribute to increase labour productivity and diversification of economic activities in rural areas. According to FAO, the energy is an essential element for both the fulfilment of basic human needs - especially cooking and heating, but also hygiene, health, etc. and for sustainable rural development, including agriculture, food processing and education (FAO, 1999). Transition from the present energy supply of mainly firewood and animal and human power, to a more diversified base and a better use of commercial energy, is the key factor to improving living conditions of rural population.

Currently in Mongolia there are 305 (about 91 percent) of total of 332 soum centres[1] and settlements connected to the electrical transmission systems. Connecting to the central gridlines system is possible for the rest of the soums but not for isolated herder households due to their nomadic life tradition. About 69 percent of herder households utilize wind or solar panels only for evening light and for a few hours of watching TV program compatible with modern human basic needs. According to the Renewable Energy for Rural Access Project (WB Project, 2006), one of the key signs of the improved life and welfare is access to modern infrastructure services, and in particular to electricity. Only about 25% of herder households have access to electricity, compared with the same access of 80% of soum centre residents, and over 90% in the urban areas where about 1.5 million people live (Reap, 2006). This finding indicates that the level of access to electricity is two times lower than official statistical data report.

[1] Herder centre

Most nomadic herder households have no access to electricity. The main reasons include (**i**) high costs of household power systems coupled with low incomes of many herder households; (**ii**) sustainable policy support for providing adequate energy sources to herder household level, and (**iii**) a nascent market of renewable energy producer which lacks basic quality and service standards. On the other hand, Mongolia is endowed with abundant solar and wind resources, which facilitate the adoption of solar home systems (SHSs) and small wind turbine systems (WTSs), two mature and highly portable technologies that suit the lifestyle of nomadic herders. With systems donated by the governments of China and Japan, the Mongolian government launched a "100 000 Solar Sets" program in 2001 and provided some 100 000 SHSs to herder households by 2009 (Zorigt 2009). Thereafter the progress of herders' electricity access has stagnated.

The article refers the study addressing several objectives: it makes an economic analysis of herder household's energy consumption and insight into the interrelationships between energy consumption and household wealth (animal numbers), find possible activities to have adequate sustainable energy sources.

MATERIALS AND METHODS

Theoretical framework of Analysis

The survey consisted of the following steps:

1. The theoretical framework developed in this study is the energy mix model which infers that households decide on the types of energy sources to use.
2. The energy consumption behaviour was analyzed. That allowed testing various assumptions on the consumer's behaviour.
3. The last step was empirical study with collection of data on household energy consumption and estimating empirical model according to the theoretically-based models.

The demand for various sources of energy has been analyzed theoretically and empirically using different approaches. They include the energy ladder hypothesis (Kebede et al., 2002; Arnold et al., 2006; Davis, 1998; Masera et al., 2000; Barnett, 2000), the Engel curves (Amacher et al., 1993, 1996, 1999; Mekonnen, 1999; Helberg et al., 2000; Gundimeda and Kohlin, 2003; Baland et al., 2005), and energy demand functions (Athukorala et al., 2007; Erdogdu, 2006).

The energy ladder hypothesis

The energy ladder model is one of the most common approaches used in studying the household energy consumption. According to the classic energy ladder a household at lower levels of income and development tends to be at the bottom of the energy ladder, using fuel that is cheap and locally available (Fig. 1). Exclusively, over three billion people worldwide are at these lower rungs, depending on biomass fuels: crop waste, dung, wood, leaves, etc., and coal to meet their energy needs. A disproportionate number of these individuals reside in Asia and Africa (Rehfuess and WHO 2006). Coal is seen as a higher quality fuel due to its efficiency and storage, and thus is higher on the energy ladder. As incomes rise, one would expect that households would substitute for higher quality fuel choices. However, this process has been quite slow. The key determinants of energy demand in the household sector include:

- Price of fuels and appliances;
- Availability of fuels and appliances;
- Disposable income of households;
- Particular requirements related to each individual; and
- Cultural preferences.

With increasing disposable income and changes in lifestyle, households tend to move from the cheapest and least convenient level (fuels) to more convenient and usually more expensive ones (Dziobinski, 1999).

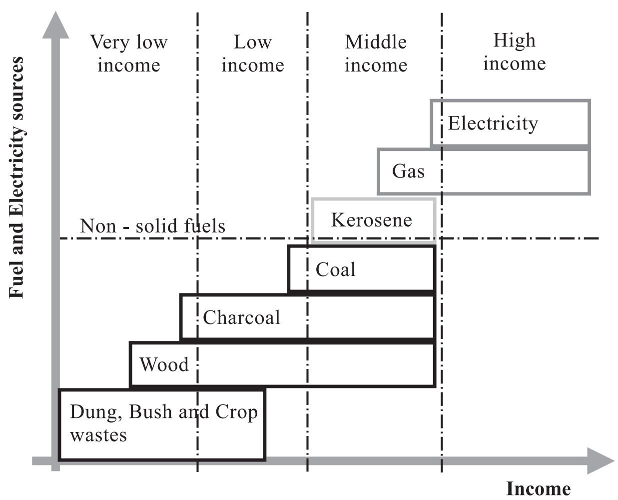

Figure 1: The energy ladder

Household energy expenditure and Engel function

In this study, Engel functions were estimated for the herder households. A hypothesis was assumed that the households first make their decision on the allocation of the total budget on total energy expenditure and then decide how much to allocate on individual fuels within the energy budget. In this study the second stage of the step-wise budgeting was tested empirically by estimating Engel curves using the functional form:

Wi=á+â (ln TEE) (1)

where, **W*i*** .... Energy budget share of fuel *i,* kWh;
TEE .... Total energy expenditure, curr. and
á and **â** ...... Parameters to be calculated

Engel curves were estimated for firewood, dung, wind, solar energy and electricity separately for all and household's averages. The semi-logarithmic model is regarded to be the best suited for empirical estimations of Engel functions (Prais and Houthakker, 1955). Budget elasticity (**çi**) for individual fuels, across sectors and over time was calculated by dividing the estimated coefficient "â" by the energy budget share (Sadoulet and Janvry, 1995).

The Almost Ideal Demand System (AIDS)

AIDS is a useful tool in the analysis of household energy consumption given the fact that both household expenditure and the prices of alternative sources of energy influence the share of any one source of energy in the energy mix (Deaton and Muellbauer, 1980).

$$\omega_i = \alpha_i + \beta_i \ln TEE + \delta X + \sum \gamma_j \ln p_j + \mu_i R_i + \vartheta \quad (2)$$

Where: ω_i… the share of energy expenditure on fuel ***i*** in total household expenditure;
p… price of fuel ***j****;* curr.
X … vector of household characteristics with corresponding coefficient;
δ… actual household characteristics that go into the functional form. They will be determined by a combination of theoretical, pragmatic and econometric considerations;
R … corresponding i^{th} region of the household (i = 1…5);
α, β, γ and μ… parameters to be calculated;
ϑ … error term.

Here β is to determine whether energy is a luxury, a necessity or of inferior importance. If β > 0, then the commodity (energy) is a luxury one, and if β < 0, the commodity becomes a necessity, or of inferior importance (Deaton and Muellbauer, 1980). The household factor X enters into the model in linear specification. The coefficients of the variables enable us to assess how the energy share is affected by household factors. The parameters of the model are related to the elasticity as follows (Berck et al. 1997)

$$\varepsilon_{ii} = -1 + \frac{\gamma_{ii}}{\omega_i} - \beta_i \quad (3)$$

$$\varepsilon_{ij} = \frac{\gamma_{ii}}{\omega_i} - \frac{\beta_i \omega_j}{\omega_j} \quad (4)$$

$$\varepsilon_{ix} = \beta_i + 1 \quad (5)$$

Where: ε_{ix} and ε_{ij} are the price and income (expenditure) elasticities respectively.

Herding households' survey has generated more than 50 variables excluding open ended questions. Variable selection has been made based on statistical significance as well as economics expectations.

Data collection and household characteristics

The model specification was based on the survey during which the herders were interviewed about their household's electricity and heating conditions, level of their satisfaction, the herder household's income and expenditures, and fuel type that they use. This information was used for an economic analysis of energy consumption of herder households of the five agro-ecological zones. Seventy six herder households were randomly selected from different agro-ecological zones for this study. Each household was different in several respects, such as: size, educational level and other characteristics that are expected to have different expenditure patterns. Because of these reasons the demand depends not only on prices and family budget but also on household characteristics. We differentiated between electrified and non-electrified households as they have different choice sets and their energy expenditure and choice were affected by socioeconomic conditions. The electrified households use electricity (small amount), firewood and dung or coal while the non-electrified ones used mainly firewood and dung or coal which were not environment-friendly. Use of coal and firewood or dung depends on region's differences and availability of these sources.

The survey was carried out by interviews with groups of key informants. Additional data on population, price of fuels were collected from administrative records.

RESULTS AND DISCUSSION

Survey Results

Herding households' survey has generated more than 50 variables. Variable selection was made based on statistical significance as well as economic expectations that we have explored in theoretical framework and in this study, too. Comparatively small sample was selected because due to timing and cost possibilities some variables did not represent the herding households on the national level. Most predefined variables were statistically significant with higher significance. A total of 19 variables selected from each household and in additionally three price vectors were included.

Results obtained through all the three equations were highly significant. We thus interpret the relationships between share of firewood, waste and coal against the other selected variables. The share of firewood in the energy budget increases when the total energy expenditure grows while in the same time the shares of waste and coal decrease. We may interpret these results so that firewood is a usual fuel and waste and coal are fuels of an inferior quality. Besides this, also traditional approach to energy sources must be taken into account, i.e. the consumption of firewood and not wastes and coal which is due to the fact that the firewood is easily available and cleaner than the other two fuels.

Energy Ladder in the Case of Mongolia

The result of the study illustrates that the Energy Ladder hypothesis fits to the case of Mongolia (Fig 2).

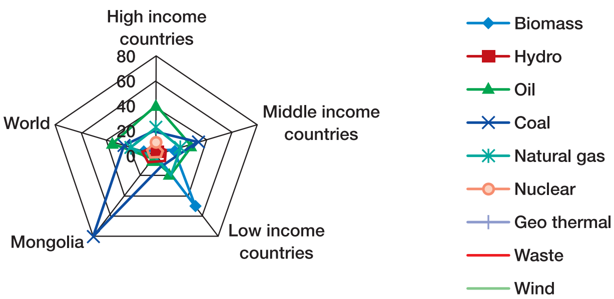

Figure 2: Application of the Energy ladder hypothesis for Mongolia

The herder households mostly use dung, wood, forest and grass wastes and coal with regard to their income and energy source availability. The share of energy expenditure on the total of herder household budget shows that the energy represents necessity for herders. The variables such as number of animals, ger size[2], family size and khot ail[3] size have positive relationship with the share of energy expenditure - this is in tune with our expectations, i.e. a bigger and/or richer family requires more energy to cover their needs. Total household expenditure is inversely related to the energy expenditure share. Total energy budget elasticity of wood, waste and coal are 1.11, 0.20 and 0.99, respectively. The number of animals, ger size, family size and khot ail size had a positive relationship with share of energy expenditure.

From the total of 76 herder households in the sample, only 16 households or 21% live close to the central gridline system while the rest (79%) are not connected to electricity transmission system. Those 16 households live within five kilometres from soum or city centre like Darkhan-Uul and Sukhbaatar. The households situated close to the town centres are usually semi-intensive or work in more than one sector (milk and/or some vegetable production). The sampling did not purposely select households without any electricity sources; thus the ratios of electrified and non-electrified are rather random outcomes. The percentage of electrified households in our sample is somewhat higher than the data of National Statistical Office of Mongolia. Amongst selected herding households some 37 or 48% have solar or wind energy generation devices.

Energy Consumption by an Average Herder Household

The calculations show that an average herder household's basic electricity consumption estimate (made by National Renewable Energy Centre of Mongolia - NREC), 1.2 kWh (36 kWh per month and 432 kWh per year) could be sufficient if the scarce resources reach this level. Presently, herder households use 16 W colour TV for 5 hours a day, 13 W fluorescent lamp for 6 hours a day, 0.5 W radio for 10 hours a day - which is together 160 Wh (0.16 kWh) per day. In our survey, herder household's electricity consumption was estimated to be about 100 - 140 Wh per day. This amount of energy consumption is 25 - 30 times lower than that in cities or towns.

Mongolian Governmental program entitled "100 000 Solar Ger" enables herders´ households to purchase solar panels for reduced prices. The program started in 2005; 100 000 solar panels of potential 55 W were delivered to the herders´ households. Its price was set around 250 000 - 280 000 MNT ($ US 200 - 225). In our sampling only three households had hybrid sources of energy (combination of solar panels and wind mills). Although they use hybrid sources the consumptions were at the level of households with a single source.

The First Stage of Budgeting – Total Energy Expenditure: Household Expenditure

Table 1: Total energy expenditure (estimated variables) for selected herder households in Mongolia

Variable	Coefficients	t-statistics
Constant	0.642	4.21
LnTE	-0.280**	1.140**
LnAnimalValue (x_1)	0.310	2.511
FamilyMembers* (x_2)	0.101	2.591
EducHH_Head (x_3)	-0.011	-3.180
GerSize (x_4)	0.001	4.370
KhotailSize (x_5)	0.121	4.671
R^2	0.308	
Durbin-Watson	2.1	
Significance level	0.001	

* Variable "Family Members" has been generated from adding up number of adults and number of kids in the household. This variable represents family size in general;
** Significant at 10%.

[2] Village level
[3] Herder centre in the steppe

Table 1 presents results of the survey on the energy expenditure shares of herding households. In conclusion, the model fits the expectations, i.e. all variables are statistically significant and are consistent with the hypothesis (see Methodology). The total expenditures are inversely related to the energy expenditure share at probability level of 10 percent. Therefore our assumption of energy ladder model is in line with our survey results.

From this we may assume that energy is a necessity or of inferior significance ($\vartheta < 0$), (Deaton and Muellbauer, 1980). The variables such as number of animals, ger size, family size and khot ail size were all in positive relationship with share of energy expenditure which met our expectation. Certainly a bigger and/or richer family would require more and more energy to cover their needs.

Based on the simulation results the Engel function can be represented as the following formula. Thus:

$$\omega_{TEE} = 0.642 - 0.280 * \text{h } E \ + 0.310 * X_1 + 0.101 * X_2 - \\ - 0.011 * X_3 + 0.001 + 0.121 * X_5 \quad \textbf{(6)}$$

The variables x_1 - x_5 represent household characteristics (see Table 1). The function above allows us to draw the Engel curve. Different income levels were applied to estimate corresponding energy budget share.

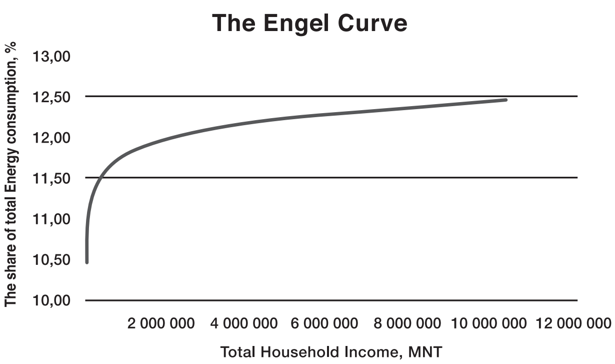

Figure 3: Engel curve of the energy consumption

The shape of the curve (Fig. 3) shows that the energy is classed as a necessity in the case of herder household's expenditure in Mongolia.

Second Stage of Budgeting – Allocation of Energy Budget

Allocation of energy budget to individual fuels has been the second stage of our modelling. It is connected to a system of equations, determining the shares of each fuel in the energy mix of certain households` total energy expenditure. The system of equations was estimated by SPSS.

Table 2 offers the estimates of the energy expenditure shares of different fuels along with the overall statistics, i.e. indication of statistical probability level of the individual variables.

All the three equations yielded highly significant results; we thus interpret the relationships between shares of firewood, waste and coal against the other selected variables listed in the above Table 2. The share of firewood in the energy budget increases as total energy expenditure increase, whereas the shares of waste and coal decrease. Economically, we may interpret that firewood is the usual good and waste and coal are of inferior significance. Besides, economic interpretation can also be traditional consumption of firewood instead of waste and coal where firewood is easily available and cleaner than the other two fuels. Total energy budget elasticity of wood, waste and coal are 1.11, 0.20 and 0.99, respectively. Thus as total energy expenditure increases, the quantitiy of wood increases by more than the percentage increase in total energy expenditure, whereas the quantity of waste increases far less than the percentage increase in total energy expenditure. Surprisingly, the change of coal quantity is nearly the same as the percentage change in total energy expenditure.

Furthermore, price elatisitices of the selected energy sources is estimated. All own price elasticities are negative, which purely meets the law of demand. Wood is inelastic, whereas the other two are relatively elastic.

All cross price elasticities have an absolute value of less than one; this means none of the highly sensitive across fuel source selection. It can be different within a region; therefore strong regional indicators should be included in a follow up study. Both wood and coal are more sensitive than waste, especially wood is 10 times sensitive than waste, which could be an important factor for policy formulation. Stimulation policy for the use of forest and grass waste could be double incentives for forest and nature conservation.

CONCLUSIONS

1. Mongolian herder households' energy equilibrium is in deficiency. Current average consumption is 160 Wh (0.16 kWh) per day. That does not meet basic human needs.
2. Analysis of the results shows that the herder household's energy supply is considered as necessity. Variables such as the number of animals, ger size, family size and khot ail size have a positive correlation with the share of energy expenditure.
3. The bigger and/or richer families will require more

Table 2. Share of individual fuels in herding households energy consumption

Variable	Share Wood		Share Waste		Share Coal	
	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.
Constant	-0.841**	1.70	1.12**	1.52	0.775**	1.64
LnTEE	0.105	2.20	-0.801	-2.41	-0.012	-2.02
LnAnimalValue	0.70	2.62	-0.009	2.511	-0.440	-2.44
FamilyMembers*	0.44**	1.32	-0.790	-2.590	0.021	2.74
EducHH_Head	0.019	3.10	-0.001	-2.003	-0.020	-3.21
GerSize	-0.21	-2.11	0.002	2.400	0.005	3.01
KhotailSize	0.014	2.48	-0.211	-3.52	0.009	2.22
FuelWoodPrice	-0.470	-2.18	0.370	3.421	0.210	2.15
FuelWastePrice	-0.301	-1.98	-0.185	2.971	0.231	1.45**
FuelCoalPrice	0.281	3.44	0.200	2.490	-0.204	1.97
R^2	0.511		0.311		0.321	
Durbin-Watson	1.620		1.711		2.001	
Significance level	0.000		0.000		0.000	

**Significant at 10%

Table 3. Price elasticities of the selected energy sources demand in herding households

ÄQ	ÄP		
	Wood	Waste	Coal
Wood	-1.13	0.12	0.05
Waste	-0.84	-0.19	0.30
Coal	-0.08	-0.004	-0.95

and more energy to cover their needs. When the size of herder´s animal herd surpass a certain number (500 and more livestock heads), then there is little correlation between the level of energy consumption and growing number of animals.

4. The poorer herders do not have the possibility to get electricity themselves. They cannot buy any solar systems although their price has recently dropped considerably. It has also been stated that women-headed households are herding lower numbers of livestock than the men-headed ones.
5. The herders have great willingness to maximize the numbers of animals instead of having enough energy resources. This hypothesis has not been proved by our survey. About 80% of herders express their wishes to have adequate and sustainable energy sources such as central gridlines system. The households which started to use small scale wind electricity generators or solar photovoltaic panels have a negative impression about these sources.
6. The herders request more powerful alternative energy sources (equipment) in order to assure their adequate (growing) electricity consumption.
7. The relevant Government intervention policy is directed towards support of improvements of rural livelihood through better management of the energy supply.
8. Mongolia has got vast resources of renewable energy and favourable climatic and weather conditions for their effective use.

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Corresponding author:

Prof. Ing. Bohumil Havrland, CSc.
Institute of Tropics and Subtropics
Czech University of Life Sciences Prague
Kamýcká 129
165 21 Prague- Suchdol
E-mail: havrland@its.czu.cz