Energy prices, energy efficiency, and fuel poverty[1]

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Abstract

Because electricity is much more efficient than other sources of energy for certain uses such as lighting, access to electricity can help in promoting energy affordability in developing countries. Using data from Guatemala, this note suggests that the price reduction per efficient kilowatt-hour which can be expected from access to electricity is substantial. This price reduction could generate a large reduction in measures of fuel poverty which capture the inability of households to meet their basic energy needs.

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1. Introduction

Many households in developing countries do not have the means to satisfy their basic energy needs. Part of the problem lies in the technologies used by those without access to electricity for lighting and powering appliances, such as candles, kerosene lamps, and batteries[2]. These technologies are orders of magnitude more expensive per efficient kilowatt-hour than electricity. Access to electricity could provide significant savings in energy costs for the population not yet connected to the grid. Using data from Guatemala, this note provides a simple method for measuring the reduction in the price of energy that can be expected from access to electricity. It also provides estimates of the reduction in fuel poverty which could be achieved with better access to electricity, where fuel poverty defined as the inability by households to meet their energy needs. Section 2 describes the method, and section 3 provides the results.

2. Methodology

A household is said to be fuel poor if its energy consumption does not meet basic energy needs. Following the income poverty literature, in order to measure fuel poverty, we use the first three measures of the FGT (Foster, Greer, and Thorbecke, 1984) class. The first measure is the headcount index of fuel poverty, which is simply the percentage of the population living in households with an equivalent energy consumption below the fuel poverty line. This is denoted by P_0. The second measure, which captures the depth of fuel poverty, is the fuel poverty gap index P_1. It estimates the average distance separating the fuel poor from the fuel poverty line as a proportion of that line (the mean is taken over the whole sample with a zero distance allocated to the households who are not poor). The third measure, which captures the severity of fuel poverty, is the squared fuel poverty gap index P_2. It takes into account not only the distance separating the fuel poor from the fuel poverty line, but also the inequality among the poor. Denoting by E_i the energy consumption for household i, by Z the fuel poverty line, by N population size, by w_i the weight for household i (equal to the household size times the expansion factor, the sum of the weights being N), the three fuel poverty measures are obtained for values of θ equal to 0, 1, and 2 in:

$$P_\theta = \sum_{E_i \le Z} (w_i / N)\left(1 - \frac{E_i}{Z}\right)^\theta \qquad (1)$$

When measuring the energy consumption of household, it is important to take into account the quality or efficiency of various fuels. In the case of Guatemala, the 1998/99 ENIGFAM (*Encuesta*

[2] The energy literature suggests the existence of a transition process whereby households gradually ascend an energy ladder. The ladder begins with biomass fuels (firewood and charcoal), moves to modern commercial fuels (kerosene and LPG), and culminates with electricity (e.g., Albouy and Nadifi, 1999). The reality is somewhat more complex and the empirical work suggests that at any given point in time, households rely on a range of fuels that encompasses at least two steps of the energy ladder (e.g., Barnes and Qian, 1992; Hosier and Kipondya, 1993; ESMAP, 1994; Eberhard and van Horen, 1995). In Guatemala, the country used for this note, our data indicates that households use on average 2.6 different types of fuels.

Nacional de Ingresos y Gastos Familiares) income and expenditure survey provides monthly household expenditures for batteries, candles, electricity, fuelwood, kerosene and butane gas (in the case of fuelwood, for the households who gather their own wood, the survey provides an estimate provided by the household as to the cost of purchasing an equivalent amount of fuelwood in the market place). We convert these expenditures into comparable units of efficient energy consumption by using not only regional unit prices from Guatemala's Consumer Price Index, but also energy efficiency factors from the United Nations (1987). Formally, denoting by P_{ik} the market or "gross" price of fuel k with $k=1, ..., K$, for household i, by C_{ik} the household expenditures for that fuel, by EF_k the efficiency factor reflecting the quality of fuel k, and by E_{ik} the amount of energy provided by fuel k in standardized efficient kilowatt-hours, we obtain the total amount of energy provided by the various fuels for household i as:

$$E_i = \sum_{k=1}^{K} E_{ik} = \sum_{k=1}^{K} \frac{C_{ik}}{P_{ik} / EF_k} \qquad (2)$$

In equation (2), the net price per efficient kilowatt-hour for fuel k is equal to P_{ik} /EF_k. Table 1 compares the gross and net prices per kilowatt-hour for each fuel. For cooking, the net prices show that despite a low gross price, fuelwood is as costly as propane gas on a comparable efficiency basis. Both fuels are slightly cheaper than electricity in net terms. For lighting, the conversion from gross to net terms dramatically wipes out any apparent cost advantage of kerosene. Candles remain by far the most expensive source of lighting, whether in gross or net terms. For appliances, the gross to net conversion is not relevant since all alternatives are based on electricity. However, the figures show that batteries are substantially more expensive per kilowatt-hour than mains electricity.

Several methods can be used in order to estimate the fuel poverty line *Z*. One method consists in computing the average energy consumption of households whose overall per capita consumption level falls within plus or minus 10 percent of the US$ 1 (Purchasing Power Parity adjusted) income poverty line used in the international literature on income poverty. In the case of Guatemala in 1998/99, this gives a subsistence energy threshold of 2,125 kilowatt-hours per year (5.8 kilowatt-hours per day). A second method consists in defining a basic set of energy needs. A consultation with energy experts in Guatemala led to the suggestion that a household should be able to run two 60 watt light bulbs and one 16 watt radio for four hours each day. A household should also be able to use five two-kilogram logs of fuelwood each day for cooking. This leads to a fuel poverty line of 2,154 kilowatt-hours per year (5.9 kilowatt-hours per day). Given the similarity between the two estimates, we will adopt the first value as the fuel poverty line since it has the advantage of being derived directly from the household survey data set.

Next, to measure the impact of access to electricity on fuel poverty, we start by noting that the average net price paid by households *i* for each efficient kilowatt-hour of energy consumed is:

$$P_i = \frac{\sum_{k=1}^{K} C_{ik}}{\sum_{k=1}^{K} (C_{ik} / P_{ik}) EF_k} \qquad (3)$$

Given that electricity is much more efficient and thereby cheaper than other fuels for lighting, households without access to electricity are likely to have a higher net price per efficient kilowatt-hour than those with access. It turns out that the average value of P_i for households with access to electricity is 0.518 Qz (1 US$ ≅ 7.65 Qz) per efficient kilowatt-hour. The average value for households without access to electricity is 1.350 Qz. While part of this difference may be due to access to electricity itself, part may also be due to other differences in characteristics between households with access and households without access. To find out the marginal impact of access to electricity on efficient energy prices controlling for other household characteristics, regression analysis is needed. Let L represent a vector of geographic location dummies, H a vector of characteristics of the residents in the household including quintile dummies for the household's position in the distribution of per capita income, R a vector describing the physical characteristics of the household's residence, G a dummy variables for access to the electricity grid, and O a vector of dummies for access to other sources of energy. We estimate the following regression:

$$\log(P_i) = \beta_0 + \beta_1 L_i + \beta_2 H_i + \beta_3 R_i + \beta_4 G_i + \beta_5 O_i + \varepsilon_i \qquad (4)$$

A negative and statistically significant estimate for β_4 would suggest that access to electricity reduces efficient energy prices by β_4 percent. When households without access gain access to electricity, their energy price would then be reduced to $P_i(1+\beta_4)$. If we assume that the amount of resources devoted to energy by the household remains unchanged after the reduction in price provided by access to electricity (this may under-estimate the impact of the reduction in price on fuel poverty if energy is a normal good), the new level of consumption is given by $E_i/(1+\beta_4)$, in which case fuel poverty becomes:

$$P_\theta = \sum_{E_i \le Z} (w_i / N) \left[1 - \frac{E_i /(1+\beta_4)}{Z} \right]^\theta \qquad (5)$$

3. Results

Table 2 provides estimates of fuel poverty based on the fuel poverty line of 2,125 kilowatt-hours per household per year. Among the households with access to electricity, the average price paid per effective kilowatt-hour is 0.52 Qz, and the average yearly consumption is 3.804 kwh. The households without access to electricity have a lower consumption (2,892 kwh) and they pay a higher price (1.35 Qz/kwh). One fourth of the population with access to electricity is fuel poor (headcount index of fuel poverty equal to 0.255), as compared to half of the population without access (headcount of 0.509). The differences between the two household groups are even larger with the poverty gap and square poverty gap. If the households without access were given access to electricity, the headcount index of fuel poverty among that group would be reduced to 0.365, and the other fuel poverty measures would be reduced similarly. The relatively large impact of access to electricity on fuel poverty comes from the regression estimates provided in table 3. At the national level, the coefficient for access to the public electricity grid is –0.277, with a confidence interval of [-0.304,-0.238]. Fairly similar results are obtained for private access to electricity (less than 2 percent of households are in this situation). The coefficient estimates are also similar in the urban and rural sub-samples. Although a few other variables have a statistically significant impact at the 5 percent level on the net price per efficient kilowatt-hour, none of those variables has an impact as large as that of access to electricity (although this is not shown in table 3, the regression also contains a large number of housing variables, but most of these are not statistically significant at the five percent level). To conclude, while access to electricity would not equalize the fuel poverty status of the two groups of households (those with and without access to electricity), it would go a long way in reducing differences between the two groups.

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Table 1: Gross and net unit prices for different fuels (US$ per kWh)

Cooking fuels	Gross	Net	Lighting fuels	Gross	Net	Appliances	Gross	Net
Electricity	0.08	0.08	Electricity	0.08	0.08	Electricity	0.08	0.08
Propane	0.05	0.06	Kerosene	0.05	5.87	Batteries	0.59	0.53
Fuelwood	0.01	0.06	Candles	0.26	13.00	Car batteries	2.57	2.31

Sources: Authors' computations from Leach and Gowen (1987), Van der Plas and De Graaff (1988), and Guatemala's Consumer Price Index.

Table 2: Fuel poverty estimates with and without access to electricity

	Households with access to electricity	Households without access to electricity	
		Current situation	After gaining access
Price per effective kwh	0.52	1.35	0.98
Net consumption (kwh)	3804	2892	3967
Fuel poverty			
Headcount	0.255	0.509	0.365
Poverty gap	0.078	0.236	0.159
Squared poverty gap	0.040	0.147	0.101

Source: Authors' estimation using ENIGFAM 1998/99.

Table 3: Determinants of the logarithm of the price per efficient kilowatt-hour, Guatemala 1998/99
[The regression also contains a large number of housing variables, most of which are not statistically significant]

	National				Urban				Rural			
	Coef.	St. Err.	95% Conf. Int.		Coef.	St. Err.	95% Conf. Int.		Coef.	St. Err.	95% Conf. Int.	
Energy												
Private elec.	-0.277	0.042	-0.359	-0.196	-0.249	0.046	-0.338	-0.160	-0.311	0.092	-0.491	-0.132
Public electricity	-0.271	0.017	-0.304	-0.238	-0.287	0.020	-0.325	-0.248	-0.252	0.036	-0.322	-0.182
Access to butane	0.136	0.021	0.095	0.177	0.061	0.057	-0.052	0.173	0.111	0.034	0.044	0.178
Cooking with elec.	0.066	0.036	-0.005	0.137	0.064	0.028	0.009	0.118	0.349	0.606	-0.839	1.537
Demographics												
Babies	-0.007	0.012	-0.031	0.016	-0.016	0.012	-0.039	0.007	0.015	0.032	-0.046	0.077
Children	-0.007	0.010	-0.026	0.012	-0.005	0.009	-0.022	0.013	-0.018	0.028	-0.073	0.036
Adults	-0.043	0.012	-0.066	-0.019	-0.025	0.011	-0.047	-0.003	-0.070	0.031	-0.131	-0.009
Babies squared	0.000	0.004	-0.007	0.008	0.004	0.004	-0.004	0.012	-0.005	0.008	-0.021	0.012
Children squared	0.001	0.002	-0.004	0.005	0.000	0.002	-0.004	0.005	0.004	0.006	-0.009	0.016
Adults squared	0.004	0.001	0.001	0.007	0.002	0.001	0.000	0.005	0.007	0.003	0.000	0.014
Female head	-0.082	0.020	-0.121	-0.043	-0.051	0.017	-0.084	-0.018	-0.183	0.067	-0.315	-0.051
Age of head	0.001	0.000	0.001	0.002	0.001	0.000	0.000	0.001	0.003	0.001	0.001	0.006
Education												
Head 6-8 years	0.006	0.015	-0.023	0.035	0.008	0.013	-0.018	0.033	0.008	0.048	-0.086	0.103
Head > 9 years	0.004	0.012	-0.019	0.027	0.002	0.011	-0.020	0.024	-0.003	0.031	-0.065	0.058
Spouse 0 years	-0.112	0.022	-0.155	-0.068	-0.060	0.020	-0.098	-0.021	-0.275	0.067	-0.406	-0.144
Spouse 6-8 years	-0.103	0.024	-0.149	-0.056	-0.066	0.020	-0.106	-0.027	-0.220	0.082	-0.381	-0.058
Spouse > 9 years	-0.109	0.021	-0.150	-0.068	-0.056	0.018	-0.091	-0.020	-0.281	0.064	-0.406	-0.155
Employment												
Head industry	-0.017	0.012	-0.041	0.006	-0.019	0.011	-0.040	0.003	-0.021	0.033	-0.085	0.043
Head family wk.	-0.103	0.049	-0.200	-0.006	-0.037	0.046	-0.128	0.054	-0.208	0.124	-0.452	0.036
Head public wk.	-0.024	0.018	-0.059	0.012	-0.030	0.014	-0.058	-0.001	0.104	0.096	-0.085	0.293
Head employed	0.043	0.017	0.009	0.076	0.019	0.015	-0.010	0.049	0.123	0.053	0.019	0.228
Head searching	0.060	0.048	-0.035	0.154	-0.017	0.040	-0.094	0.061	0.382	0.184	0.021	0.742
Spouse industry	-0.061	0.021	-0.102	-0.019	-0.054	0.018	-0.089	-0.019	-0.075	0.070	-0.213	0.063
Sp. Family wk.	-0.079	0.031	-0.140	-0.018	-0.075	0.027	-0.129	-0.022	-0.057	0.096	-0.246	0.132
Sp. Public wk.	-0.071	0.030	-0.129	-0.013	-0.068	0.024	-0.114	-0.022	-0.211	0.209	-0.621	0.199
Sp. Employed	0.080	0.020	0.041	0.118	0.069	0.017	0.036	0.102	0.069	0.065	-0.059	0.197
Sp. Searching	-0.028	0.080	-0.186	0.129	-0.037	0.068	-0.171	0.096	-0.089	0.267	-0.613	0.435
Location												
Norte	-0.029	0.030	-0.088	0.030	-0.041	0.028	-0.095	0.014	-0.030	0.080	-0.187	0.127
Nor-oriente	0.035	0.029	-0.022	0.092	0.042	0.025	-0.006	0.091	0.048	0.097	-0.142	0.238
Sur-oriente	-0.024	0.023	-0.068	0.021	0.004	0.022	-0.039	0.046	-0.075	0.056	-0.185	0.035
Central	0.017	0.025	-0.032	0.065	0.035	0.022	-0.009	0.079	-0.043	0.069	-0.179	0.093
Sur-occidente	0.171	0.028	0.117	0.226	0.021	0.027	-0.033	0.075	0.362	0.065	0.234	0.489
Nor-occidente	-0.048	0.044	-0.134	0.038	-0.022	0.037	-0.094	0.050	-0.139	0.154	-0.442	0.164
Peten	-0.047	0.044	-0.134	0.040	-0.054	0.042	-0.136	0.028	-0.008	0.112	-0.228	0.213
Income												
1st quintile	0.033	0.026	-0.018	0.085	0.051	0.031	-0.009	0.112	-0.017	0.064	-0.141	0.108
2nd quintile	-0.010	0.022	-0.053	0.033	-0.012	0.023	-0.056	0.033	-0.049	0.058	-0.162	0.065
3rd quintile	-0.056	0.018	-0.091	-0.020	-0.038	0.016	-0.070	-0.006	-0.123	0.053	-0.228	-0.018
4th quintile	-0.010	0.015	-0.039	0.019	-0.005	0.012	-0.029	0.020	-0.054	0.051	-0.154	0.046
Constant	-0.445	0.048	-0.538	-0.352	-0.277	0.074	-0.422	-0.132	-0.391	0.121	-0.628	-0.153

Source: Authors' estimation using ENIGFAM 1998/99. 7127 observations (5229 urban, 1898 rural). Adjusted R2 of 0.084 for the national sample (0.089 urban, 0.088 rural).