ABSTRACT

Title of Dissertation: METHODOLOGY AND ESTIMATION OF THE WELFARE IMPACT OF ENERGY REFORMS ON HOUSEHOLDS IN AZERBAIJAN

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This dissertation develops a new approach that enables policy-makers to analyze welfare gains from improvements in the quality of infrastructure services in developing countries where data are limited and supply is subject to interruptions. With the tight budgetary constraints that usually exist, it is important to be able to prioritize public sector investments on the basis of expected benefits. However, policy analysts are rarely able to measure the benefits of improving the quality of infrastructure services, even though they may yield large welfare benefits. The most frequently cited reason for failures to carry out such welfare analysis is the scarcity of data on service quality.

The main contribution of this dissertation is a new model of welfare evaluation of changes in the quality of infrastructure services. This model is estimated using the existing data from household energy surveys or data from the energy sections of multi-purpose household surveys. Potential applications of this model range from ex-ante reform evaluation to ex-post monitoring of policy outcomes, which makes this approach a useful contribution to policy analysis and to the literature on welfare evaluation of quality changes in infrastructure.

An application of the proposed model in the former Soviet Republic of Azerbaijan demonstrates how this approach can be used in welfare assessment of energy sector

reforms. The planned reforms in Azerbaijan include a set of measures that will result in a significant improvement in supply reliability, accompanied by a significant increase in the prices of energy services so that they reach the cost recovery level. Currently, households in rural areas receive electricity and gas for only a few hours a day because of a severe deterioration of the energy infrastructure following the collapse of the Soviet Union. The reforms that have recently been initiated will have far-reaching poverty and distributional consequences for the country as they result in an improvement in supply reliability and an increase in energy prices.

The new model of intermittent supply developed in this dissertation is based on the household production function approach and draws on previous research in the energy reliability literature. Since modern energy sources (network gas and electricity) in Azerbaijan are cleaner and cheaper than the traditional fuels (fuel wood, etc.), households choose modern fuels whenever they are available. During outages, they rely on traditional fuels. Theoretical welfare measures are derived from a system of fuel demands that takes into account the intermittent availability of energy sources.

The model is estimated with the data from the Azerbaijan Household Energy Survey, implemented by the World Bank in December 2003/January 2004. This survey includes an innovative contingent behavior module in which the respondents were asked about their energy consumption patterns in specified reform scenarios. Estimation results strongly indicate that households in the areas with poor supply quality have a high willingness to pay for reliability improvements. However, a relatively small group of households may incur substantial welfare losses from an electricity price increase even when it is combined with a partial reliability improvement. Unlike an earlier assessment of the same reforms in Azerbaijan, analysis in this dissertation clearly shows that targeted investments in improving service reliability may be the best way to mitigate adverse welfare consequences of electricity price increases. Hence, policymakers should focus their attention on ensuring that quality improvements are a central component of power sector reforms.

Survey evidence also shows that, although households may incur sizable welfare losses from indoor air pollution when they rely on traditional fuels, they do not recognize indoor air pollution as a factor contributing to the high incidence of respiratory illness among fuel wood users. Therefore, benefits may be greater if policy interventions that improve the reliability of modern energy sources are combined with an information campaign about the adverse health effects of fuel wood use.

METHODOLOGY AND ESTIMATION OF THE WELFARE IMPACT OF ENERGY REFORMS ON HOUSEHOLDS IN AZERBAIJAN

by

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1 Introduction

Transition economies have witnessed radical changes in the energy sector in the last decade. In many countries electricity service quality has deteriorated most notably due to unanticipated interruptions in supply, while many households have lost their supply of network gas completely. The service quality deterioration has been especially severe in the poor countries of Central Asia and the Caucasus (Armenia, Azerbaijan and Georgia). Deterioration has been caused by the lack of investment in the energy infrastructure in the former Soviet countries since the collapse of the Soviet Union, and the disruptions in energy exchange and trade between the newly independent countries.

The reforms that have begun in the electricity sector in the former Soviet countries have resulted in an increase in electricity tariffs and, in some cases, also in an improvement in service quality, particularly in the capital cities. The pace of reforms differs by country. For example, Armenia and Moldova have already implemented substantial electricity price increases, while Kazakhstan and Azerbaijan have yet to raise the electricity tariff to the cost recovery level, estimated to be around 4.5-5.5 US cents/kWh (Table 1).

Table 1. Average residential electricity tariffs (current US cents/kWh). 1/

	1994	1995	1996	1997	1998	1999	2000	2001	2002
Armenia	0.48	2.46	2.90	3.36	3.80	4.67	4.63	4.50	4.36
Azerbaijan	0.02	0.06	0.42	1.26	2.48	2.33	2.15	2.06	1.99
Georgia	Na	na	1.55	2.35	2.41	2.31	2.40	2.60	2.98
Hungary	3.00	4.34	4.65	5.40	5.69	5.94	6.59	6.59	6.79
Kazakhstan	2.12	3.25	3.19	4.63	4.78	3.15	2.68	2.57	2.53
Moldova	2.00	2.00	2.83	4.76	4.66	4.37	4.67	4.82	4.94
Poland	5.53	5.73	7.18	7.23	6.59	6.79	6.52	6.63	7.78

Note: 1/ These are nominal tariffs converted into US currency using the current exchange rate. Nominal electricity tariff remained at AZM 96 in Azerbaijan, and the observed reduction after 1998 is due to exchange rate fluctuations.
Source: Data are provided by local consultants for the World Bank study *Power's Promise*, 2004.

At a time when some people are cash constrained because of wage and pension arrears, a drastic electricity tariff increase may mean a significant welfare burden for some households. At the same time, others may benefit from an improvement in service quality if they can afford the higher-priced electricity service. The focus of my dissertation is on the reforms in Azerbaijan, a former Soviet Republic located east of Turkey on the coast of the Caspian Sea (see Map 1.1).

Map 1.1 Azerbaijan on a political map of the region.

Source: Perry-Castañeda Library Map Collection 2003 (http://www.lib.utexas.edu/maps/asia.html).
Note: The area in the Southwest is Naxichevan, and is separated from the rest of the country by the territory of Armenia.

Reforms in the energy sector may affect the welfare of consumers through a change in the price of service, coverage, and service quality. Methodologies for evaluating the welfare impact of a change in price or access to service via a new connection are well established. Evaluation of the welfare impact of a service quality change, however, is more complicated and ideally requires accurate data on pre- and post-reform service quality, which are rarely available. If the anticipated outcome of reforms is a lower price, higher access and higher service quality, project benefits calculated by including only the gains from a price decline and omitting the welfare gains from a service quality improvement unambiguously provide a lower bound of the benefits. This is a likely reform scenario in the countries where increased competition following de-monopolization and unbundling of the utilities into separate distribution, transmission and generation entities is expected to lower the price of service. However, if the welfare effects of the price and quality changes are in opposite directions, omitting the quality component may lead to policy conclusions that are wrong even qualitatively. Yet in project and policy analysis, methodology is lacking for estimation of the welfare change from service quality improvement or deterioration. The main reason is scarcity of data on service quality and ambiguity about the appropriate methods to analyze the associated welfare effects.

The main contribution of this dissertation is an analytical framework to analyze the effects of service quality changes due to infrastructure reforms. A structured methodology is developed for theoretical and empirical measurement of the welfare effects of reforms in the energy sector that affect the reliability of supply. The model of intermittent supply developed here can be estimated using the existing data from household energy surveys or data from the energy sections of multi-purpose household surveys when various data are missing. Potential applications of this model range from ex ante reform evaluation to ex post monitoring of policy outcomes. Broad applicability and fairly modest data requirements make this approach a useful contribution to policy analysis and to the literature on welfare evaluation of quality changes in infrastructure.

In this dissertation, I use the model of intermittent supply to assess the welfare impact of reforms in the electricity sector in Azerbaijan. As a legacy of central planning, residential energy supply is still heavily subsidized in Azerbaijan and electricity prices are below the cost-recovery level. Lack of adequate financing for new investments and maintenance of energy infrastructure has led to a severe deterioration in the quality of energy supply, and service interruptions have become wide-spread in many parts of the country. The reforms of the electricity sector envisage a substantial price increase of approximately 50 percent in 2006 and equally large increases in subsequent years until electricity prices reach the cost-recovery level. Electric utility companies would presumably use the additional proceeds to make investments in improvement of supply reliability. Thus, the reforms hold the promise of a higher quality level at a higher price. A dramatic price increase at this scale, however, could have serious consequences for the poverty level in the country. The fear of social consequences and broad-based opposition to reforms stall the efforts of the government to proceed with the unpopular price increase. The main policy objective of this dissertation is to assess the relative magnitude of the losses from a price increase and the gains from quality improvement. Another objective is to identify the losers and make policy recommendations about whether it will be necessary to devise a social protection scheme to mitigate the losses of these households.

The remainder of this dissertation is organized as follows. Chapter 2 describes the reform program in the energy sector in Azerbaijan and basic facts about the energy sector, and discusses the political factors influencing the pace of reforms. Chapter 3 is a detailed discussion of the data sources used in this dissertation. Chapter 4 describes the nationally representative pattern of energy consumption by Azeri households and sets the stage for an evaluation of the welfare impact of reforms in subsequent chapters. It also draws preliminary policy conclusions. The literature review in chapter 5 puts the problem of poor reliability of electricity supply in the broader theoretical prospective of the literature in environmental and energy economics. Chapter 6 is the main contribution of this dissertation. It presents the new model for empirical examination of intermittent supply. Contrary to the conventional approach, the discussion of the data precedes the literature review and a chapter describing the theoretical model, because data availability plays a key role in the choice of a modeling approach proposed in this dissertation. Chapter 7 describes the results of model estimation using household survey data from Azerbaijan. Chapter 8 presents analysis of policy simulations based on the model estimated in chapter 7. Chapter 9 presents conclusions of the analysis.

2 Household energy consumption in Azerbaijan: Background

The transmission and distribution networks in Azerbaijan were originally designed to provide almost universal access to electricity. However, the power sector has suffered from inadequate funding to perform essential maintenance functions, resulting in a severe deterioration of the quality of supply and frequent rolling blackouts of electricity.[1] The power sector in Azerbaijan is in dire need of investment. By some estimates, investment needs exceed $475 million in order to meet the future energy demand in Azerbaijan. Over half of this amount would be required before 2007.[2]

Furthermore, the state-owned electricity company Azerenerji, which manages electricity generation and distribution, is not financially viable.[3] At the current tariff levels it is unable to meet its cash flow requirements and it receives budgetary financing for the purchase of fuel for domestic electricity generation and for imported electricity. These transfers to Azerenerji represent a heavy budgetary burden. By some estimates, the cost of the quasi-fiscal transfers to the energy sector in Azerbaijan exceeded 10 percent of GDP per annum during the second half of the 1990s. This amount is greater than the total annual spending on pensions and social assistance programs, which average 5-6 percent of GDP (World Bank 2004, 2005).

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[1] The power sector as used here refers only to electricity.

[2] These estimates are from a least-cost planning study, concluded in 2003 by Burns and Roe Inc. and funded by the European Bank for Reconstruction and Development (World Bank 2005).

[3] This company manages generation and transmission. Distribution activities are grouped in four regional distribution companies, two of which are privately operated under concession agreements. A private company, Barmek Holding AS, has managed the Baku and Sumgayit power distribution networks since 2002 and 2003, respectively, and the state-owned Baku High Voltage Electrical Equipment Company manages the Ali-Bayramli and Ganja networks (World Bank 2005).

Historical background, institutional setting and reforms in the power sector

During the Soviet period, the provision of network gas was nearly universal whenever it was technically feasible. Thus, the gas network extended everywhere except for the remote rural and mountainous areas. Gas was provided by Russia at highly subsidized prices. The rising cost of imported gas from Russia in recent years and the poor condition of gas pipelines in Azerbaijan have led to gas shortages, leaving some rural areas entirely without access to gas during the last decade, as shown in Table 2.1 and Map 2.1.

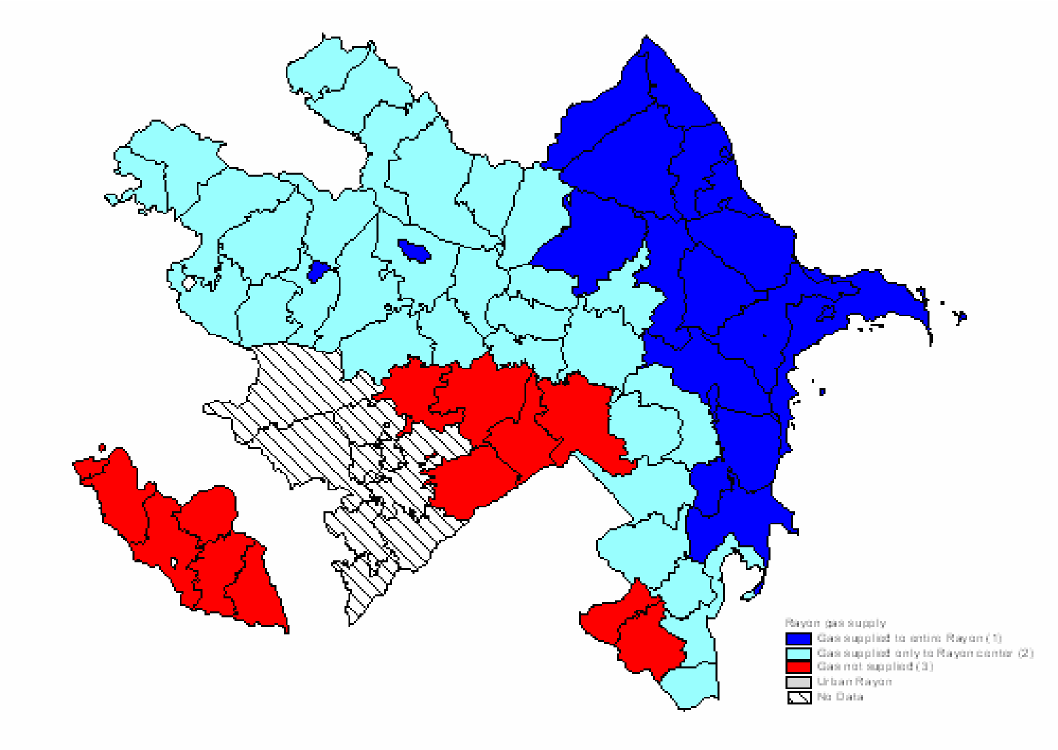
For example, although 79 percent of households have gas connections and had gas supply in the past, only 56 percent receive gas at least part of the time. According to the 2003 Household Energy Survey data, gas is available 20 hours a day during the winter for those with gas supply, and almost a quarter of all households with gas supply experience service interruptions. Even when gas is supplied, the pressure is sufficient for only one fifth of the households.

Table 2.1 Gas supply quality by region.

			Share of households that report having gas		Average hours per day gas is available	
	Connection	Supply	Interruptions (last two weeks)	Good pressure (last two weeks)	during winter	during summer
Alibayramly	100%	91%	33%	42%	22	23
Baku	99%	94%	27%	38%	23	24
Ganja	95%	71%	70%	45%	14	16
Goycay	95%	23%	17%	4%	17	22
Guba	63%	25%	3%	0%	23	24
Imishly	0%	0%	0%	0%	-	-
Ismailly	98%	40%	3%	10%	24	24
Mingecev	100%	100%	100%	18%	10	11
Sabirabad	37%	10%	3%	2%	23	24
Sumgayit	100%	99%	24%	25%	21	23
Total	79%	56%	23%	19%	20	22

Source: 2003 Azerbaijan Household Energy Survey.

Map 2.1 The quality of gas supply in Azerbaijan.



Note: Dark blue denotes areas where gas is supplied to an entire administrative district (called *rayon*), turquoise – only to district center, red – gas is not supplied, shaded or gray – no data.
Source: Created by GeoData, U.K. (2004) using information published in a local newspaper about gas supply in 2003 (*Azerbaycan*. No. 57. March 10, 2004).

Having lost their supply of natural gas, around 40 percent of households in urban areas now use electricity as either the primary or secondary source of heating (see chapter 4). Electricity is produced in Azerbaijan by thermal stations using natural gas and oil or by hydropower stations. Because of energy losses in the process of conversion, it is inefficient to use electricity for heating from the economy-wide point of view.

The government has recently embarked on a path of market reforms in the provision of utility services to address the supply problems and financial insolvency of the energy company. The reform objective is to eliminate the sizable fiscal burden of subsidizing utility companies and to improve consumption efficiency while releasing funds for much needed investments in upgrading energy supply systems. The key components of the government strategy are the promotion of private participation in the provision of utility services and the establishment of a tariff policy to raise the price of utility services to the full cost recovery level.[4] In addition, the government is planning to introduce metering to all households whose consumption of utility services is currently not metered.[5] The anticipated reforms will affect electricity and gas. They will also affect municipal water supply, but water sector reforms are beyond the scope of this dissertation.

The prices of utility services are regulated by the tariff-setting commission in the Ministry of Economic Development, which acts as the regulatory body for the entities that provide utility services. In the course of reforms, the residential price of natural gas will rise four-fold and for electricity it will rise more than two-fold over the next five years. The price of natural gas to residential consumers has already more than doubled from AZM 35,560 per 1,000 m^3 in 2003 to AZM 81,000 in 2004. This is still below the full cost recovery price, calculated as approximately AZM 140,000-150,000 per 1,000 m^3. A further price increase will be necessary over the medium term to meet this benchmark. The residential electricity price has remained unchanged at AZM 96 (or approximately 2.0 US cents depending on the exchange rate) per kWh in spite of the earlier intentions of the government to implement a price increase.

In the recent "Letter of Development Policy," the government has committed to eliminate all financial support for the provision of electricity, gas, and water services and

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[4] See the "Letter of Development Policy for the Poverty Reduction Support Credit" (PRSC-I, 2005) (World Bank 2005).

[5] As shown in Appendix Table 4.8, less than half of residential electricity and gas consumption is metered, and most metered households are in the Barmek utility company's service area covering Baku, Sumgayit and the rest of the Absheron Peninsula.

to achieving full cost recovery tariffs by 2010. The reform option that appears the most plausible envisages a 50 percent increase in wholesale electricity tariffs (from 71 AZM/kWh to 106.5 AZM/kWh) effective in 2006, with equal annual percentage increases thereafter in order to reach full cost recovery, estimated at 174 AZM/kWh, by the end of 2010[6] (World Bank 2005).

Social cost-benefit analysis of power sector reforms

The reform process has been slow. The nominal electricity price has remained constant, even though in 2003 the government planned to implement pricing reforms no later than 2005.[7] Raising residential electricity prices is a politically sensitive issue, met with great social opposition. If the reforms are to be successful, the government needs to build a strong constituency of support of reforms, a daunting challenge for an unstable government. The most effective approach to building such a constituency is to ensure that the distributional objectives of reforms are well addressed and that an increase in prices indeed leads to better service quality. To achieve this, the government may need to develop an effective social protection scheme to mitigate the adverse effect of an increase in electricity prices on the most vulnerable households and set clear targets of improving service quality. Even then, the reform process will meet strong opposition as many low income households will probably be ineligible for compensation, given that the poverty rate has been estimated at 50 percent in 2001 and 45 percent in 2002. Fiscal resources to finance transfers on such a scale, if necessary, are not likely to become available (World

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[6] The residential prices are expected to increase in similar proportion to the wholesale electricity prices and reach the full cost recovery level of about 4.5-5.5 US cents/kWh by 2010.

[7] “Letter of Intent of the Government of Azerbaijan,” April 21, 2003.

Bank 2005).[8] Furthermore, identifying the poor is highly problematic, especially in countries such as Azerbaijan where income is not accurately reported and much of it is from non-formal employment.

The existing cost-benefit analysis of the proposed reforms assumes that the gains from higher service quality will outweigh the losses from higher prices, simply because the government has committed to use the budgetary resources currently used to support the energy company to better protect vulnerable households (World Bank 2005). However, many households who do not receive support will not experience welfare gains as a result of the on-going reforms, because to them the losses from a price increase may exceed the potential gains from an improvement in quality. Whether the welfare gains from a reliability improvement exceed the losses from a price increase remains to be determined empirically and is one of the goals of this dissertation.

In the capital, Baku, and other big cities, the welfare gains from electricity reforms will likely be small because service quality is already high in the sense that electricity is available 24 hours a day with very few interruptions. In most other areas, electricity supply is often interrupted, especially in a large part of the rural communities. Rural households in Azerbaijan experience frequent outages in electricity supply, with the rural areas receiving electricity an average of only 9 hours per day during the winter (Table 2.2).[9] The evidence about low daily hours of supply of electricity (and gas) is

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[8] An on-going World Bank-financed technical assistance project aims to help the government improve the social protection system with better targeting of social assistance payments than with the current system. However, only a small share of the poor households will most likely be covered by such a program given the high poverty rate in the country.

[9] Unlike the somewhat higher estimates in the 2004 Energy Survey, the 2002 World Bank Rural Infrastructure Survey reports that households received electricity an average of 4 hours per day.

confirmed by the nationally representative 2004 Household Budget Survey (Appendix Table 2.1).

Table 2.2 Electricity supply quality by region.

	Hours per day of electricity availability		Share of households that experienced		
	Average during winter	Average during summer	Appliance damage due to outages	Voltage fluctuations	Appliance damage due to fluctuations
Alibayramly	17	22	21%	46%	17%
Baku	24	24	18%	71%	74%
Ganja	10	22	43%	68%	3%
Goycay	15	18	19%	42%	22%
Guba	9	15	38%	90%	28%
Imishly	8	20	25%	90%	0%
Ismailly	18	21	13%	77%	17%
Mingecev	9	21	27%	86%	0%
Sabirabad	8	20	31%	78%	1%
Sumgayit	24	24	30%	67%	55%
Total	16	21	25%	72%	31%

Source: 2003 Azerbaijan Household Energy Survey.

Even if electricity is supplied in the rural areas, the voltage is sometimes insufficient to operate certain electric appliances, and appliance damage due to outages and voltage fluctuations is commonplace.[10] Appliance damage causes a further welfare loss for households, but its measurement requires detailed data on the types and costs of appliances that were damaged by the fluctuations. Since such data are not available for Azerbaijan, this dissertation cannot consider this aspect of the welfare losses. Most likely that will not significantly affect the results since the appliance costs are low relative to the incremental expenditures on high-cost substitute sources of energy during supply interruptions.

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[10] Low voltage in rural areas means that even light is barely bright enough to read. Much greater voltage is required for heating or cooking. (Personal communication with 2004 Energy Survey interviewer supervisors, March, 2004.) For statistics on fluctuations, see Table 2.2.

Factors determining household choice of fuels

Household choice of fuels is determined mainly by the availability of network fuels and reliability of supply because network energy sources are cleaner and less expensive than fossil fuels. Heating oil, dung, and fuel wood, if they are purchased, are the most expensive fuels when their market prices are converted into the price per kilogram of oil equivalent and adjusted for the efficiency of using a particular fuel for cooking or heating.

As shown in Table 2.3, at current prices, natural gas is by far the cheapest cooking and heating alternative based on the energy content and conversion efficiency. Electricity is the second cheapest alternative for heating, followed by wood, LPG, and kerosene. For cooking, the order is similar except that LPG is cheaper than wood, and charcoal is the most expensive fuel after adjusting for energy content and appliance efficiency. Gas and electricity, in that order, are clearly the preferred energy sources when they are available, but energy sector reforms are expected to change these relationships.

Table 2.3 Energy prices in Azerbaijan, 2004 1/

	Market price, AZM per unit (median)	Standard deviation	Market price, USD per unit	kgoe per unit	Price per kgoe	Cooking conversion coefficient	Effective price per kgoe for cooking 2/
Central gas (m^3)	35.56	0	$ 0.01	0.833	$ 0.01	0.60	$ 0.01
Electricity (kWh)	96	0	$ 0.02	0.085	$ 0.23	0.75	$ 0.31
LPG (kg)	1,000	69	$ 0.20	0.635	$ 0.32	0.37	$ 0.86
Wood (kg)	100	52	$ 0.02	0.056	$ 0.36	0.25	$ 1.46
Kerosene (liter)	900	566	$ 0.18	0.288	$ 0.64	0.35	$ 1.82
Dung (kg)	750	313	$ 0.15	0.341	$ 0.45	0.12	$ 3.74

Note: 1/ It is assumed here that 1 cubic meter of fuel wood (which costs on average AZM 20,000) contains 300 kg of dry wood; 2/ Effective price per kgoe of LPG can be lower than for wood when these fuels are used for heating rather than for cooking, depending what heating conversion coefficients are applied (e.g., relative fuel costs reported in Environmental Resources Management 2002).

Source: Calculated from 2004 HBS data and converted into kilogram of oil equivalents (kgoe) using energy conversion coefficients of the International Energy Agency. Cooking conversion coefficients were provided by Energy Sector Management Assistance Program (O'Sullivan and Barnes 2006).

The costs of technology adoption usually represent a significant barrier for switching to a different cooking or heating fuel. For example, in Bolivia the costs of switching from fuel wood to LPG were found to be a significant barrier. Cultural factors, lifestyle, cooking habits and education also explain the persistence of fuel wood use when LPG is available (Israel 2002). However, the situation is different in Azerbaijan. A recent survey of appliances utilized by households in the North of Azerbaijan shows that most appliances are home made. Surprisingly, this is true not only of the appliances that use fuel wood, but also electricity and, to some extent, even LPG (Environmental Resources Management 2002).[11] Clearly, more sophisticated appliances are also used in Baku and some other areas of the country. However the low-cost alternatives are always available for use as long as the fuels to operate them are supplied. In fact, due to intermittent supply, most households have the appliances, primitive as they may be, that are necessary to switch readily from one fuel source to another when gas or electricity supply is interrupted. Consequently, the cost of appliances and cultural factors are a less significant determinant of fuel choice in Azerbaijan than in typical developing countries.

Summary and conclusions

To sum up this chapter's findings, the Government of Azerbaijan has initiated a series of market reforms in the public utilities sector with the aim of improving the financial viability of utility companies and the quality of services provision. Although electricity pricing is not the only reform on the agenda, and the natural gas and public water

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[11] Out of 120 households sampled in the 2002 Environmental Resources Management (ERM) Appliance Survey, 100 percent of cookers, ovens and heaters were found to use fuel wood or electricity and 17 percent of LPG cookers were home made. For example, an electric heater is simply a spiral and an electric oven is a simple appliance consisting of a spiral attached to a metal box. Appliances that use network gas are factory-made but households with a working supply of network gas either already own a gas stove, or they can purchase it as cheaply as US$8. Several other models of gas cookers and heaters are available for purchase, with the prices ranging from US$8 for a Turkish cooker to US$120 for a Spanish-Iranian butane water heating unit (ERM, 2002).

supplies will also undergo reforms, electricity pricing reforms are a highly sensitive area from the social point of view. The slow process of reforms in this area attests to the significant obstacles faced by government and regulator alike. Even if reforms reduce the gaps between the prices of network and non-network energy sources, given how wide these gaps are at present, relative fuel prices are not likely to change in the near term. Network gas and electricity are very inexpensive in Azerbaijan and even after a significant price increase they will remain the preferred energy sources for a majority of Azeri households, as other factors such as appliance costs and cultural factors do not appear to impede consumption of network energy.

Appendix to chapter 2: Reliability of electricity supply

Appendix Table 2.1 Average number of hours electricity and network gas are available.

	Electricity			Network gas		
	Cities	Towns	Rural areas	Cities	Towns	Rural areas
Poorest 20%	18.9	13.3	9.9	18.1	15.9	20.8
2	17.3	13.2	9.3	16.9	16.4	19.5
3	18.7	12.6	9.4	17.6	15.9	18.1
4	18.8	12.2	9.4	17.3	16.4	19.2
Richest 20%	19.6	16.3	9.9	19.1	18.2	20.2
Total	18.8	13.2	9.6	17.9	16.4	19.6

Note: Averages are for households that use electricity and network gas, respectively.
Source: 2004 Household Budget Survey.

3 Recent household energy surveys and other sources of data

Data sources

The main sources of data for this dissertation are the 2004 Azerbaijan Household Budget Survey (HBS) and the 2003 Azerbaijan Household Energy Survey (HES). The HBS is a nationally representative survey that is implemented quarterly by the State Statistics Committee (SCC) of Azerbaijan. In the second quarter of 2004, the SCC included a detailed module on energy consumption in addition to the other modules in the regular questionnaire. This chapter uses the HBS data collected through the energy module to present a nationally representative picture of the patterns of energy use by households in Azerbaijan. Chapter 4 uses these data to examine the relationship between energy use and household income. The second source of data is the 2003 HES. It is the main source of data used for the estimation described in chapters 7 and 8. These two data sources and their overlap as well as some related data are described in Table 3.1.

Table 3.1 Description of data sources.

Data source	Observations	Available information and comments
2004 Household Budget Survey (2nd quarter data)	2,111	This module contains energy consumption and supply quality information, as well as data on self-collected fuels (fuel wood and dung). After merging the module with the remaining modules of the 2004 2nd quarter HBS, housing structure, demographic and expenditure information are also available for all households.
2003 Household Energy Survey	2,000	This survey contains housing structure, demographic data, income, actual and hypothetical electricity consumption and actual gas and fossil fuel consumption and price data. Few households report time costs and other information related to fuel collection. The survey does not contain accurate information on total expenditures.
Monthly electric utility household-level billing and payment records	1,559 (727 metered and 832 unmetered)	These data include monthly billing and payment records from January 2002 to December 2003 for most households that were included in the HES.
Subsample of the 2003 HES that is also in the 2002 HBS	504	This subsample allows constructing an empirical relationship between total expenditures and variables that are in both the HBS and the HES, which permits imputing total expenditures for households with missing total expenditures in the HES.

The HES was implemented by the World Bank in December 2003 and January 2004 as part of the Poverty and Social Impact Assessment of the planned energy reforms in Azerbaijan (World Bank 2004). The HES sample includes a total of 2,000 households, of which 1,210 are in the urban and 790 in the rural areas of Azerbaijan. It contains detailed household-level data on the consumption of all types of energy in the current and the hypothetical reform scenarios. In addition, it includes information on housing conditions, demographics, and a detailed income section. There is also an overlap of 504 households between the 2003 HES sample and the 2002 HBS sample. Since the HBS contains a detailed expenditure module, and the HES contains only income, this overlap provides a source of more accurate information on the level of welfare in terms of permanent income.[12]

By design, the 2003 HES is not representative at the national level because this survey did not collect a statistically representative sample of all households in the country, unlike the case of the HBS. Instead, the HES sampled households from several regions of the country with access to different combinations of energy sources. The sample was drawn according to the following dimensions: access to gas, availability of fuel wood (proximity to forest areas), and the type of area (rural or urban). Thus, the survey data include sub-samples of approximately equal size from four types of areas: regions with a good supply of network gas, areas without a reliable network gas supply

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[12] Reliability of the consumption aggregates in the HBS and therefore of the poverty measures in Azerbaijan have been questioned because of a very low income inequality (Gini coefficient ranging from 0.09 to 0.32) obtained when these aggregates are used as a proxy of household income. A recent evaluation of the data quality in the HBS concluded that the sample design, data collection and supervision practices were satisfactory. The interviewers were very consistent in the three years 2002, 2003 and 2004 when the survey was conducted, and the survey data satisfy such basic empirical regularities as Engel's Law. The food share is inversely related to the logarithm of total consumption expenditures. ("Assessment of Household Budget Survey Data in Azerbaijan." World Bank (2006), mimeographed).

but with reliable electricity service, areas where neither electricity nor gas supply is available but which are forest-rich and have easy access to wood, and areas without a reliable supply of any of the above energy sources where the use of dung is common.

The areas included in the 2003 HES can be categorized into geographic zones. The first zone is the Absheron Peninsula (Baku, Sumgayit and Ali-Bayramly), the second zone consists of Guba, Ismailly and Goycay in the North, the third zone includes Sabirabad and Imishly in the South and the forth zone is Mingechevir and Ganja City. The Absheron Peninsula has the most reliable supply of gas and electricity. The second and third zones have poor supply of gas and electricity. While the second zone has abundant forest resources, forests in the fourth zone have been degraded. The fourth zone is fairly similar to the Absheron Peninsula in terms of fuel availability. These zones and the breakdown of the sample are shown in Map 3.1 and Table 3.2.

Map 3.1 Regions in the 2003 Household Energy Survey sample.

The 2003 HES data include detailed information about the consumption levels of market fuels, network gas and electricity by season, demographic characteristics, and energy prices. These prices are used in conjunction with the information available from other sources on the energy content and conversion efficiency of different fuel types for heating, cooking and lighting uses to calculate effective prices of fuels from different sources. Other information included in the 2003 HES questionnaire is summarized in Table 3.3.

Table 3.2 Sample of the 2003 HES.

Cities:	
Baku	499
Sumgayit	150
Ganja	150
Mingecev	100
Alibayramly	100
Regions (rural areas and regional centers):	
Guba	201
Sabirabad	200
Imishly	200
Goycay	200
Ismailly	200
Total	2,000

Table 3.3 Summary of the information contained in the 2003 HES.

Survey section	Available information and comments
Housing characteristics	Type of housing, number of rooms, type of insulation and other information about housing conditions.
Electricity usage	Quality of electricity supply, average daily hours of uninterrupted supply in winter and summer, information about damage to electric appliances due to voltage fluctuations, last month's (i.e., December) electricity bill and detailed information about the hours of use of each electric appliance in the current scenario and in the reform scenario.
Gas usage	Quality of gas supply and whether it is available, average daily hours of supply in winter and summer, last month's bill, and information about gas pressure.
Fuel wood usage	Information about fuel wood use and collection, quantity of wood collected and collection costs (monetary and time expenditures), distance to the site of collection, mode of transportation, type of wood collected, information about the last wood purchase (quantity and expenditures), as well as information about usage of each wood stove. Note that information on the expenditures associated with fuel wood collection is very poor as it is illegal to collect wood on public grounds, and households were reluctant to respond to these questions.
General patterns of fuel use	Average quantities and the corresponding cost of each non-network fuel (LPG, kerosene/heating oil, and dung) consumed in an average winter month and in an average summer month.
Responses to electricity sector reform	Contingent behavior questions about fuel choice and hours of use of each electric appliance that is currently owned or that will be purchased in the reform scenario. Each household was asked about its consumption of electricity and substitute fuels only in one scenario, with the price bids specified in the scenario varying by respondent. Information on consumption of substitute fuels in the reform scenario is poor because few households replied to those questions.
Household characteristics	Total expenditures of the household in the past month including food and non-food expenditures but excluding durable items, education level of the respondent, household size; age, employment status, occupation and salary or pension of each household member; household income by source.

The average quantities of market fuels, such as fuel wood, kerosene, heating oil and LPG, are reported in the survey for a typical winter and summer month. Using these data for estimations in this dissertation allows controlling for seasonal differences in energy demand. The survey also contains information on the average number of hours of electricity and gas supply in the previous month, which will be the basis for measuring supply reliability. In order to enable the imputation of the shadow price of fuel wood for households that collect wood themselves, the survey includes questions on collection expenses and time costs. However, very few households answered these questions.[13] Thus, I valued self-collected fuel wood at the average market price of fuel wood in a village or settlement where a household is located. This approach is not ideal, as market prices of wood are likely to be an overestimate of the shadow price of wood collection. However, no data were available in the survey that would allow the imputation of shadow wages.

Contingent behavior questions in the 2003 HES

Electricity and gas tariffs are set at the national level and do not vary by region in Azerbaijan. The 2003 HES includes a contingent behavior module in order to create the necessary price variation from hypothetical data for estimation of the electricity demand function and calculation of the welfare effects of a price and reliability change. In this section first I describe the structure of contingent behavior questions and then I evaluate the plausibility of the responses.

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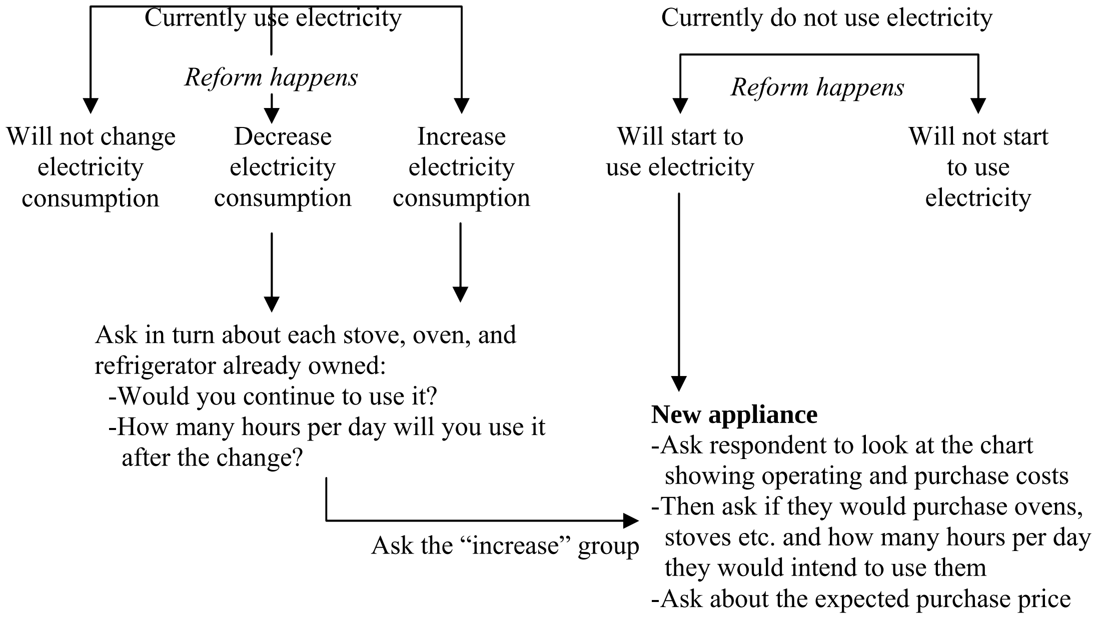
[13] In the 2003 HES, the households were reluctant to report the amount of wood they collect or the associated time and monetary costs because of legal restrictions on unauthorized harvesting of wood in government-owned forest and park areas. The majority of households that report use of collected wood do not state how much they collect nor where and at what cost it is collected. According to the information provided by the 2003 HES interviewer supervisors, households are more reluctant to provide such information in the winter than they are in the summer because of fear of the authorities. In the summer, a sufficient amount of time has passed so that they are less concerned about providing such information to the interviewers (Personal communication, 2004).

In the contingent behavior section, respondents are presented with a scenario in which electricity became available 24 hours per day, 7 days a week, and asked how much electricity they would consume at different price and reliability levels of electricity supply. As shown in Figure 3.1 for the example of electricity consumption for cooking, first the respondents are asked whether they already use electricity for cooking. Then they are presented with the reform scenario of a price increase and a reliability improvement. Households that already use electricity are asked whether they would decrease or increase their level of electricity consumption, or there would be no change. If respondents indicate they would change their consumption level, they are asked about the hours of use of each appliance they currently own, assuming the price and reliability levels specified in the reform scenario. Questions about new appliance purchase decisions and the intended usage level of those appliances are posed only to households that report they would increase their electricity consumption or those who don't currently use electricity and would start using it in the reform scenario. Questions about heating and cooling use of electricity are similarly structured. The structure of questions about the use of electricity for lighting is simpler as respondents were not asked about their purchase of new light bulbs in the reform scenario.

In order to facilitate understanding of the stated price increase, the question about the new consumption level after reforms asked for hours of use of each electrical appliance currently owned as well as the appliances that would be purchased in the reform scenario. In order to ensure that respondents were aware of the cost implications of their choices, they were shown tables with a range of possible daily hour usage of typical appliances, the associated costs, and the total monthly bill.

Figure 3.1 Structure of the contingent behavior questions (cooking).



A large share of respondents indicate that they would not change the level of their electricity use for lighting, heating or cooking in the reform scenario, as shown in Table 3.4. In cases where the respondent report "no change" in the reform scenario, the current usage level and the resulting electricity consumption can be assigned for both the actual and the reform scenarios. The data on usage of appliances that are not currently owned and would be purchased in the reform scenario are missing for the majority of the respondents. Therefore, these data are insufficient to consider the long-run response of appliance ownership to prices and quality of supply.

Consumption of substitute energy sources may change when electricity consumption falls or rises following the proposed reform. While a significant share of respondents report a change in the consumption of alternative energy sources, especially for cooking, few actually stated the amount by which consumption would be increased or reduced.

Table 3.4 Distribution of price bids by region in the 2003 HES (percent of respondents).

	96 1/	120	144	192	240	Total	Number of observations
Alibayramly		23%	29%	27%	21%	100%	100
Baku		27%	28%	25%	21%	100%	499
Ganja		21%	25%	26%	28%	100%	150
Goycay	25%	17%	29%	24%	7%	100%	200
Guba	24%	25%	25%	22%	5%	100%	201
Imishly	26%	22%	22%	24%	7%	100%	200
Ismailly	22%	28%	25%	21%	5%	100%	200
Mingechevir		19%	36%	23%	22%	100%	100
Sabirabad	21%	26%	24%	24%	7%	100%	200
Sumgait		27%	32%	21%	20%	100%	150
Total	12%	24%	27%	24%	14%	100%	2,000
Number of observations	232	482	538	470	278	2,000	

Note: 1/ Blanks indicate that by design nobody in the corresponding regions was given the current price bid of 96 Manat per kWh, since these areas have relatively few supply interruptions and if the reform scenario specified the current price, there would be almost no change from the present reliability and price.
Source: 2003 Azerbaijan Household Energy Survey.

Electricity prices that households would have to pay in the reform scenario vary randomly and include the following price bids: zero, 25, 50, and 150 percent increase over the current price per kWh (96 Manats). Areas where there is presently no rationing did not receive the bid of zero price increase, as this would imply no changes at all in the reform scenario (Table 3.4). Importantly, survey respondents were told in the reform scenario that they would have to pay their monthly electricity bill in full.

Payment discipline is not strictly enforced in Azerbaijan, although this situation is changing through the process of reforms that are transferring management of electricity distribution to private companies. Baku probably has the highest payment discipline, and the billing records of the private distribution company, Barmek, which is responsible for electricity distribution in the capital city, indicate that payment is still far from 100 percent (Table 3.5). This situation is likely to change in the future as payment enforcement is one of the key issues on the reform agenda. Taking into account the low collection rates at the current price of 96 Manat per kWh, a price increase that is stated in the 2003 HES assuming a 100 percent collection rate, as specified in the survey questionnaire, represents a higher effective than nominal price increase. However, it is likely that respondents do not believe that payment would be strictly enforced. This issue is further investigated in chapter 4 and requires testing in the estimation in chapter 7.

Table 3.5 Baku previous month electricity bill payment rate.

Payment rate category	Percent of households
0-19	14%
20-49	25%
50-79	22%
80-89	11%
90-100	16%
Missing	11%
N	499

Source: Barmek electric utility records for a subsample of households in the 2003 HES.

Plausibility of responses to contingent behavior questions

Next, I assess the validity of the responses to contingent behavior questions about fuel use choices in the reform scenario which posits a higher electricity price and reliability level. In the urban areas where the quality of the electricity supply tends to be much higher than in the rural areas, most households report that they would reduce electricity consumption and few of them would switch to electricity in the reform scenarios (Table 3.6). On the contrary, as shown in Table 3.6, around 10 percent of the rural households in Imishly and Sabirabad, the rural regions with the fewest hours of daily electricity supply, report that they would start using electricity in the reform scenario. Electricity supply tends to be unreliable in the urban areas in these regions as well, so it is not surprising that we observe the highest increase in electricity consumption and some incidence of switching to electricity in these regions even in the urban areas.

Overall, many more respondents report that they would reduce their electricity consumption than those who say that they would switch from fossil fuels to electricity or increase their electricity consumption level. This suggests that households may be more sensitive to the price increase than they are to an improvement in service quality. This, in turn, implies that, for many households, the rationing constraint due to poor supply reliability may not be binding, and raising the electricity price would lead to a reduction in consumption. I will further examine the implications of these responses in a formal model of household energy consumption in chapter 7.

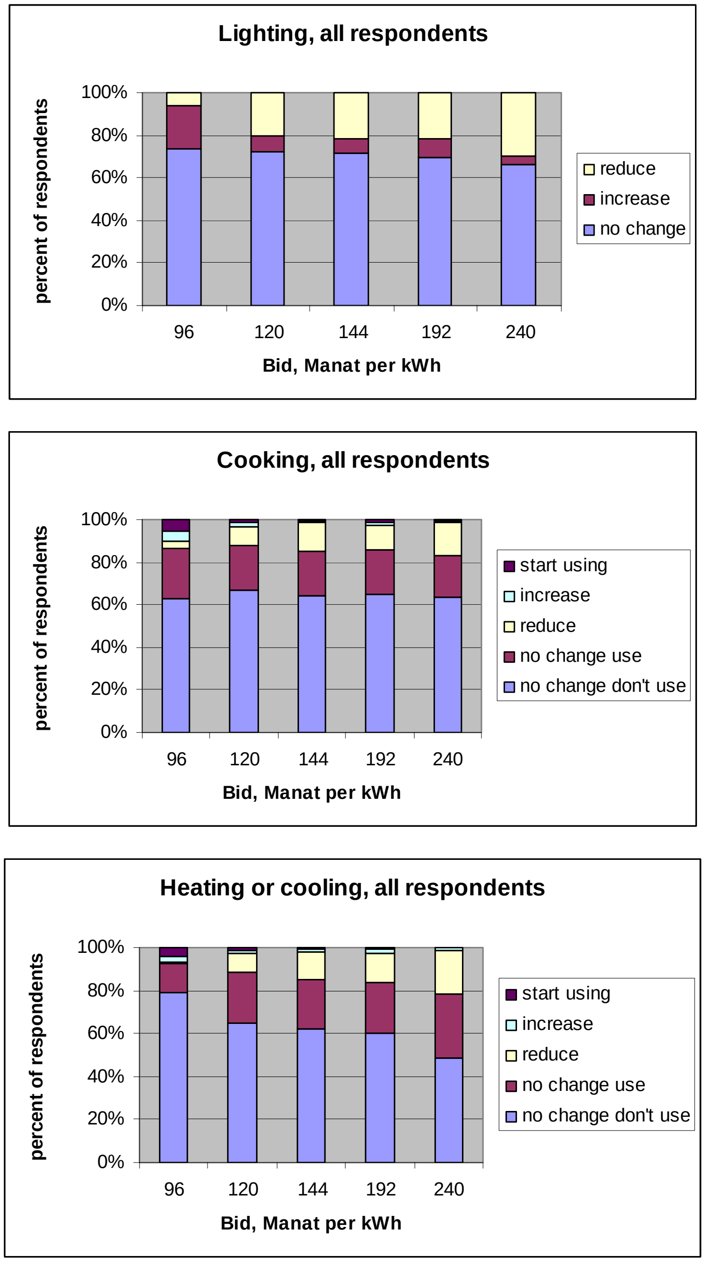
Table 3.6 Reported change in electricity use in the reform scenario. 1/

	No change	Switch	Increase	Reduce	N
Urban:					
Alibayramly	71%	0%	0%	29%	100
Baku	66%	0%	0%	33%	499
Ganja	38%	0%	0%	62%	150
Sumgait	47%	0%	0%	53%	150
Minchegevir	67%	1%	4%	28%	100
Goychay	74%	0%	0%	26%	50
Guba	73%	0%	0%	28%	40
Imishly	88%	3%	10%	0%	40
Ismailly	85%	0%	0%	15%	40
Sabirabad	40%	3%	5%	53%	40
Rural:					
Goychay	90%	1%	0%	9%	150
Guba	92%	1%	0%	7%	160
Imishly	61%	11%	16%	12%	160
Ismailly	94%	0%	0%	6%	160
Sabirabad	41%	9%	6%	44%	160

Note: 1/ All columns other than the last indicate the percentage of respondents in each area. "Switch" means that the respondent reports he/she does not currently use electricity for either cooking or heating, and would start using it in the reform scenario.
Source: 2003 Azerbaijan Household Energy Survey.

The share of households that report they would reduce their electricity consumption rises as the electricity price increases in the reform scenarios, while the share of those who would increase their electricity consumption or would start using it if they are not presently using it falls (Figure 3.3). Switching to electricity is limited largely to the rural areas, where the supply is currently unreliable, but would become perfectly reliable in the reform scenario. These findings further reinforce the credibility of the contingent behavior data.

Figure 3.3 Response to the electricity usage questions in the reform scenario. 1/



Note: 1/ The bids are the stated prices per kWh in the reform scenario.
Source: 2003 Household Energy Survey.

Imputation of electricity consumption from information on the use of appliances

Electricity consumption in kWh in the current price and reliability scenario and in the reform scenario is imputed using the information on hourly usage of electric appliances in these two scenarios. Electric appliances are used for heating, cooking, lighting, refrigeration and entertainment. Since households report hourly usage for each appliance separately, it is possible to impute electricity consumption for heating, cooking, lighting and refrigeration in the baseline and in the reform scenarios, using the wattage of typical household appliances in Azerbaijan and the information on hourly usage. Electricity use for other less energy-intensive purposes such as entertainment (radio, television etc.) was not available in the survey, with the result that total consumption is slightly underestimated. The resulting electricity consumption is reported in Table 3.7 both in terms of monthly winter kWh and in terms of the budget shares that those levels of consumption correspond to.

Table 3.7 Monthly imputed electricity consumption during the winter (all households). 1/

	kWh/month				Electricity as a percent of total monthly expenditures			
	All uses	Heating	Cooking	Lighting 2/	All uses	Heating	Cooking	Lighting 2/
All households 3/								
Unmetered	267	62	111	99	1.2%	0.3%	0.5%	0.4%
Metered	230	49	96	77	3.0%	0.7%	1.3%	1.0%
Households using electricity for heating 3/								
Unmetered	438	193	149	112	1.8%	0.9%	0.7%	0.4%
Metered	368	149	125	80	4.8%	2.0%	1.8%	0.9%
Households not using electricity for heating 3/								
Unmetered	184	0	92	93	0.9%	0%	0.4%	0.5%
Metered	162	0	81	76	2.1%	0%	1.1%	1.0%

Note: 1/ Winter consumption estimates in this table are generally comparable and somewhat higher than summer electricity consumption estimates from the 2004 Household Budget Survey data reported in chapter 4; 2/ Electricity use for lighting and refrigeration is combined; 3/ The reported budget shares were calculated assuming that households pay their bill in full, so that actual electricity expenditures are proportionally lower by the amount of non-payment.

Source: 2003 Household Energy Survey.

In order to assess the accuracy of the imputation of total electricity consumption based on the hours of use of each appliance, I compare the average level and distribution of electricity consumption obtained from this imputation procedure with consumption calculated based on utility company records. In this comparison I use a sub-sample of metered households from the 2003 HES for whom utility records are available. As described in Table 3.1, the data from the 2003 HES were matched household-by-household with the monthly billing and consumption records provided by the electric utility companies for a subsample of households in the survey.[14] These records are more accurate than the self-reported payment and consumption records collected in the 2004 Household Budget Survey.

Thus, I used electricity consumption figures calculated from the utility company records to verify that imputed electricity consumption based on the reported hours of usage of electric appliances is reliable. On average, electricity consumption calculated from the information on hourly appliances usage for metered households in Baku is 250 kWh per month in the current scenario and 223 kWh per month in the reform scenario. This is a good approximation of actual electricity consumption. As shown in Table 3.8, actual average electricity consumption calculated from the company billing records for metered households in Baku is 252 kWh per month. These averages are calculated for a subsample of households for which electric utility company records were available, while the distribution of actual and imputed electricity consumption is depicted in Figure 3.2.

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[14] The 2003 HES data are supplemented by the electric utility records provided for most households for a two-year period from January 2002 to December 2003. The utility records contain monthly billing and payment by each household in the subsample. However, only the records provided by the utility company that services two main cities, Baku and Sumgayit, give an indication of actual electricity consumption, since most households are metered there. In other urban and in rural areas usage is not metered. Rather, the bill is based on normative consumption, which is calculated based on the number of electric or gas appliances and household size.

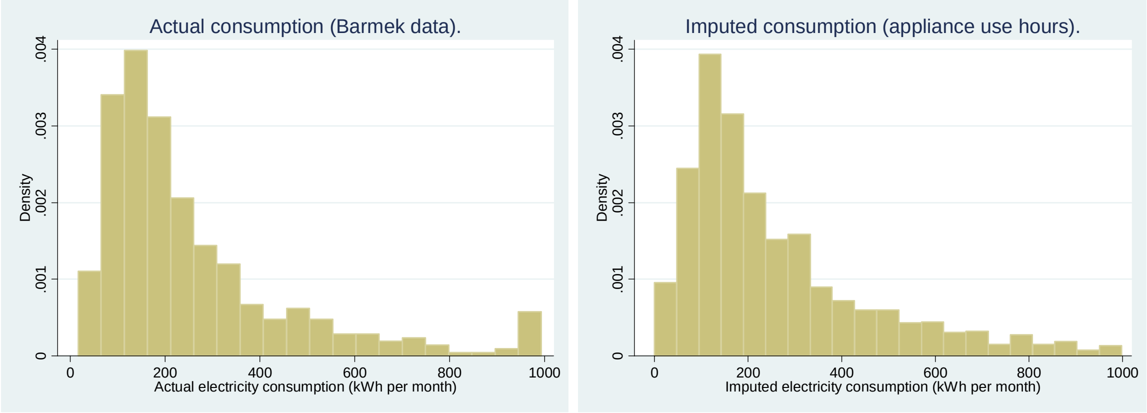
Table 3.8 Electricity consumption in Baku (metered households).

	kWh/month 1/	% of total budget
Current use		
Actual kWh (from utility records)	252	1.1%
Imputed kWh (from hours of appliance use)	250	1.3%
Imputed kWh in reform scenario		
All uses	223	3.2%
Of which heating	49	0.6%
Cooking	88	1.2%
lighting 1/	82	1.3%

Note: 1/ Electricity consumption for lighting and refrigeration were aggregated to represent the base load of electricity consumption.
Source: 2003 Household Energy Survey data and Barmek billing records for metered households.

As shown in Figure 3.2, the distributions of actual and imputed electricity consumption in the current scenario are similar except for households with the low range of electricity consumption below 100 kWh.

Figure 3.2 Distribution of actual and imputed monthly electricity consumption.



Note: These histograms compare actual and imputed current electricity consumption for metered households for whom the utility company billing records were available. Actual consumption is calculated by dividing the total monthly bill by electricity price. Imputed electricity consumption is calculated based on the current stated hours of usage of electric appliances.
Source: 2003 HES data and Barmek records.

The discrepancy in imputed and actual electricity consumption at low consumption levels is not surprising. This result might be explained by the fact that information on hourly usage of multiple low-wattage appliances, such as radio and television, was not collected in the 2003 HES, and it is excluded from usage-based imputed electricity consumption.

Imputation of total consumption expenditures

The model estimated in chapter 7 requires information on total consumption expenditure, as this variable appears in the denominator of the budget share equations. However, total expenditures, which are used as a proxy for total income, were not available for three quarters of the total sample in the 2003 HES and had to be imputed based on the subsample of 504 households. This subsample includes households for whom total consumption was available in the 2003 HES and in the 2002 HBS. In this section I develop an imputation procedure and verify its validity.

There is a debate in the literature about the relative merits of using total expenditures and total income as measures of the level of well-being. Overall, in developed countries income rather than expenditures tends to be used as a measure of well-being, while the reverse is true in most developing countries. The aggregate of total expenditures includes four components: consumption of food and non-food items, consumer durables and housing. In order to correctly account for expenditures on durables and housing, consumption of these items is usually valued at the "user cost" or "rental equivalent" that is usually imputed from the stock of durables rather than the purchase costs (Deaton 1997).

As shown in the literature that establishes an empirical relationship between total income and total expenditures, in developing countries total consumption expenditures are a more satisfactory measure than total income for two reasons. First, total expenditures are not closely tied to short-term fluctuations in income, for example when a large share of income is of seasonal nature. As a result, total expenditures provide a smoother and less variable measure of welfare than total income. Second, it has been shown that an accurate income measure is notoriously difficult to obtain whenever self-employment in small-scale business or agricultural production is common and, more generally, whenever households have diverse income sources (Deaton 1997, Deaton and Grosh 1999, Grosh and Glewwe 1998). Last, in the former Soviet countries under-reporting of income is a common problem, rendering income aggregates a poor measure of the level of well-being.

The 2003 HES was not designed to include a comprehensive module on itemized monthly expenditures, and instead survey respondents were asked about their income by source. As discussed earlier, total income is not a reliable measure of the level of well-being, particularly in Azerbaijan with pervasive tax evasion and under-reporting of income. In addition, the survey included a question about total monthly expenditures in a single question rather than asking for itemized expenditures and the stock of durables. Clearly, it is not possible to disentangle the expenditures on durables and impute the corresponding “user cost” from this information. It has been shown that this approach tends to provide a measure of total expenditures that may not be well correlated with the actual income level (Scott 2003). Indeed, I found that the total income variable reported in the 2003 HES is poorly correlated with the total expenditures variable in the 2002 HBS.

The State Statistics Office of Azerbaijan relies on the expenditure aggregate generated from the 2002 HBS to undertake poverty analysis and calculate poverty rates in the country. Even though some concerns have been raised about the reliability of the consumption aggregate in the HBS, as discussed earlier, this is a far more reliable measure of total income than the income information that was collected in the 2003 HES.

In order to impute total expenditures for households in the 2003 HES sample for whom this information was not available from the 2002 HBS I developed the following imputation procedure. I combined information on total expenditures and demographic and location characteristics for 504 households from the 2002 HBS, and information on the same demographic and location characteristics from the 2003 HES, and predicted total expenditures (income) for 1,496 households with missing total expenditures. The models, shown in Table 3.9, are OLS regressions of the logarithm of total expenditures on a range of variables representing demographic and location characteristics, with the second model incorporating a set of household assets as dependent variables. These estimation results need to be interpreted with caution. The purpose of the imputation procedure presented here is to obtain the best possible prediction of total expenditures rather than explain the factors that determine total expenditures and focus on the interpretation of the meaning of individual coefficients on particular variables.

Table 3.9 Alternative models for imputation of total consumption expenditures for households with missing data. 1/

	OLS Model 1a	OLS Model 1b
Demographic variables:		
Household size (log)	0.37**	0.34**
	(5.28)	(4.78)
Household size*region 1 (Baku and Absheron Peninsula), logarithm	0.12	0.12
	(1.00)	(0.93)
Household size*region 2 (Sabirabad and Imishly), logarithm	-0.06	-0.05
	(0.41)	(0.3)
Household size*region 3 (Guba, Ismailly and Goycay), logarithm	-0.17*	-0.16*
	(2.38)	(2.12)
Dummy = 1 if household head has higher education (complete or incomplete) 2/	0.02	0.02
	(0.37)	(0.34)
Dummy = 1 if household head has a low level of education (incomplete secondary, vocational, primary or none) 2/	0.02	0.02

	(0.3)	(0.3)
Number of children as a share of all household members	-0.2	-0.19
	(1.77)	(1.69)
Number of employed persons as a share of all household members	-0.31	-0.32
	(1.72)	(1.75)
Number of unemployed persons as a share of all household members	0.12	0.12
	(0.84)	(0.77)
Number of retired persons as a share of all household members	0.08	0.06
	(0.52)	(0.41)
Dummy = 1 if living in a house	0.09	0.07
	(1.3)	(1.01)
Total area (sq. m, log)	0.16**	0.14**
	(3.69)	(3.13)
Number of heated rooms (log)	0.02	0.01
	(0.26)	(0.21)
Income structure expressed as income from each source as a share of total income (omitted - pensions):		
Salaries of all household members	0.13	0.13
	(1.61)	(1.52)
Other labor income	0.02	0.02
	(0.19)	(0.16)
Social assistance payments (allowances)	0.11	0.09
	(1.16)	(0.91)
Seasonal income	-0.13	-0.15
	(1.04)	(1.15)
Remittances (transfers from other household members and friends)	0.04	0.04
	(0.62)	(0.55)
Income from product sales	0.18	0.17
	(1.78)	(1.6)
Other income	-0.05	-0.03
	(0.28)	(0.15)
Energy use and location characteristics:		
Dummy = 1 for space heater use	-0.03	-0.04
	(0.68)	(0.94)
Dummy = 1 for water heater use	0.1	0.11
	(1.26)	(1.38)
Dummy = 1 for wood collection	-0.07	-0.07
	(1.07)	(1.14)
Dummy = 1 for fuel wood use	0.25*	0.23*
	(2.33)	(2.13)
Fuel wood use dummy*Zone 2 3/	-0.26	-0.2
	(1.45)	(1.13)
Fuel wood use dummy*Zone 3 3/	-0.17	-0.15
	(1.26)	(1.09)
Dummy = 1 for dung use	-0.12	-0.11
	(1.5)	(1.3)
Dummy = 1 for network gas use	-0.12	-0.13
	(1.34)	(1.38)
Average daily hours of electricity supply in village/town (sq. root, log)	0.73**	0.67**
	(3.44)	(3.05)

Average village/town payment ratio for electricity (sq. root)	-2.68**	-2.41**
	(3.85)	(3.35)
Dummy = 1 if rural household	0.65**	0.56*
	(2.67)	(2.27)
Administrative region dummy variables (Baku, Sumgayit and Sabirabad omitted):		
Ganja	1.55**	1.42**
	(3.78)	(3.38)
Goycay	-0.11	-0.06
	(0.47)	(0.26)
Guba	1.50**	1.41**
	(4.56)	(4.18)
Imishly	0.29	0.32
	(0.91)	(0.98)
Ismailly	0.99**	0.94**
	(3.59)	(3.35)
Mingecev	1.01**	0.92**
	(3.24)	(2.85)
Household asset dummy variables:		
Air conditioner		0.06
		(0.86)
Color TV		0.01
		(0.28)
Satellite TV		0.04
		(0.73)
VCR		-0.06
		(1.25)
Video camera		-0.02
		(0.14)
Washing machine		0.03
		(0.72)
Sewing machine		-0.02
		(0.5)
Cell phone		0.05
		(0.9)
Motorcycle		0.17
		(0.92)
Car/truck		0.07
		(1.26)
Constant	10.85**	11.05**
	(15.59)	(15.47)
Observations	504	504
R-squared	0.35	0.36
Adjusted R-squared	0.30	0.31
Pseudo R-squared		

Note: 1/ The absolute values of t statistics are given in parentheses. Significance at the 5% level is indicated by '*' and significance at the 1% level is indicated by '**'; 2/ Omitted categories are specialized secondary and secondary education levels; 3/ Zone 1 is the omitted category and zone 4 was dropped due to multicollinearity; 4/ Dummy variables for Sumgayit and Sabirabad were dropped due to multicollinearity with the variables constructed as a product of wood use and region dummy variables.
Source: 2003 HES and 2002 HBS.

Estimation results indicate that total expenditures rise with household size (especially for households living on the Absheron Peninsula and the capital city), education level of household head, total housing area and the quality of electricity supply measured by average daily hours of supply. The estimated coefficients on these variables are statistically significant at the one-percent or five-percent levels. Interestingly, total expenditures fall as payment discipline rises, as captured by the average village or town payment ratio for electricity, and the coefficient on this variable is significant at the one-percent level. I have included this variable to capture the unobservable characteristics specific to location that have not been captured by other dependent variables. For example, variation in payment enforcement may be correlated with variation in the level of development of infrastructure and public services in a particular location.[15] The negative coefficient on this variable suggests that, after controlling for other factors and locational characteristics, stricter payment enforcement is correlated with lower incomes. Another interesting and somewhat counter-intuitive result is that, after controlling for other factors, total expenditures are higher for rural than urban households. Since the regional dummy variables are also included in the model, this result is less surprising.

Model 1b with the asset variables appears to be preferable because it has a good fit compared to typical cross section analyses, and the signs of the coefficients are generally as expected. Thus, model 1b is used to impute total consumption expenditures for 1,496 households for whom this information is not available.

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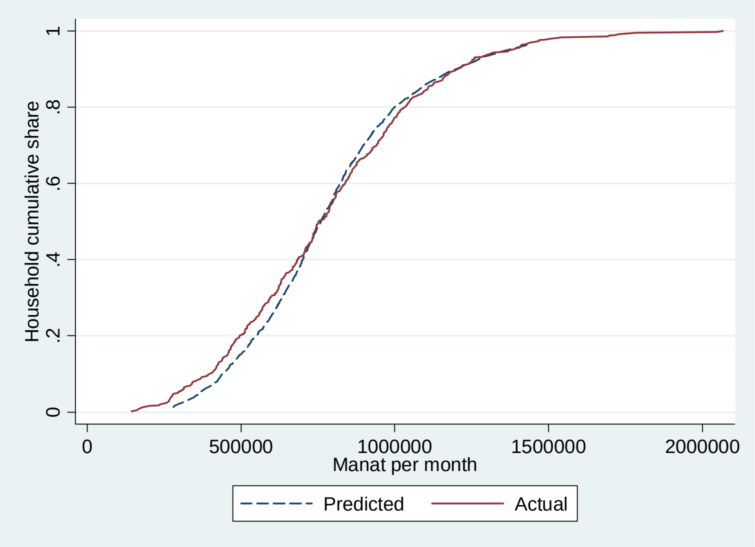
[15] Judging by communication with local energy experts, the stringency of payment enforcement is particularly low in areas that are poorly accessible to meter readers from the utility company and where it is easy for customers to either tamper with the meters or bribe meter readers. In the areas where the management of electricity distribution companies has been transferred to the private sector (i.e., Barmek utility company covering Baku and Sumgayit service areas), the utility company is implementing a set of measures to raise collections and raise the credibility of disconnection for nonpayment.

To examine the accuracy of this approach of imputation further, the errors of imputation in predicting the overall distribution of expenditures were examined using data on the 504 households for which expenditures were reported in the HBS data. Results suggest that the imputation procedure yields a very accurate characterization of the overall distribution of expenditures. As shown in Figure 3.4, the cumulative distribution of predicted expenditures is very similar to the actual expenditures from the 2002 HBS data for the 504 households.

Figure 3.4 Actual and predicted total expenditures (N=504).



Predicted expenditures have a somewhat narrower distribution than actual expenditures, but only mildly so. The somewhat narrower distribution is also evidenced by the smaller standard errors of predicted expenditures compared to actual expenditures as reported in Table 3.10. While the predicted overall distribution of expenditures is quite accurate, the errors in the regression of Table 3.10 are apparently intra-distributional, meaning that the imputation procedure predicts a very accurate overall distribution, but there are errors in predicting the correct quintile of individuals.

Table 3.10 Actual and predicted total consumption expenditures for 504 households with reported expenditures.

	Actual		Predicted	
	Mean	Standard Deviation	Mean	Standard Deviation
Alibayramly	740,886	242,004	721,105	174,667
Ganja	709,748	317,615	662,954	181,189
Goycay	807,324	243,339	780,310	106,298
Guba	789,354	362,714	717,358	130,731
Imishly	1,064,978	355,932	1,028,395	164,109
Ismailly	819,638	308,480	772,738	95,546
Mingecev	620,560	262,970	586,567	149,709
Total	784,803	323,230	744,041	192,285

Note: Consumption expenditures were predicted for 1496 households with missing data.
Source: 2002 HBS and 2003 HES.

Ideally, the poverty ranking would remain unchanged when using the actual and predicted expenditure aggregate. Table 3.11 shows that only 37 percent of the households who are in the bottom quintile of per capita total expenditures in the 2002 HBS are also in the bottom quintile using the imputed measure of per capita expenditures. However, and the corresponding figure for the top quintile is 73 percent. While the former percentage is troubling, the latter is encouraging. Furthermore, 66 percent of households who are in the bottom quintile of actual expenditures are classified in the bottom two quintiles by imputed expenditures.

Table 3.11 Tabulation of quintiles of actual and imputed expenditures (N=504).

Quintile of actual expenditures	Quintile of imputed expenditures				
	Poorest 20%	2	3	4	Richest 20 %
Poorest 20%	37%	29%	22%	10%	1%
2	20%	22%	22%	20%	15%
3	14%	18%	19%	28%	20%
4	6%	15%	23%	26%	30%
Richest 20%	0%	3%	9%	15%	73%

Note: Quintiles were weighted by household size. The null hypothesis that the classification of households into quintiles based on actual total expenditures is independent from the classification based on imputed total expenditures is rejected at 1 percent level by a chi square test.

Similarly, the percentages classified in the correct or adjacent quintile are 64% for quintile 2, 65% for quintile 3, 79% for quintile 4, and 88% for the richest quintile. Only one percent of the 504-household sample is erroneously classified as being in the top quintile (richest) when they are actually in the bottom (poorest) and no households in the top quintile are classified as being in the bottom quintile using the predicted measure of expenditures. Thus, the evidence presented here suggests that, while the imputed expenditure measure is not perfect, it is a useful imputation procedure, and particularly so for the better off households.

It is not surprising that the model does not perform as well in predicting total expenditures for the poor as for the nonpoor. The 504-household subsample in the 2002 HBS that was used as the basis for the prediction is not a random selection of households in the survey. There is bias in terms of location. For example, no one from the capital city of Baku is included in the 504-household subsample that was available for merging with the 2003 HES data (Table 3.12).

Table 3.12 Number of households with reported and imputed total expenditure variables.

	Source of the total expenditures variable		
	2002 HBS	Imputed	Total
Alibayramly	51	49	100
Baku	0	499	499
Ganja	150	0	150
Goycay	100	100	200
Guba	59	142	201
Imishly	60	140	200
Ismailly	40	160	200
Mingecev	44	56	100
Sabirabad	0	200	200
Sumgayit	0	150	150
Total	504	1,496	2,000

Source: 2002 HBS and 2003 HES.

In addition, average household expenditures for the whole sample of the 2002 HBS is 690,709 Manat per year, but is somewhat higher at 784,803 Manat per year for the subsample of 504 households.[16] This means that poor households are under-represented in the 504-household subsample. Thus, it is not surprising that the model used to predict total expenditures appears to perform worse for the poor than for the nonpoor households.

Conclusions

To sum up the findings in this chapter, the results of the contingent behavior module in the 2003 HES are plausible and the imputation procedures of total electricity consumption and aggregate consumption expenditures are relatively reliable. The overlap in the samples of the 2002 HBS, 2003 HES and utility company billing records was used throughout the different steps of the imputation procedure to assess the reliability of the predictions. Since the imputation of total expenditures is somewhat more reliable for the nonpoor than for the poor households, poverty analysis in this dissertation should be interpreted keeping that in mind. Furthermore, using the predicted total expenditures variable on the right-hand side of an energy demand model could produce biased results, while using this variable as the dependent variable (or its component) leads to the less serious problem of measurement error. Keeping in mind these data limitations, the model proposed in chapter 6 and estimated in chapter 7 does not utilize the predicted total expenditures as an independent variable.

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[16] Statistics are for the entire sample of the 2002 HBS as reported in "Assessment of Household Budget Survey Data in Azerbaijan" (World Bank, 2006, mimeographed).

4 Overview of energy consumption patterns in Azerbaijan

Households in Azerbaijan use a variety of fuels for heating, cooking and lighting. The choice of fuel is largely determined by the availability and supply quality of modern energy sources. This chapter argues that supply factors are far more important determinants of the fuel mix than household income or appliance ownership. I show this by examining how energy consumption patterns vary by income and other socio-economic dimensions and by location and the quality level of gas and electricity supply. The data used in this chapter are from the 2004 Household Budget Survey. So the pattern of energy consumption presented here is nationally representative.

The importance of supply reliability in explaining fuel consumption patterns

Usually, reliance on traditional fuels (e.g., wood, coal, dung) declines with income, while the share of households using modern fuels (e.g., central heating, network gas, electricity) rises with income (Barnes et. al. 2005, Lampietti and Meyer 2002). This tendency is also apparent in the household survey data from a sample of the former Soviet republics. Figures 4.1 and 4.2 indicate that this trend generally holds for fuel wood and network gas, however it is also true of the other modern and traditional fuels. There are some exceptions to this tendency, such as the higher incidence of fuel wood use among the nonpoor than among the poor in Armenia, Latvia and Lithuania, but typically the use of modern fuels is lower among the poor than among the nonpoor. [17]

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[17] It may seem surprising that the incidence of fuel wood use is higher among the nonpoor than the poor in Armenia, Latvia and Lithuania. At the time this survey was implemented in Armenia, it was experiencing the consequences of an energy blockade during a period of particularly tense relations with Azerbaijan, and electricity supply interruptions were very severe, leaving little except fuel wood for households at some income levels. In Latvia and Lithuania the situation is very different. Fuel wood could be considered a luxury good and its consumption is more comparable to Western Europe than the other former Soviet countries.

Figure 4.1 Fuel wood use among the poor and nonpoor.

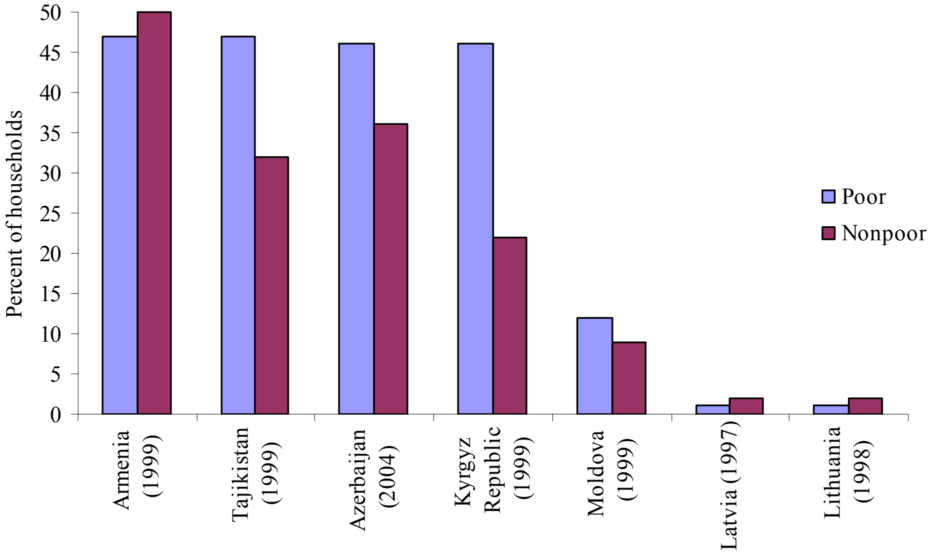
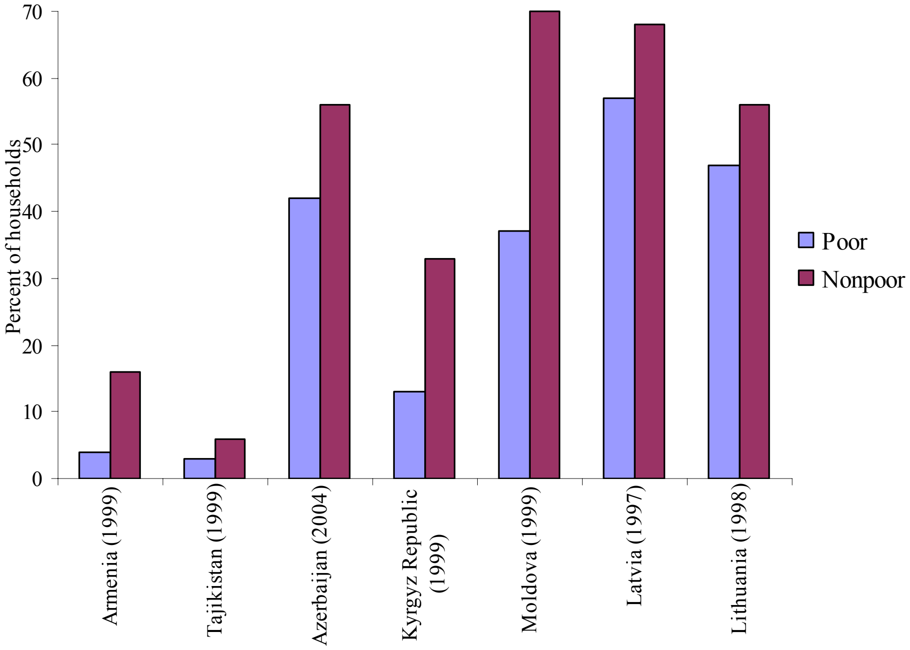


Figure 4.2 Network gas use among the poor and nonpoor.



Source: calculated from household survey data and reported in Lampietti and Meyer (2002); author’s calculations for Azerbaijan using 2004 HBS data. Poor are defined as households in the bottom 20 percent of total household expenditures, and nonpoor as households in the top 80 percent.

Reliance on network gas and fuel wood is rather high in Azerbaijan compared to other countries in the region, because gasification in Azerbaijan occurred on a much larger scale than in neighboring Armenia or in the Central Asian countries (Tajikistan and the Kyrgyz Republic). These charts do not take into account supply quality. It is not surprising that, given such a high level of reliance on network gas, problems with its supply are viewed as a serious social problem in Azerbaijan.

Supply constraints may explain much of the large variation in observed patterns of consumption by location. For example, in large cities households use a combination of electricity and network gas, as they tend to have relatively reliable supply of these fuels (Table 4.1). In small towns the supply of network gas is not reliable, leading to some reliance on fuel wood and liquefied petroleum gas (LPG) as back-up energy sources. In rural areas network gas is either not available at all or gas supply is so unreliable that very few households are able to use it. This is believed to be the reason why almost 40 percent of rural households report using fuel wood and LPG in rural areas.

Table 4.1 Reported energy use by households in cities, towns and rural areas.

	Network gas	Electricity	LPG	Heating oil, kerosene	Wood	Dung	Other
Large cities	96%	98%	8%	0%	1%	0%	0%
Towns	78%	94%	39%	6%	23%	1%	0%
Rural areas	6%	82%	64%	18%	78%	22%	1%
Total	53%	90%	38%	9%	38%	10%	0%

Source: 2004 Household Budget Survey.

In Azerbaijan, a country with low relative prices of network gas and electricity, the patterns of energy consumption appear to vary more by location than by income level. As shown in Table 4.2, regardless of the income level, around 96 percent of households in large cities use network gas, while the corresponding shares of households in towns and rural areas around 80 and less than 10 percent, respectively, again with little variation by income level.

Table 4.2 Reported energy use by households in different income groups.

	Network gas	Electricity	LPG	Heating oil, kerosene	Wood	Dung	Other
Cities							
Poorest 20%	94%	96%	8%	0%	1%	0%	0%
2	97%	98%	10%	0%	2%	0%	0%
3	96%	99%	5%	0%	0%	0%	0%
4	96%	97%	8%	1%	0%	0%	0%
Richest 20%	95%	98%	8%	1%	0%	0%	0%
Total	96%	98%	8%	0%	1%	0%	0%
Towns							
Poorest 20%	75%	95%	45%	6%	25%	1%	0%
2	76%	96%	41%	7%	20%	2%	0%
3	83%	95%	33%	4%	17%	1%	0%
4	71%	90%	46%	3%	35%	0%	0%
Richest 20%	92%	95%	23%	8%	18%	0%	0%
Total	78%	94%	39%	6%	23%	1%	0%
Rural areas							
Poorest 20%	3%	86%	57%	26%	77%	33%	1%
2	4%	80%	69%	17%	79%	25%	1%
3	5%	86%	67%	16%	76%	18%	0%
4	6%	76%	64%	16%	80%	12%	2%
Richest 20%	12%	79%	64%	13%	75%	12%	0%
Total	6%	82%	64%	18%	78%	22%	1%

Source: 2004 Household Budget Survey.

Electricity is used by more than 90 percent of households in towns and cities and only somewhat less in rural areas, although supply reliability varies. Lack of access to reliable gas and electricity supply in some towns and in the majority of the rural areas is compensated by a high incidence of LPG and fuel wood use, especially in rural areas. Dung is also used in some rural areas, especially in the South of the country where the forest is degraded, and high transportation costs result in high market prices of fuel wood. The relative lack of correlation between the usage patterns and income for the modern and fossil fuels, and the distinct regional differences, clearly indicate the importance of supply constraints rather than demand factors in fuel choice at current relative prices of fuels.[18] Any model explaining fuel choice and electricity demand must clearly reflect that.

A similar story to the pattern of energy use is true of the levels of consumption of different types of energy, to the extent that energy expenditures reflect consumption quantities. Energy expenditures vary from an average of 2.8 percent of total household expenditures in big cities to 4.7 percent in the rural areas, and their share is particularly high for the rural poor (Table 4.3). If the collection costs of fuel wood and dung in the rural areas were included, the shares would be even higher in rural areas.

Table 4.3 Structure of monthly energy expenditures. 1/

	Percent of total energy expenditures							
	Electricity	Network gas	Wood	LPG	Heating oil, kerosene	Dung	Total energy expenditures (Manat per month)	Energy expenditures (% of total income)
Cities								
Poorest 20%	59.7	40.1	-	0.2	-	-	20,574	3.5
2	61.7	37.5	-	0.7	-	-	22,574	2.9
3	61.8	37.3	0.4	0.5	-	-	22,163	2.7
4	63.9	35.2	-	0.7	0.2	-	20,892	2.6
Richest 20%	60.4	38.9	-	0.7	-	-	22,626	2.5
Total	61.4	37.8	0.1	0.6	-	-	21,878	2.8
Towns								
Poorest 20%	53.1	32.7	9.9	3.9	0.3	-	31,200	4.7
2	51.2	26.4	20.4	1.8	0.2	-	39,304	4.5
3	58.9	25.7	9.9	5.2	0.3	-	31,006	3.6
4	59.4	32.3	4.3	4.0	0.1	-	26,286	3.5
Richest 20%	56.2	34.1	6.6	2.3	0.8	-	23,799	2.5
Total	55.7	29.4	11.0	3.5	0.3	-	31,239	3.8
Rural								
Poorest 20%	61.4	1.9	29.5	4.8	2.2	0.2	36,084	5.3
2	55.6	1.6	34.3	5.8	2.5	0.2	39,567	4.9
3	50.8	5.4	33.2	8.2	2.0	0.4	42,918	4.7
4	54.3	3.4	34.4	6.3	1.6	-	42,766	4.3
Richest 20%	56.9	3.7	29.9	7.3	2.1	0.1	36,815	3.9
Total	56.1	3.0	32.3	6.3	2.1	0.2	39,604	4.7

Note: 1/ Expenditure quintiles were created using total expenditures net of food and alcohol expenditures. Collection expenditures on fuel wood and dung are excluded.
Source: 2004 Household Budget Survey.

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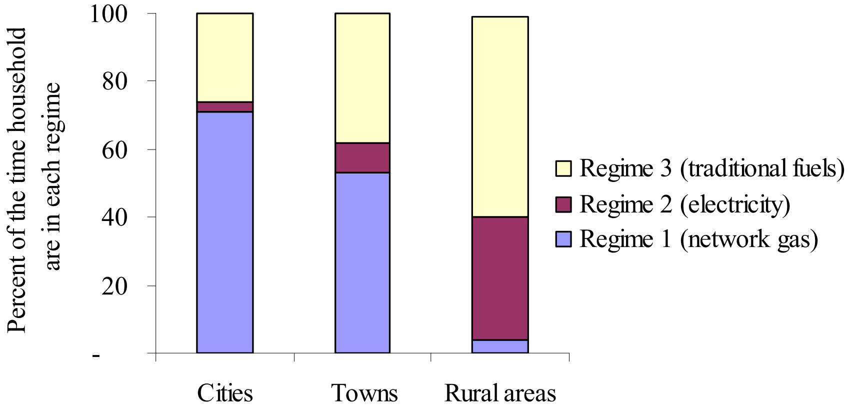
[18] In the case of network gas, the supply quality is better in less remote areas, which also tend to have higher income.

The differences in supply quality can be made apparent by defining three regimes of fuel availability pertaining to any given point in time. Let the first regime denote a situation when all fuels (network gas, electricity, wood, LPG and kerosene) are available. Let the second regime denote the situation when all fuels except for network gas are available. The third regime denotes the situation when households have access only to wood, LPG, and kerosene. For simplicity, the first regime is referred to as the "network gas regime," the second as the "electricity regime," and the third as the "traditional fuels regime," although the latter includes wood, LPG and kerosene. Figure 4.3 clearly shows the striking differences in fuel availability by location (also see Appendix Table 4.1). Hence, it is not surprising that households in towns and in rural areas rely on multiple energy sources, some of which are used as back-up sources of energy during supply interruptions of network gas and electricity.

Figure 4.3 Percent of time in each availability regime.

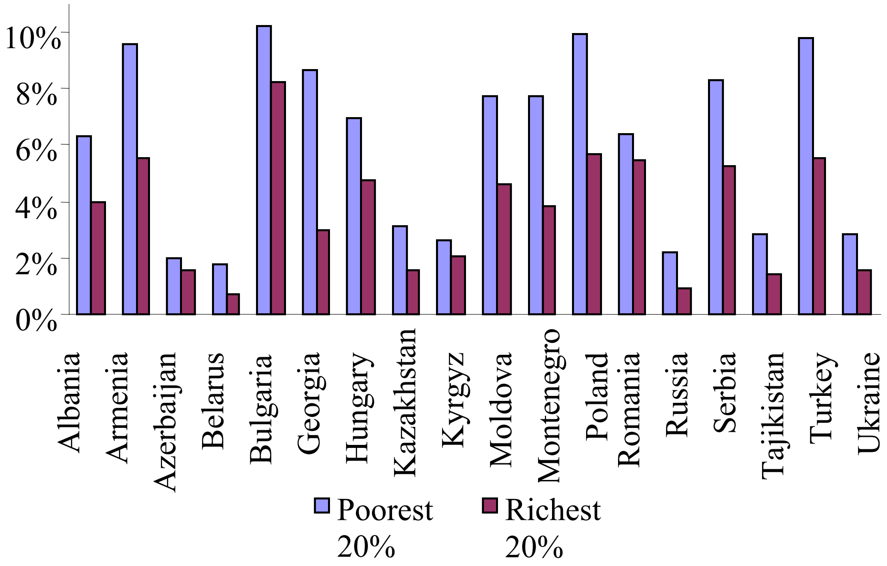


Source: 2004 Household Budget Survey.

The relationship between electricity consumption and income

Electricity expenditures constitute less than 2 percent of total household expenditures and are comparable to the budget shares in Belarus, Russia, Kazakhstan, and Ukraine, none of which have yet implemented electricity pricing reforms. As indicated in Figure 4.4, the discrepancy between the electricity budget shares of households in the lowest and highest income categories grows in tandem with electricity prices.

Figure 4.4 Electricity expenditure shares of poorest and richest households.



Source: World Bank staff estimates, as reported in Alam et al (2005).

Although budget shares do not have welfare significance from an economic point of view, they are often used as a benchmark in the course of evaluation of possible welfare consequences of reforms. There is no accepted rule of thumb of what level of electricity expenditures relative to household income is affordable, although a 10 percent budget share, recently proposed by the UK government, is sometime used as the benchmark level of affordability.[19]

In spite of their frequent use as an indicator of the magnitude of the affordability burden, budget shares could be low for various reasons, each having different policy implications (Foster and Tré 2003). For example, they could be low because of non-payment of utility bills, because of high income, or because of low energy consumption. Hence, it is crucially important to understand which of these reasons are important in each particular case.

In Azerbaijan income level does not appear to be an important determinant of electricity and network gas consumption. The absolute level of monthly electricity consumption exhibits surprisingly little variation by income level, even though there is significant variation by location (Table 4.4).

Table 4.4 Monthly average summer electricity consumption by region and type of area. 1/

	Per capital expenditure quintile					
	1	2	3	4	5	Total
By region:						
Nakhchyvan	287	266	279	354	310	295
Absheron	132	225	106	124	114	141
Ganja-Gazakh	177	171	185	154	143	172
Shaki-Zagatala	89	107	110	161	89	104
Lankaran-Astara	175	187	100	104		159
Guba-Hachmaz	101	159	111	78	114	109
Aran with Yuh. Karabah	163	177	140	200	217	174
Baku city	122	131	142	131	140	135
Dagliq shirvan	99	127	118	99	116	109
By type of area:						
Large city	130	149	137	137	142	139
Town	139	155	125	160	101	138
Rural area	127	159	199	178	172	157
Total	130	151	142	141	141	141

Note: 1/ These figures are calculated as the monthly bill divided by electricity price (including only metered households, N=848). Note also that quintiles were created based on total per capita expenditures excluding food and alcohol.
Source: 2004 Household Budget Survey.

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[19] DTI (Department of Trade and Industry). 2001. *United Kingdom Fuel Poverty Strategy.* London: DTI. Cited in Komives et. al. (2005).

On average, households living in towns and cities report that they consume 139 kWh/month of electricity and 211 m^3/month of network gas during the summer.[20] In the rural areas, network gas is rarely available, and average electricity consumption is slightly higher, but households meet most of their energy demand by using fuel wood.

There is also surprisingly little correlation of the consumed quantities with income across all regions. This finding is not consistent with evidence from other countries in the former Soviet Union and in the world, but in Azerbaijan it is not unique to the 2004 Household Budget Survey.[21] The levels of monthly electricity consumption show little variation by income level even when consumption is calculated from the records of the electric utility company for the capital city Baku.[22] Most of the variation is between regions, reinforcing again the conclusion supply factors have overriding importance in household fuel choices.

Variability in collection rates is a plausible explanation of the surprising finding that energy consumption levels are not correlated with income. It is common among Azeri households not to pay electricity bills or not to pay them in full. In the capital city Baku, the collection rates calculated as the actual payment divided by the bill amount tend to be lower for the poor than for the nonpoor (Table 4.5).

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[20] Consumption was calculated by dividing the reported amount of the last bill by the price of electricity and network gas, respectively. The table includes average electricity consumption for households with metered electricity consumption and average gas consumption for households with metered gas consumption. During the heating season, electricity and gas consumption is higher, but information about winter consumption was not available in this survey.

[21] Wu et. al. (2004) show in several former Soviet countries that the poor consume less energy for heating than the nonpoor when monthly energy consumption from different sources is converted into kilogram oil equivalents and aggregated into total energy consumption. However, there is also evidence that quantity of electricity consumption is not very well correlated with income (Komives et. al. 2005).

[22] Average consumption was 198 kWh/month, and there was very little variation by income quintile. This was based on the 2002 Household Budget Survey and 2002 Barmek records (electric utility company) for 1,094 metered households in Baku (Source: World Bank 2004).

Table 4.5 Evidence that differences between the poor and nonpoor are small (Baku only). 1/

Quintiles	Household Income US$/month	Household consumption kWh per month	Share of income on electricity	Collection rate 2/ Payment/bill
Poorest 20%	123	190	2.1%	65%
2	137	202	1.9%	61%
3	154	192	1.9%	74%
4	161	201	1.9%	68%
Richest 20%	189	200	2.2%	81%
Total	158	198	2.0%	71%

Note: 1/ Figures for Baku are based on records for 1,094 metered households in the HBS.
2/ The difference between the collection rate of the poorest 20% and the richest 20% is statistically significant at 5 percent level.
Source: calculated from 2002 Household Budget Survey and 2002 Barmek records and reported in World Bank (2004).

The average collection rate for the households in the bottom quintile of per capita expenditures was 65 percent compared to 81 percent for the households in the top quintile (World Bank 2004). If the payment discipline is weaker among the poor households than the richer households in other locations as well, then the effective price of electricity is lower for the poor because they tend to pay a smaller share of the bill. Hence, it is not so surprising that the electricity consumption levels vary little with income. The situation could be similar with network gas, although there is no empirical evidence.

Reform measures to enforce payment collection are accompanied by the planned introduction of universal metering. At present, slightly less than that half of all electricity and gas consumers pay according to meters (Table 4.6). The remaining households pay according to normative consumption depending on a variety of factors including their ownership of appliances, housing area and household size.

Table 4.6 Share of metered among connected households.

Region	Percent of households with metered consumption 1/	
	Electricity	Network gas
Nakhchyvan	na	24%
Absheron	10%	48%
Ganja-Gazakh	17%	18%
Shaki-Zagatala	6%	86%
Lankaran-Astara	0%	8%
Guba-Hachmaz	2%	31%
Aran with Yuh. Karabah	32%	24%
Baku city	73%	92%
Dagliq Shirvan	0%	49%
Total	43%	46%
N	2,110	1,112

Note: 1/ These are percentages of households with an electricity (gas) connection.
Source: 2004 Household Budget Survey.

Other factors affecting fuel choice

Although world-wide evidence points to a significant effect of fuel wood or coal use for heating and cooking on the incidence of respiratory illness, concerns about indoor air pollution resulting from the high reliance on fuel wood do not appear to be an important determinant of fuel choice by the Azeri households.[23] Respiratory illnesses are more prevalent among users of wood than among non-users in the urban areas, especially in large cities. However, these figures are only suggestive because they are not based on an epidemiological study and do not control for the income level and other confining factors.[24] Nevertheless, survey respondents do not appear to be very concerned with indoor air pollution from burning fuel wood at home.

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[23] See, for example, evidence from international experience presented in Ahmed et. al. (2005).

[24] In 28 percent of the households that use wood, at least one household member experienced chronic cough during the previous winter, compared to 10 percent in those that did not use wood. The corresponding figures in towns are 14 versus 12 percent, and in the rural areas 15 versus 19 percent (2004 HBS).

When asked about the relative importance of the factors affecting their choice of a heating fuel, over 50 percent of survey respondents indicated that fuel price, convenience, availability and reliability of supply, or the possible adverse effects of gas leaks had the strongest influence (Table 4.7).

Table 4.7 Factors affecting the choice of heating fuel (percent of respondents).

	Weak				Strong	
(in percent of all respondents)	**1**	**2**	**3**	**4**	**5**	**Sum of 4 and 5**
Price	7	10	21	26	36	62
Convenience	5	12	27	26	30	56
Uninterrupted supply/availability for purchase	9	14	26	30	22	51
Possible adverse effects of gas leaks on health	13	16	20	16	34	51
Availability of appliances/equipment at home	13	15	25	25	22	47
Health of household members	13	15	25	28	19	47
Possible adverse effects of smoke on health	18	23	21	18	20	38
Taste of food cooked on a wood stove	17	23	24	18	19	37

Note: respondents were asked to rank on a scale from 1 (weakest) to 5 (strongest) the influence of eight factors on their heating fuel choice. The numbers denote percentages of households.
Source: 2004 Household Budget Survey.

Ownership of appliances, health effects of smoke from burning fuel wood and the taste characteristics of food prepared using a wood stove appear to influence the choice less strongly. At the same time, only 30 percent of the households seem to be aware of the effects of smoke from fuel wood on the incidence of respiratory illness (Table 4.8).

Table 4.8 Factors that in the view of respondents are responsible for respiratory illnesses.

	Weak				Strong	
(in percent of all respondents)	**1**	**2**	**3**	**4**	**5**	**Sum of 4 and 5**
Poor diet/insufficient vitamins	6	10	17	28	39	67
Smoking	11	10	21	21	37	58
Low indoor temperature at home	9	14	21	28	28	56
Poor drinking water quality	17	14	15	20	34	54
Smoke associated with coal use	17	18	21	20	23	44
Smoke at home from fuel wood use	21	25	25	19	11	30
Genetic predisposition	16	24	33	15	11	26

Source: 2004 Household Budget Survey.

These findings may indicate that the population is not well informed about the health effects of fossil fuel use for heating or cooking. They also suggest that other problems, such as the affordability of heating sources and nutritious food, are simply more important to the people, as they indicate in the survey.

Implications for modeling household choice of fuels

The empirical findings in this chapter have several implications for the modeling approach adopted in chapter 6. First, income does not seem to play a large role in affecting fuel choice or consumption levels. The location and fuel availability are the key determinants of fuel choice decisions by Azeri households. This suggest that the main constraint to modern energy use at present is rationing (supply), not income (demand). But that can change in the future as supply reliability is improved, the prices of electricity and network gas increase, and payment discipline is improved. This is a fortunate situation given that income is poorly measured in the available survey data, and there are serious concerns about the reliability of the total expenditures aggregate even in the HBS data where it is available.[25] That is, in this situation, omitting the income variable is not likely to cause serious bias in estimation.

Second, because of the wide variation in supply availability constraints and intermittent reliability, explicit modeling of these supply constraints and effects of intermittent reliability appear to be of overriding importance. The demand for fuel use by type must appropriately reflect the high dependence of fuel use patterns on fuel availability, defined by the location.

Third, households do not appear to be very concerned with indoor air pollution from fuel wood use. Since households do not appear to be well informed about the health consequences from indoor air pollution, externalities from fossil fuel use seem to be

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[25] Pers. communication with the World Bank team for the Poverty Assessment for Azerbaijan. Based on the reported consumption aggregate, Azerbaijan has a very low level of inequality, which cannot be true.

unimportant as affecting energy choices. Therefore, the preference parameters for indoor air quality in an intermittent supply model are not likely to be significant. This means that the choice of fuels is likely to be driven by the prices alone after accounting for fuel availability.

Fourth, the cost of heating and cooking appliances does not appear to have a strong influence on the decision by households to use network gas or electricity for cooking and heating. This is not surprising, given that homemade cooking and heating appliances, made by the local craftsmen, are commonly used in Azerbaijan. As long as there is access to a reliable supply of gas or electricity at a sufficiently low price, households seem to prefer those sources.

Last, it is important to differentiate between the nominal tariff and the effective tariff paid by the households with low bill collection rates. If the reforms result in more than a doubling of tariffs to reach the full cost recovery level and an increase in collection rates, which currently vary between 35 and 80 percent, the effective tariff increase could be substantially higher than the nominal increase.

Appendix to chapter 4: Fuel availability regimes

Appendix Table 4.1 Percent of the time households are in each fuel availability regime.

	Cities			Towns			Rural areas		
	Regime 1	Regime 2	Regime 3	Regime 1	Regime 2	Regime 3	Regime 1	Regime 2	Regime 3
Poorest 20%	71%	3%	26%	50%	10%	40%	3%	38%	59%
2	68%	2%	30%	51%	12%	36%	3%	36%	61%
3	70%	3%	27%	55%	8%	37%	4%	36%	60%
4	69%	3%	29%	48%	9%	43%	4%	35%	60%
Richest 20%	76%	3%	21%	70%	3%	27%	10%	34%	56%
Total	71%	3%	26%	53%	9%	38%	4%	36%	59%

Note: Regimes are defined as follows:
Regime 1: All fuels are available
Regime 2: All fuels except for network gas are available
Regime 3: Only traditional fuels are available
Source: 2004 Household Budget Survey.

5 Alternative approaches for infrastructure service quality modeling[26]

Before focusing on modeling the intermittent supply problem in Azerbaijan, this chapter reviews traditional methods for welfare evaluation of infrastructure service quality changes and puts these methods in a broader theoretical perspective of welfare measurement. It describes the theoretical assumptions, data requirements and illustrates each method with examples highlighting common features and differences among methodologies. This review demonstrates that the problems of intrinsic service quality changes can be analyzed using willingness-to-pay estimates derived from market-based consumer surplus estimates, averting behavior analysis, and discrete choice welfare methods. However, the choice of modeling approach depends on data availability and on the way the quality affects household behavior.

Theoretical framework

From a theoretical standpoint, the benefits of improvements in service quality can be interpreted as a resulting change in an individual's or household's utility and can be measured by *compensating variation* (*CV*). By definition, *CV* is the money payment (possibly negative) necessary to compensate a consumer for a price and quality change after it occurs in order to bring her back to her initial level of well-being. Formally, *CV* can be defined in terms of the indirect utility function as $V(p^1, q^1, y - CV) = V(p^0, q^0, y)$ where p^0 and q^0 is the initial price and quality combination, p^1 and q^1 is the price and quality combination after the change, and y is income. The change in welfare could also be measured by the *equivalent variation* (*EV*), which is defined as the money payment to

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[26] This chapter is adapted from a paper co-authored with Michael Lokshin (Klytchnikova, I. and M. Lokshin (2006). "Measuring Welfare Impact of Infrastructure Service Quality Changes." Development Economics Research Group Working Paper. Washington, D.C.: The World Bank. Forthcoming).

a consumer (possibly negative) that would make her well-being the same in lieu of the price/quality change as if it had occurred. In terms of the indirect utility function, *EV* is defined as $V(p^0, q^0, y + EV) = V(p^1, q^1, y)$. These two measures are equal when the changes in utility from the change in quality are small enough so as not to alter the marginal utility of income.[27]

Infrastructure services have a variety of attributes that fall into two categories: service reliability and intrinsic service quality. Examples of intrinsic service quality are voltage fluctuations for electricity services, pressure for network gas, or the level of contaminants in a water supply. Service reliability for utilities is reflected in the frequency of outages and the predictability of their timing. As shown in Figure 5.1, several modeling approaches could be used to assess the welfare effects of a change in the reliability and intrinsic qualities of infrastructure services.[28]

The choice of an approach depends on the implications of outage occurrence for household behavior. For example, in some cases outages can be analyzed in the framework of rationing if the rationing restrictions apply uniformly across observed time periods. In others, they may have the same implications for household behavior as a change in intrinsic quality, permitting analysis in the same framework as intrinsic quality changes. In yet other situations, none of the existing approaches are adequate, such as in the case of intermittent supply when households substitute back and forth within

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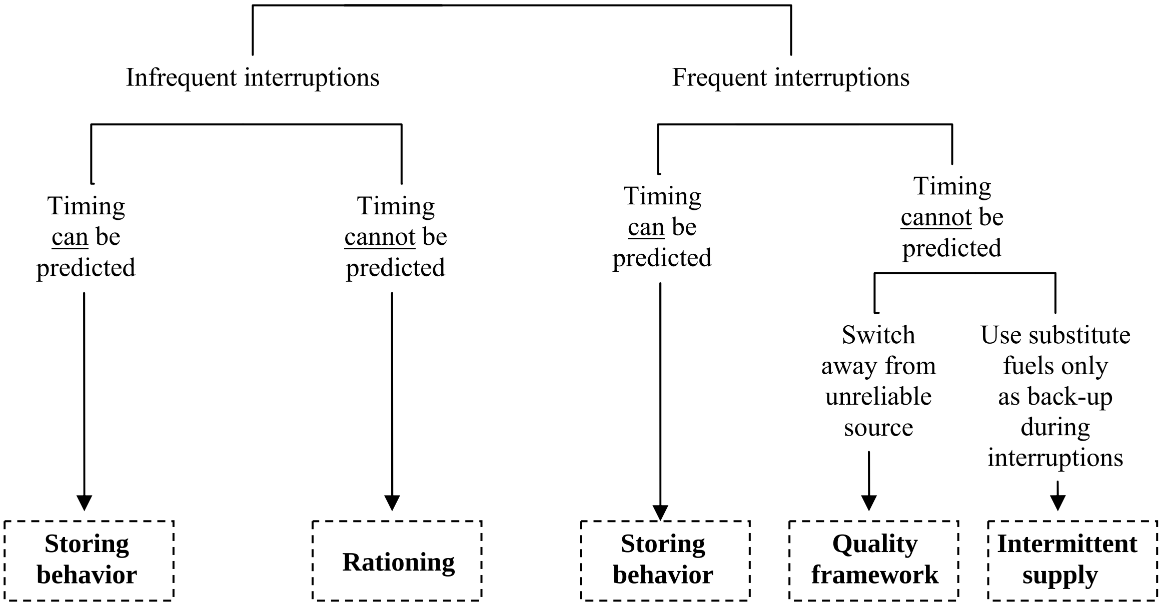
[27] *Willingness-to-pay* (WTP) and *willingness-to-accept* (WTA) are alternative definitions of the same theoretical measures of welfare. For an improvement in circumstances, *CV* is equal to the maximum WTP to obtain better quality, and *EV* is the minimum WTA to forgo the improved service quality. For degradation in service quality, *CV* is the minimum WTA to agree to new circumstances, and *EV* is the maximum WTP to avoid new conditions (Haab and McConnell 2002).

[28] Another possibility is that households may do nothing during outages and simply wait for the supply of a service to resume. This is probably less likely than the case when households engage in some type of storing behavior. I do not consider either of these cases in this chapter.

observed time periods between the network source of an infrastructure service and its market substitutes depending on whether the network source is available. One of the main objectives of this chapter is to clarify the conditions under which one of the existing approaches is appropriate, and provide motivation for a new model of intermittent supply developed in chapter 6.

Figure 5.1 Characteristics of supply interruptions and household modeling approaches.



Poor reliability of a service causes rationing for the households for which the quantity of services consumed falls below the quantity that would otherwise be demanded at prevailing prices. Since prices do not reflect the marginal utility of consumption in rationed markets, observed consumption levels cannot be used in welfare analysis of service reliability changes (Deaton 1981; Pudney 1989; Hentschel and Lanjouw 2000). In these cases, several methods have been proposed to account for the discrepancy between the observed consumption level and the true quantity demanded.[29]

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[29] Deaton (1981) and Pudney (1989) propose an econometric approach that accounts for the discrepancy between observed consumption quantities and unobserved quantities demanded. Sometimes an unbiased measure of consumer surplus or *CV* can be obtained when it is possible to impute the unobserved quantity

The case of pure rationing describes a situation of outage when outages are not frequent and their timing cannot be predicted. Hence, households do not adjust their energy consumption pattern in response to their expectations about supply quality, but simply do without an energy service on the rare occasions that outages occur. Cases of pure quantity rationing are rare in developing countries and are mostly found in countries with high service reliability. For example, household welfare losses from a recent blackout in New York could be analyzed in the framework of pure quantity rationing.[30]

Conversely, in developing countries with persistent supply problems, outages tend to be frequent. In some cases, outages are frequent but predictable (i.e., they always occur the same time of day). In this case, households may simply incur the inconvenience of having to time their use of services to match predictable periods of availability so that the welfare implications of inconvenience are inherent in observed demands as in the case of intrinsic quality models. In other cases, storage may be possible as in the case where water can be stored for consumption at other times when water pressure is adequate. In this case, the effects of quality can be measured by the averting behavior, which incurs the additional cost of storage facilities. However, both of these cases are unlikely to be common for energy demand in the developing world because storage of energy is not

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that would be consumed if the rationing constraint were not binding. Alternatively, it may be possible to impute a virtual price, which is a price that corresponds to the observed consumption if this was the actual quantity demanded. Virtual prices can be obtained from markets with very similar conditions, but no rationing (Hentschel and Lanjouw 2000).

[30] The pure rationing approach has been used in the electricity reliability literature to estimate the cost of outages. This framework is only applicable to analyzing welfare gains from improved service reliability in countries where outages are infrequent and unexpected. In a review of outage cost literature, Caves et al. (1990) describe the consumer surplus approach to outage cost estimation. It relies on the assumption about advance warning of an outage. The shorter the warning time, the less the consumers are able to adjust their consumption patterns, and thus the steeper is the demand curve and the greater are the welfare losses from an outage (Sanghvi 1983). With no advance warning, this method is equivalent to the rationing model.

practical and outages normally occur due to unplanned system failures rather than managed power cuts.

The conventional methods described in this chapter apply to (i) change in intrinsic quality, (ii) cases where outages are infrequent, (iii) cases where the timing of outages can be predicted, or (iv) rationing and outages that apply uniformly across observed time periods. When outages are frequent but their timing cannot be predicted, households may adjust to the changes in infrastructure service quality by investing in appliances that use substitute sources of energy when outages occur. These adjustments allow households to reduce losses from an outage but, at the same time, may cause additional costs associated with mitigating actions. Households may permanently shift away from an unreliable source and start using a more reliable substitute, for example fuel wood instead of electricity for heating and cooking. If all such adjustments are permanent changes in the choice of energy source, then this situation can be described in the same framework as a change in an intrinsic quality of a service. In this case, it could be represented by an inward shift of the demand curve for electricity. However, households may continue to use the unreliable service part of the time when it is available, and use substitutes during outages. In this situation, household consumption of a service is unconstrained when the service is supplied, and it is zero when it is not available. Thus, part of the time the demand curve is unconstrained and part of the time it is inapplicable because supply is zero. On average, the observed demand is below the level it would be in the absence of outages, but the extent to which it is below depends on what portion of the time the outage applies in each observed time period. The review in this chapter makes clear that this case cannot be represented in the conventional frameworks of rationing associated with cases (i), (ii), (iii) or (iv). Chapter 6 presents a new approach to modeling this case.

Empirical methods of measuring the welfare impact of quality changes

The welfare impact of changes in infrastructure service quality in cases (i), (ii), (iii), and (iv) can be measured with revealed or stated preference data using one of three methods reviewed in this chapter: exact measurement of the welfare impact of a change in service quality with the *direct demand estimation method*, welfare approximation based on the *averting behavior model*, and measurement of the expected welfare impact through *conjoint analysis*.

The revealed preference approach is comprised of various methods that use data on actual spending on market goods associated with the service in question. These data permit estimation of an implicit value of welfare improvements due to the change in quality of a particular service. Revealed preference methods include direct demand estimation, averting behavior, travel cost models based on random utility modeling, hedonic pricing, and, in the case of effects on human health, cost of illness models. Since the latter two methods are not particularly useful in welfare evaluation of infrastructure service quality changes, I omit their discussion from this chapter.

With the exception of the random utility modeling approach, most revealed preference methods of measuring the welfare impact of infrastructure service quality changes are based on the household production function approach (Becker 1965; Gorman 1956; Lancaster 1966). In this theoretical framework, households use infrastructure services as inputs in the production of household services. For example, electricity combined with household appliances produces lighting, heat, energy for cooking, and entertainment provided by the radio and television. Network gas can be used to produce heating or cooking services. Water can be consumed for drinking or for bathing and cleaning (which could be considered as health services). At the same time, if water is contaminated with harmful bacteria, it provides a disservice through an increase in the risk of illness. This framework applies to the direct demand estimation method and the averting behavior approach as well as the intermittent supply model discussed in the next chapter.

The term “stated preferences” refers to survey-based methods that rely on information about households’ willingness to pay for a service quality improvement, or about their choices and behavioral changes in hypothetical scenarios involving service quality changes (Freeman 2003). Stated preference methods include *contingent behavior*, *conjoint analysis,* and *contingent valuation*. *Contingent behavior* methods are based on survey questions about respondents’ behavior in a hypothetical situation. For example, such a survey might ask whether a respondent would switch to a different fuel or water source if its price or quality were to change by a certain amount. In *conjoint choice surveys*, a respondent is given a choice of alternative projects or commodities with specific quality and price attributes. In the *contingent valuation* approach, respondents are asked to directly report their willingness to pay for a change in quality of a service.

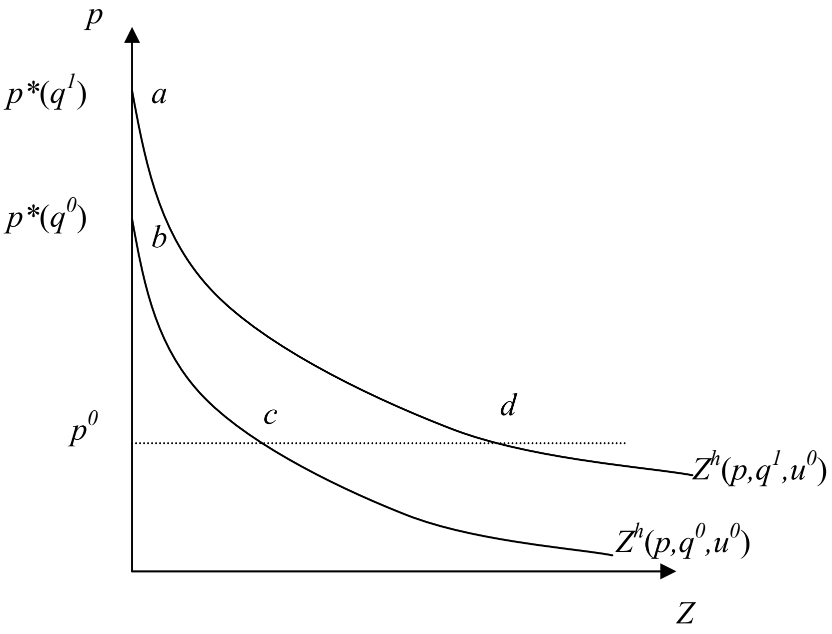
Most of the approaches discussed in this chapter may use revealed preference data and/or stated preference data from contingent behavior or conjoint choice surveys. In subsequent sections of this chapter, I discuss the theoretical basis, applicability and data requirements for each of these methods and provide illustrative examples of welfare evaluation of changes in the quality of different infrastructure services.

Direct demand estimation method

The most straightforward way to estimate the welfare effect of a change in service quality is to measure it by the area between demand curves at the original and improved quality levels and above the price line. This is the essence of the *direct demand estimation method*. This approach is applicable when two assumptions are satisfied. The first assumption is weak complementarity, which requires that the consumer's welfare is unaffected by changes in the quality of a service he or she does not consume (Mäler 1974). For example, we can assume that the welfare level of a household that consumes no electricity is unaffected by a change in the quality of electricity supply. The second assumption is non-essentiality. It implies that there exists a sum of money that would compensate the individual for complete loss of the service. This assumption would not be satisfied for a vitally important service or good, such as air, food, water or heat. However, in the case of infrastructure services like water and heat, the non-essentiality assumption can be relaxed. Although water and heat are essential goods, inputs in their production such as bottled water, public water, gas and electricity are individually non-essential. This condition is satisfied in household production models that allow complete substitution for any particular input used in the production of an essential household service.

When the weak complementarity and non-essentiality assumptions are satisfied, the area between two compensated (Hicksian) demand curves is finite and can be interpreted as an exact welfare measure of a change in service quality (Just et al. 2004; Train 2003). Graphically, the *CV* of a change in quality is represented by area *abcd* in Figure 5.2, where Z^h denotes the Hicksian demand for the service, q^0 and q^1 are quality levels before and after the change, respectively, u^0 is the initial level of utility, p^0 is the price of service, and $p^*(q^1)$ and $p^*(q^0)$ are the so-called choke prices at the initial and final quality levels. The choke price is the lowest price at which the demand for the service is zero. It is only defined for non-essential goods because otherwise the demand curve does not intersect the vertical axis.

Figure 5.2 Compensating variation of a quality change.



Formally, the area *abcd* between the Hicksian demand curves at the initial and final quality levels and above the price line can be expressed in terms of the earlier notation as $\int_{p^0}^{p^*(q^1)} Z^h(p,q^1,u^0)dp - \int_{p^0}^{p^*(q^0)} Z^h(p,q^0,u^0)dp$.

Using Shepherd's Lemma, from which the Hicksian demand is derived by differentiation of the expenditure function with respect to price, $Z^h = \partial e / \partial p,$ evaluation of these integrals at the limits of integration obtains area $abcd = e(p^*(q^1), q^1, u^0) - e(p^0, q^1, u^0) - e(p^*(q^0), q^0, u^0) + e(p^0, q^0, u^0)$, where the sum of the first and the third terms is equal to zero if the weak complementarity assumption is satisfied (Freeman 2003). In terms of the expenditure function, *CV* is then the difference between the expenditure necessary to attain the same level of utility after a change in service quality as before the change, $CV = e(p^0, q^0, u^0) - e(p^0, q^1, u^0)$. Thus, the sum of the second and fourth terms is equal to the compensating variation of the quality change from q^0 to q^1. The *EV* can be found similarly by replacing u^0 by u^1.

In practice, the compensated (Hicksian) demand is not directly observable because it depends on unobservable utility. Alternatively, many studies measure the welfare implications of quality changes by using the uncompensated or ordinary (Marshallian) demand, which is directly observable. Calculations similar to those above with ordinary demand functions measure the change in consumer surplus, which approximates the welfare change (*CV* or *EV*) when certain conditions are satisfied.[31] The welfare effect of a price and quality change, represented by a change in consumer surplus, is depicted in Figure 5.3, where ordinary demand curves for service x at the initial and improved quality levels are represented by $D(q^0)$ and $D(q^1)$, respectively. The change in consumer surplus associated with a simultaneous change in price from p^0 to p^1

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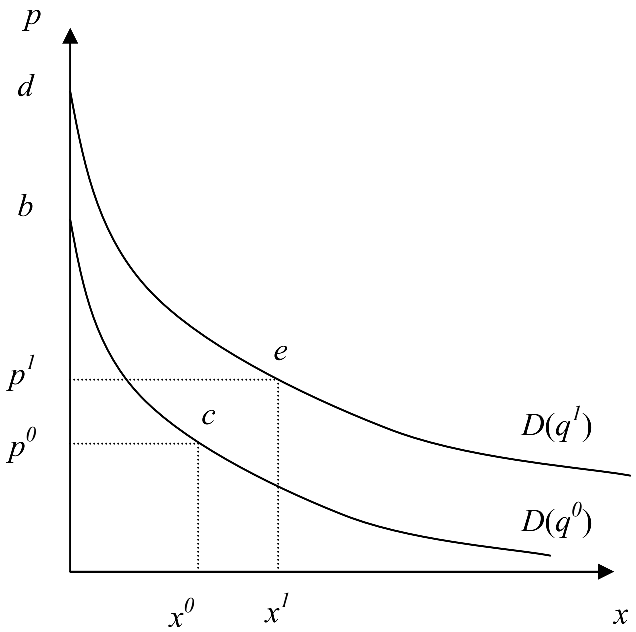
[31] Hicksian demand curves are utility-constant and are not directly observable, unlike the observable Marshallian demand curves, which are income-constant. Willig (1976) shows under which conditions the consumer surplus (CS) measure (the area under the Marshallian demand) provides a close approximation to the area under the Hicksian demands, which is the true measure of welfare change. If these conditions hold, i.e., if the expenditures on the good in question form a small share of the overall household budget, and the income elasticities are low, then the change in CS associated with a price change falls within tight bounds between the *CV* and *EV* measures. If Marshallian demands are used to approximate the welfare impact of a change in quality rather than price, then an additional restriction is necessary to establish these bounds (Bockstael and McConnell 1993; Palmquist 2005).

and a change in quality from q^0 to q^1 is the difference between the initial and final consumer surplus, denoted by area p^1de – area p^0bc.

Figure 5.3 Consumer surplus change associated with a quality and price change.



While Hicksian demands cannot be observed directly, work by Hause (1975) and Hausman (1981) has shown how Hicksian demands can be inferred from estimates of ordinary demands. With the development of modern second-order flexible forms, e.g., the translog, generalized Leontief, and generalized Cobb-Douglas forms, which can be used to represent indirect utility, these methods are quite flexible. Just et al. (2004) describe the application of this approach to welfare measurement for a variety of flexible functional forms. Thus, exact welfare measures of price changes (*CV* or *EV*) can be calculated based on estimates of corresponding specifications of ordinary demands derived from those indirect utility forms. While quality variables can be integrated into this approach by making some of the parameters functions of quality levels, the popular second-order flexible forms impose essentiality on all goods so that choke prices do not exist. Thus, goods for which weak complementarity applies cannot be modeled directly with such forms.

For the case of weak complementarity exact welfare measures have been derived only for semilog demand functions, which somewhat limits the applicability of this approach in the evaluation of welfare impacts of quality changes. Further, for large price changes, such as are contemplated in this study, Kling has shown that functional form can have critical implications for the measurement of welfare change. Thus, more flexibility in the demand specification is desirable.[32] However, flexibility can be attained by modeling demand for essential household services such as cooking and heating using a flexible functional form, and then modeling substitution of the household technologies that produce the household services. This is the approach pursued further in the following chapter.

Alternatively, the traditional approach has been to use the direct demand estimation method to assess the welfare impact of changes in reliability of residential electricity provision. With this approach, the demand for fuel is modeled as an ad hoc function of some reliability measure. For example, the costs of electricity outages are estimated using data on consumption of electricity at different reliability and price levels. Having estimated demand functions for alternate reliability levels, a researcher can calculate the change in welfare resulting from a reliability improvement (e.g.,Westley 1984; Dias-Bandarnaike and Munasinghe 1983). This approach is based on the observation that households reduce their reliance on electricity, switching to substitute

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[32] The choice of functional form for the demand function has a large impact on consumer surplus measures. In a simulation experiments, Kling (1989) shows that the errors resulting from the use of an incorrect functional form for large price changes can range from 4 to 107 percent of the estimated consumer surplus. The error is equal to only a few percentage points for small price changes. This leads her to conclude that for small price changes, the choice of functional form is not nearly as critical as it is for a large change.

sources of energy and/or increasing their consumption of non-energy goods when electricity supply becomes unreliable. A reliability improvement has the opposite effect, causing an increase in consumption of electricity. The electricity demand curve shifts outward from $D(q_0)$ to $D(q_1)$ in Figure 5.2 and this shift is assumed to represent an increase in a consumer's willingness to pay for all units of electricity delivered with higher reliability.

An evaluation of the welfare impact of changes in electricity supply reliability in Costa Rica illustrates this method. Dias-Bandarnaike and Munasinghe (1983) use county-level time-series data on residential electricity consumption to estimate demand at the very low, low, and medium reliability levels. Three demand equations at alternate reliability levels are used to derive demand projections depending on supply reliability levels. The estimated increase in consumer surplus was about fifty percent of the initial consumer surplus when supply reliability in Costa Rica improved from the very low to medium level.

In practice, applications of the direct demand estimation approach are limited by the availability of data. The prices of infrastructure services tend to be regulated and set nationally or at least regionally, resulting in insufficient price variation for the estimation of a demand function. Moreover, when supply interruptions constrain consumption, the observed consumption may be below true demand, and therefore these observations cannot be used in demand estimation without accounting for discrepancies between demand and observed consumption.

An additional assumption of perfect substitutability between the publicly supplied infrastructure service and its market substitutes extends this method's applicability and is commonly made in practice (e.g., World Bank 2002; Choynowski 2002; Barreix et al. 2003). Two examples of an evaluation of the welfare effect of service quality improvement of municipal water supply and electricity provision illustrate this point.

In the recently launched Public Enterprise Reform Program, the Panamanian government sought to encourage private sector service delivery in the water supply and sewerage sector. The cost-benefit analysis of the sector's reforms focuses on the behavior of unmetered consumers who cope with intermittent water supply (Barreix et al. 2003). Before the project, these consumers paid a fixed monthly fee, receiving water at a zero marginal price, and dealt with supply interruptions by using overhead water tanks. The implicit price of water when overhead tanks are used is the marginal cost of operating a tank. After the project, households received service twenty-four hours a day, but they were forced to pay a new tariff depending on their water consumption rather than a zero marginal price.

Assuming that water from overhead tanks is a perfect substitute for water from the public supply, the price-quantity combinations of these two sources are sufficient to estimate a linear demand function and to calculate a change in consumer surplus. The welfare impact of the project can then be approximated as a sum of two components. The first component is a reduction of consumer surplus resulting from a decline in consumption at a higher marginal tariff because of the introduction of consumption-based volumetric charges. The second component is an increase in consumer surplus due to the savings in electricity, maintenance, and other expenses associated with the operation of overhead tanks.

The drawback of this analysis is that it fails to account for changes in behavior of households with intermittent supply. It assumes that households always rely on the use of the overhead tanks, even when water is available from the public supply system. These assumptions could lead to overestimating the benefits from improving supply quality. Before the reform, some of the time the formerly unmetered households relied on water from the public supply, which they received at a zero marginal price, for which they were charged after the change. Another problem with this approach is the assumption of perfect substitution between water from overhead tanks and from the public water supply. The analysis assumes that households experience no additional benefits from consuming water from the public supply system versus the overhead tanks, which are more cumbersome to operate. This assumption could lead to underestimating the benefits of a service quality improvement. Overall, the direction of the bias in the calculated welfare measure is unclear.

The assumption of perfect substitutability requires more careful consideration when employed for household energy use. The direct demand estimation approach has been used to approximate welfare gains of electrification in the Philippines (World Bank 2002; Choynowski 2002). In the Philippines, electricity is primarily used for lighting. If kerosene and electricity are assumed to be perfect substitutes in producing light, the data on kerosene consumption by non-electrified households and electricity consumption by electrified households give two points on the demand curve for lumens. This information is sufficient to calculate consumer surplus of electrification under an assumption of linear demand function for electricity.

However, the assumption of perfect substitutability is not always plausible. While it could be reasonable to assume that public water and water from overhead tanks are perfect substitutes, its applicability is more questionable for electricity versus kerosene used for lighting or for electricity versus fuel wood used for heating. For example, in the Philippines the majority of non-electrified households that use kerosene for lighting recognize that indoor air pollution can cause health problems, so they place a higher value on a lumen from electricity than on a lumen from a kerosene lamp (World Bank, 2002). In some cases, consumer surplus calculated with the assumption of perfect substitutability can be interpreted as the lower bound on the true welfare gains even when this assumption is not satisfied in practice. Thus, in the Philippines the consumer surplus of switching from kerosene to electricity is the lower bound on the welfare gains, as long as lumens from electricity are cheaper than lumens from kerosene.

The direct demand estimation method is a highly useful approach when adequate data are available. If necessary data are available, direct demand estimation permits accurate welfare measurement of an impact of a service quality change with *CV* (*EV*). However, modeling weak complementarity and non-essentiality, where appropriate, with flexible functional structure is a challenge. Further, price and quality variation in the data on consumption of the service in question are rarely sufficient for demand estimation. Even when such data exist, if the anticipated service quality and price changes fall outside the range of observable data, the estimated welfare measures based on observed data may not be statistically accurate. Experimental data from contingent behavior surveys are particularly useful in this case as they can supplement observed data and provide useful observations outside the variation of observed sample data. As demonstrated by Azevedo et. al. (2003), combining data in this way is an advantageous approach as it imbeds stated preference data in observed behavior. To the best of my knowledge, except for this dissertation, an evaluation of the welfare impact of infrastructure service quality changes has never been attempted using the direct demand estimation method combining revealed preference data with data from contingent behavior surveys.

Averting behavior model

The direct demand estimation approach may be too demanding in terms of data requirements for some applications. In situations where direct demand estimation is not feasible, the welfare impact of infrastructure service quality changes can be estimated using a *model of averting behavior*, which is referenced in the literature alternatively as defensive expenditures, mitigating behavior, or coping cost models (Freeman 2003). This approach is less demanding in terms of the data requirements.

The averting behavior model estimates bounds on CV using information on expenditures associated with deterioration in service quality. This model assumes that a consumer can mitigate deterioration in service quality by using some purchased commodities. In other words, the quality of the service and the purchased commodity are assumed to be substitutes. Under this assumption, a change in averting expenditures triggered by a change in service quality represents bounds on the welfare effect.

Consider, for example, a household that purchases bottled water to avoid exposure to contamination in the public water supply. Suppose a household maximizes a utility function $U(q, z(x,b))$ subject to a budget constraint, where q is a composite bundle of purchased commodities, x is purchased bottled water, b is the quality of public drinking water supply, and z is the level of health services a household obtains from drinking water.[33] The utility function is increasing in q and z, and z is increasing in x and b. Also suppose that public water is supplied at no charge. This household utility maximization problem can be represented as a dual problem of expenditure minimization.

The expenditure function, $e(p,r,b,U)$, represents the minimal expenditure that is necessary to reach the level of utility U, where p is the price of the consumption bundle q, and r is the price of bottled water. The expenditure function is decreasing in b and increasing in the other arguments. The expenditure minimization problem can be written as follows:

$$\min_{q,x} e(p,r,b,U) = pq + C(z,r,b) + \mu(U - U(q,z(x,b))),$$

where $C(z,r,b)$ is the cost function for the production of health services from drinking water. Compensating variation resulting from a change in the quality of public water supply can be expressed as $CV = e(b^0,U^0) - e(b^1,U^0)$, where U^0 denotes the utility level before the change, and b^0 and b^1 denote the quality of the public water supply before and after the change, respectively. The change in the cost of producing the original level of health services is given by the averting expenditure $AE = C(z^0,b^0,r^0) - C(z^0,b^1,r^0)$, and z^0 is the original level of health services from drinking water.

It can also be shown that $e(b^0,U^0) - e(b^1,U^0;z^0) = C(z^0,b^0,r^0) - C(z^0,b^1,r^0)$ (Bockstael and McConnell 1999). By adding and subtracting the same term, the expression for CV can be rewritten as

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[33] This presentation of the model borrows from Bockstael and McConnell (1999). See also Freeman (2003, 105) and Ribaudo and Hellerstein (1992).

$CV = e(b^0, U^0) - e(b^1, U^0; z^0) + e(b^1, U^0; z^0) - e(b^1, U^0)$. The third term is a restricted expenditure function and the fourth term is unrestricted, whereby the former is necessarily greater than the latter (Bockstael and McConnell 1998). In other words, compensating variation is equal to averting expenditures plus a term that is positive. This is a well-known bounding result due to Bartik (1988), who showed that averting expenditures provide an underestimate of the benefits associated with a quality improvement, and an overestimate of the losses in a case of quality deterioration.

A crucial assumption underlying this result is that the losses from the deterioration in service quality are completely mitigated by a purchased substitute good. If this is not true, then the averting expenditures associated with quality deterioration may be an underestimate of the actual welfare losses.

It is also important to note that households respond to the quality change by adjusting their consumption of *z*. For example, they may demand a lower level of health services, *z,* after deterioration in the quality of water from the public supply, *b*, than before the change. Bartik's lower bound is given by the averting expenditures necessary to hold *z* constant after a change in *b*. This is sometimes overlooked in practice, when the observed change in expenditures on health or energy services is used as the lower bound on *CV* (*EV*) (Ribaudo and Hellerstein, 1992).

Averting expenditures provide an exact measure of the welfare impact of a change in service quality if the purchased good (e.g., bottled water) and quality (e.g., the quality of public water supply) are perfect substitutes in the production of good *z*. In this example, the perfect substitutability relationship is likely to hold, but usually this is not a plausible assumption, in which case averting expenditures give a lower bound on $CV(EV)$ rather than an exact measure of welfare change.

A classical example of the averting behavior method is the much cited study of the welfare effect of drinking water contamination in Pennsylvania (Abdalla et al. 1992). Following the detection of contamination with Trichloroethylene (TCE) in a Pennsylvania community, the Environmental Protection Agency issued a warning to notify customers of the contamination incident. Mail questionnaires were sent to households in this community to elicit information about increases in averting expenditures to avoid exposure to the contaminant. These expenditures included the time costs of undertaking averting actions and cash outlays. In attributing averting expenditures to the contamination incident, Abdalla et al. (1992) were careful to satisfy the assumptions necessary for Bartik's (1988) bounding result to hold. First, the averting expenditures had to exhibit no jointness in production. This means that, for example, the purchase of bottled water has no additional benefits apart from mitigating the health risk from exposure to TCE. On the contrary, if households purchased water for taste reasons, unrelated to the contamination incident, bottled water expenditures cannot be considered as averting expenditures. Second, the averting expenditures should not involve sunk costs in the purchase of durable goods. For example, the purchase of home water treatment systems results in benefits that extend beyond the contamination incident, and so their cost can be only partially included in the estimate of averting expenditures. When the two assumptions about jointness in production and the purchase of durable goods are satisfied, the averting expenditure estimates provide a lower bound on WTP to avoid exposure to contamination.

Applications of the averting behavior model are limited to cases where households respond to deterioration in infrastructure service quality by undertaking specific expenditures, either in terms of time or monetary expenditures. The averting behavior model has been used for the analysis of welfare implications of changes in the quality of air and drinking water, although the range of its potential applications is much broader (McConnell and Bockstael, forthcoming). In the area of infrastructure services, the most natural area of application of this method is welfare evaluation of changes in the quality of drinking water.

Most studies of drinking water quality, which are described in Table 5.1, use averting expenditures as a lower bound on welfare gains from improvements in service quality.

Table 5.1. Applications of the averting behavior model.

Problem description and reference	Averting expenditures used in the study
Organic chemical contamination by a microorganism *Giardia lamblia* of water supply in Pennsylvania, USA (Harrington 1989)	Cost of public supply drinking water substitutes and value of time
Bacterial, mineral, or organic chemical contamination in West Virginia, USA (Collins and Steinbeck 1993)	Expenditures of households that rely on individual wells in West Virginia for cleaning and repairing water systems, hauling water, and treatment
Organic chemical contamination of ground water with trichloroethylene in two Pennsylvania communities, USA (Abdalla, Roach, and Epp 1992)	Increased expenditures and new purchases of bottled water, expenditures in home water treatment systems, hauling, and boiling water
Low perceived quality of drinking water, France (Carpentier and Vermersch 1997)	Household purchases of soft drinks and bottled water to avoid drinking tap water
Low perceived quality of drinking water in Moscow, Russia (Larson and Gnedenko 1999)	Prevalence of household activities to reduce potential health risks by boiling, settling, filtering, and buying bottled water
Drinking water contamination in Brazil (McConnell and Rosado 2000)	Increases in expenditures on drinking water filtration, boiling, and bottled water purchases
Perceived contamination of the drinking water supply in Korea (Um, Kwak, and Kim 2002)	Costs of boiling tap water, purchasing bottled water, installation of filtration systems, and drawing spring and ground water

Some studies estimate averting expenditures associated with a specific contamination incident (e.g., Harrington 1989; Collins and Steinbeck 1993; Abdalla et al. 1992), while others analyze household behavior on the basis of perceived rather than measured contamination levels (e.g., Larson and Gnedenko 1999; McConnell and Rosado 2000; Um et al. 2002). The latter group of studies postulates that individuals act on the basis of their perceptions of risk from contamination rather than the objective levels of contamination. Perceived rather than objective measures of contamination have been incorporated in the framework of the averting behavior model and used as the basis for empirical analysis (Um et al. 2002).

Conjoint analysis approach

In some cases, households may have a choice from a range of providers, or a choice from alternative energy or water sources. Such situations can be described in the framework of conjoint analysis. In this approach, it is possible to use actual data from revealed household behavior or experimental data provided by conjoint choice or contingent behavior surveys. The household decision problem can be conveniently modeled in the framework of the random utility model (RUM) (McFadden 1974). The RUM postulates that households, which have several choices of the types of service or providers, choose the alternative that yields the highest utility. This problem lends itself to econometric estimation with discrete choice models (Hanemann 1984; Train 2003).

The welfare impact of a service quality change can be measured in the framework of the random utility model with modest assumptions about the form of the indirect utility function and the distribution of the error term. The indirect utility function is usually assumed to be linear in household characteristics, the infrastructure service quality, and other service attributes. Writing the indirect utility function in terms of these characteristics and attributes results in an expression for the expected WTP for service quality change. As Haab and McConnell (2002) show, if the error term is distributed as a type I extreme value, then this expression is given by

$$WTP = \beta_y^{-1} \cdot \left[\ln\left(\sum_{n=1}^{J} \exp\left(-\beta_y c_n^* + s_n^* \gamma\right)\right) - \ln\left(\sum_{n=1}^{J} \exp\left(-\beta_y c_n + s_n \gamma\right)\right)\right],$$

where β_y and γ are parameters to be estimated, c_n is the price of service *n*, s_n is a vector of attributes of service *n*, and *n* denotes a specific scenario from a range of J scenarios. The expression obtained in this calculation is normalized by the marginal utility of income, β_y, which is the estimated parameter on the price of service or any other monetary attribute of service that represents its cost (Haab and McConnell 2002). The WTP is computed as the willingness to pay to achieve conditions $(c_n^*, s_n^*, n = 1, ..., J)$ when the current conditions are $(c_n, s_n, n = 1, ..., J)$. Willingness to pay can be computed for changes in service price or service quality and removal of a choice option.

In conjoint choice surveys, a series of experiments are presented to each surveyed customer. The alternatives in the experiments are characterized by a range of service attributes, such as frequency and duration of service interruptions, voltage or pressure levels, etc., as well as price of service (e.g., Henscher et al. 2004; Goett et al. 2000; Louviere et. al. 2000; Cai et al. 1998). Each attribute, such as the service price or quality or the type of service provider (e.g. public or private), is varied across respondents in order to provide variation in the data. The advantage of this method is that it allows estimation of marginal WTP for each service attribute.

The obstacles to wider use of the conjoint choice approach in infrastructure service quality valuation are related to the complexity of survey design and the potential biases associated with the hypothetical nature of stated preference data. In general, welfare estimates generated from contingent valuation surveys, or any other stated preference methods, have been criticized because of the hypothetical nature of the data. This is considered to be the main drawback of stated preference methods and is frequently revisited in the literature on contingent valuation (Diamond and Hausman 1994, Carson et. al. 2000, Carson et. al. 2001).[34] However, estimates of WTP for infrastructure services obtained from stated preference data may be more reliable and suffer less from hypothetical bias than similar estimates for environmental quality changes, for which these methods were originally developed (Whittington et al. 1990; Briscoe et al. 1990; Griffin et al. 1995). This is particularly likely to be true when respondents are very familiar with the infrastructure services described in a survey.

Griffin et al. (1995) compare the results from a contingent valuation survey of households' WTP for a piped water connection in the Kerala State in India with whether these households actually chose to connect after the service was offered. In the survey, households stated whether they would connect based on scenarios specifying the connection charge, monthly fees, and future service reliability. The results of this survey were remarkably precise in predicting the share of households that chose to be connected to the newly provided piped water supply, thus validating the use of the contingent valuation approach in the valuation of infrastructure services.[35]

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[34] A summary of the references on this issue is contained in Devicienti et al. 2005.

[35] Another study compared WTP for infrastructure services from contingent valuation surveys with revealed preference data in three Latin American countries and came to a different conclusion (Walker et

An example of an application of the conjoint choice approach in the infrastructure context is given by the research on water and wastewater services in Canberra, Australia (Henscher et al. 2004). This study is based on a survey where respondents were presented with two choice experiments, one regarding drinking water services and the other regarding wastewater services. The experiments specified the price of service and a range of service attributes, including the frequency, duration, time of the day, and prior notification for service interruptions. Analysis of the responses using a discrete choice model estimated WTP for each service attribute. A similar survey was recently conducted in Sri Lanka to evaluate demand for quality of water services (Yang et al. 2005).

Discrete choice models also provide a framework for analyzing contingent behavior data if the survey experiment simulates the discrete choice of a source or provider of a service. In a study of Chinese households in the Wolong nature reserve area, An et al. (2002) modeled the household choice between wood and electricity for cooking and heating. The respondents report whether they would switch from fuel wood to electricity with a specific price and electricity reliability scenario. Scenarios were varied among respondents. Using the share of respondents that would switch to electricity in each specified scenario, the paper estimates a decrease in the volume of fuel wood consumption and the impact on the panda habitat in the nature reserve.

The discrete choice framework can also be applied to modeling actual choices of an infrastructure service provider or types of substitutes for publicly provided services. Humplick et al. (1993) analyzes households' behavioral responses to changes in the quality of water supply in Istanbul, Turkey, and Faisalabad, Pakistan. The paper

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al., 2000). Survey estimates of WTP fall below the actual expenditures on substitute sources of water, which suggests, contrary to the earlier finding in Kerala, that WTP estimates are not reliable. Of course, the results depend on specific conditions in survey areas and on the survey framework.

postulates that households demand attributes of the service, which can be classified as reliability, availability, and accessibility attributes. Water supply reliability is defined in terms of adequacy of the service, and is measured by the pressure level, interruptions of supply, and the quality of water in terms of odor, color, taste, and turbidity. Availability is measured for each source of water, i.e., piped water, streams, lakes, rivers, or rainwater. Accessibility is defined by the ability of a household to use each particular source. The study argues that the prevalence of supply interruptions were one of the service attributes that determined a household's choice of water source. Implicit in this approach is the assumption that if there are severe interruptions in the supply of a particular source, then a household would not use it even part of the time. This assumption precludes, for example, situations when households would use piped water if it is available and backup sources otherwise. When this is not a realistic assumption, an intermittent supply model such as suggested in the following chapter is a more appropriate modeling approach.

Criteria for choosing a welfare evaluation method

In this chapter, I have reviewed methods for welfare evaluation of changes in infrastructure service quality, described the theoretical assumptions and illustrated each method with examples that highlight common features and differences among these methodologies. I have also evaluated the methods that are used in project evaluation in the broader theoretical perspective of welfare measurement. In doing so, I follow an important observation by Bockstael and McConnell (1999), who conclude that extending current thinking about welfare economics to new problems is more likely to be fruitful when one confronts a problem with general notions of how behavioral methods work, rather than with the specific toolkit of travel cost models, defensive expenditures, etc.

Direct demand estimation techniques are well-developed, highly adaptable, and lend themselves to convenient estimation of accurate measures of CV and EV when data are available. In contrast, averting behavior models either require stringent assumptions or else produce only bounds on WTP. The averting behavior approach allows calculating lower (upper) bounds on welfare gains (losses) from improvement (deterioration) in service quality. This method also relies on the assumptions of weak complementarity and non-essentiality. In rare cases, when the mitigating inputs and service quality can be assumed to be perfect substitutes, a change in averting expenditures gives an exact measure of CV rather than a lower bound. This approach is particularly useful when for various reasons the direct demand estimation method is not a viable analytical tool.

In some situations, random utility models represent household behavior better than continuous utility maximization models. This happens when consumers have a choice from among a finite number of service providers, types of substitutes, or other options. This choice could be observed in the data on service consumption or could be modeled through conjoint choice or contingent behavior surveys. These surveys are beginning to be used for the purpose of conducting welfare analysis of infrastructure service quality changes. The downside of this method is the complexity of survey design and, if survey data are used, the potential for bias common to all stated preference methods. Conjoint analysis of discrete choice problems with RUM models has extensive data requirements and requires continuous observations on all attributes of all alternatives.

Assumptions of weak complementarity and non-essentiality are required by most methods (direct estimation, averting behavior, and conjoint analysis) which may or may not be appropriate in specific applications. However, they can be overcome in the direct demand estimation method by relaxing non-essentiality for essential household services such as cooking and heating, while allowing weak complementarity for specific energy sources such as electricity or gas. This can be achieved in a household production framework that explicitly models the substitution of energy sources in the household technology used to produce essential household services. This is demonstrated in the approach proposed in the next chapter, which also has the advantage of eliminating the need to observe characteristics such as the prices of energy sources that are, in effect, temporarily unavailable with intermittent supply.

When revealed preference data are inadequate, stated preference data can be a useful supplement because revealed preferences can lead to better model calibration in the range of observed data while contingent behavior surveys can be used to better estimate behavior for conditions far outside the bounds of observed data. Thus, a combination of data sources is desirable. The combined use of revealed and stated preference data can significantly extend data availability and enable thorough welfare analysis of reform at a relatively low cost. All three methods discussed earlier, as well as the model proposed in the next chapter, can use revealed preference data or stated preference data. Traditionally, direct demand estimation has relied solely upon revealed preference data, which leaves such models vulnerable to poor projections for counterfactual policy alternatives far outside the bounds of observed data. However, combining stated preference data with revealed preference data is perfectly feasible in direct demand estimation and eliminates that weakness. Furthermore, revealed preference data is more likely available for direct demand estimation and averting behavior models while the extensive data requirements of RUM models (i.e., continuous observations on all attributes of all alternatives) often renders limited revealed preference data unusable.

Problems of intermittent supply with frequent and unpredictable service interruptions suggest a new modeling approach. The discrete choice model is cumbersome at best and inapplicable at worst for problems with intermittent supply because the choice set is continually modified. The traditional direct demand estimation approach can rarely be used because the data on unconstrained consumption at different reliability levels are almost never available. The averting behavior model is not an appropriate modeling approach when the data on fixed expenditures on appliances that use alternative sources of energy during service interruptions is weak. Fully accounting for the costs of averting actions and the additional benefits beyond the actions required to mitigate supply deterioration are both crucially important and particularly difficult with intermittent supply problems. The averting behavior model is much better suited to situations when households permanently switch to a substitute source of energy or water as a result of poor intrinsic quality of the supply rather than temporary switching due to intermittent outages. Rather than using one of the traditional approaches, intermittent supply problems can be modeled within the framework of a switching regression model of direct demand estimation. In the next chapter, I propose such a model aggregated over time to correspond with observed time periods in revealed preference data.

6 A model of household energy demand with intermittent supply

This chapter develops an intermittent supply model that is better suited to the household energy economy of Azerbaijan than the various models reviewed in chapter 5. It can be considered a special case of the direct demand estimation method adapted for the case where supply interruptions are frequent, their timing cannot be predicted, and their duration does not correspond to observed time units of measurement. Unlike most direct estimation methods, the intermittent supply model takes into account the supply constraints, so data on rationed consumption can be used directly in the model without further adjustments. This intermittent supply approach is useful in situations where price variation is insufficient for the estimation of a conventional demand function for a service, but variation in supply scenarios created by supply interruptions generates variation in effective energy prices to the household as the mix of available fuels changes. Thus, the data on variation in hours of supply and on consumption and prices of substitute fuels can be used for periods when they are available, but are not needed for periods when they are unavailable. Estimated parameters from demand equations for household services can be used to calculate the *CV* or *EV* of a price and service quality change based on the household technology. In its current version, the intermittent supply model estimates a short-run welfare impact of changes in service quality, treating the stock of appliances as constant.

The Model

Households can obtain energy services from a variety of fuels to produce each home good. In Azerbaijan, the most common heating fuels are natural gas, electricity and wood (see chapter 4). Heating oil (kerosene) and LPG are also used for heating, but to a very small extent. The main cooking fuels in Azerbaijan are natural gas, electricity, and wood although LPG is also an important cooking source in some regions. For lighting, households in Azerbaijan use electricity and to a much lesser extent kerosene. After adjusting for the energy content and the conversion efficiency of different fuels into useful energy, natural gas is by far the cheapest energy source for either cooking or heating. It is followed by electricity, wood, LPG and kerosene, with the latter the most expensive source. The planned reforms in the electricity sector, if the government proceeds with the electricity and gas price increase as planned, would change the relative cost of electricity, making it the most expensive fuel by 2010.

However, electricity and network gas supplies are frequently interrupted. Households use gas when it is available, and during interruptions they rely on more expensive substitutes. The second best choice is electricity. If it is also not available, then households use the fuels they can buy on the market or collect themselves, like fuel wood or dung. While LPG is a relatively cheaper cooking source than wood, is not widely used at the national level because of its limited availability in some regions.

An important aspect of this energy choice modeling problem is that supply interruptions for gas and electricity are frequent and unpredictable. To model this problem, a useful approach is to consider the instantaneous utility maximization problem of the household. For example, consider the fuel choice decision of a single household over the course of a month. Assuming uncertainty, i.e., that supply interruptions cannot be predicted, consider the short-run problem of how much of each type of energy to consume at each point in time given the current stock of appliances owned by the household.

At each instant, a household maximizes utility as a function of consumption of heating, cooking and lighting services, and the numeraire good,

$$\max \tilde{U}(h, c, l, X_0)$$

where *h*, *c* and *l* denote the quantities of heating, cooking and lighting consumed as home goods, and X_0 is quantity of the numeraire good consumed. These home goods can be produced from either network or market fuels using the household technology. The choice variables in the problem thus also include how much of each energy source to use in producing the home goods.

To simplify the representation of the household technology, the conversion of input energy from different sources into the home goods can be represented conveniently as follows. First, the amount of gas, electricity, and wood can be converted into common energy units. For the purposes of this study, each energy source is converted into oil equivalents to make price comparisons. Since some fuels such as electricity are more efficient in heating and cooking than fossil fuels, a further adjustment for appliance efficiency is necessary in order to calculate the amount of home goods obtained from different fuels. The same fuel can be more efficient in heating and less efficient in cooking. However, for given appliances the assumption of fixed input-output coefficients makes modeling the household technology relatively simple, particularly when data are available on energy conversion coefficients.

The relationship between energy inputs and home goods consumed can be represented by production functions of the form

$$\begin{aligned} h &= h(z_{HG}G_H + z_{HE}E_H + z_{HW}W_H) \\ c &= c(z_{CG}G_C + z_{CE}E_C + z_{CW}W_C) \\ l &= l(z_{LE}E_L + z_{LK}K) \end{aligned}$$

where G_i, E_i, W_i, and K_i denote the quantities of network gas, electricity, wood and kerosene, respectively, used for home production of energy service $i = H$, C, and L, where H, C, and L denote use for heating, cooking, or lighting, respectively; and z_{ij} represents both the conversion into oil equivalents and the efficiency of converting energy source j into energy service i given household appliances, $i = H, C, L$; $j = G, E, W, K$.[36] For purposes of clarifying terminology, the quantities of the associated home goods consumed, denoted by h, c, and l, are differentiated from the quantities of energy services used to produce them, $H = z_{HG}G_H + z_{HE}E_H + z_{HW}W_H$, $C = z_{CG}G_C + z_{CE}E_C + z_{CW}W_C$, and $L = z_{LE}E_L + z_{LK}K$ (gas is not used for lighting in Azerbaijan and kerosene is used only for lighting). Consumption of energy services is not observable whereas input quantities are observable given available data on energy conversion coefficients. Note also that in Azerbaijan some regions rely on LPG rather than wood for cooking when neither network gas nor electricity are available. For purposes of illustrating the theoretical model, this fuel choice is not modeled, but it is included as a choice in the empirical estimation for households that live in such areas.

Households maximize utility subject to the following budget constraint

$$P_G(G_H + G_C) + P_E(E_L + E_H + E_C) + P_W(W_C + W_H) + P_K K_L + X_0 = Y,$$

assuming nonsatiation where P_j denotes the price of energy source j, $j = G, E, W, K$; X denotes the quantity of all other goods consumed in the form of a numeraire good; Y denotes total household income (or expenditures); and the price of the numeraire good is

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[36] The energy conversion coefficients vary across households depending on the age and type of appliances, however information about the type of appliance was not sufficient in the 2003 HES or 2004 HBS to discern differences in conversion coefficients across households. Thus, in the dissertation I use standard conversion coefficients from international sources reported for developing countries (International Energy Agency, reported by O'Sullivan and Barnes 2006).

normalized to 1. The prices of gas, electricity and wood are the market prices, unadjusted for energy content or appliance efficiency.

Two further constraints can be added to represent the availability of network gas and electricity,

$$G_H + G_C = G \leq \overline{G},$$
$$E_H + E_C + E_L = E \leq \overline{E},$$

where $\overline{G}$ and $\overline{E}$ are available amounts of gas and electricity, respectively. In the Azerbaijan problem of instantaneous consumption, however, gas or electricity are either available in effectively unlimited quantities to the household, or are not available at all. As a result, given the technological framework above, availability of gas or electricity can be represented simply by a price change from the network or market price to an infinite price or, equivalently, by eliminating it from consideration in the household problem during outages.

Assuming that fuels substitute in fixed proportions in producing energy services based on efficiency considerations imposed by technologies embodied in current appliances, utility maximization implies that only the least expensive available fuel is used at each point in time. The fuel choice is thus determined by a combination of relative prices and availability. This approach greatly reduces data requirements for estimation when certain data are missing (during periods of outages for the relevant energy source). In this framework, energy source j is chosen to produce energy service i at a given point in time if it is available and $P_j / z_{ij} < P_k / z_{ik}$ for j, k = G, E, W, K, $k \neq j$ where i denotes the energy service, $i = H$, C, L. The respective ratios of market prices of fuels to the energy coefficients represent the effective prices of a unit of heating, cooking, and lighting services. For example, P_G / z_{HG} is the effective price of one oil equivalent of heating services from network gas.

Based on preliminary empirical verification, the relative prices per effective unit of energy services from different fuels, after adjusting for energy content and appliance efficiency, are described by the following relationships throughout the sample data:

Heating: $P_G/z_{HG} < P_E/z_{HE} < P_W/z_{HW}$

Cooking: $P_G/z_{CG} < P_E/z_{CE} < P_W/z_{CW}$

Lighting: $P_E/z_{LE} < P_K/z_{LK}$

This allows considerable simplification in the modeling effort (although switching of efficiency relationships among fuels could certainly be accommodated in the model). Thus, let fuel choices for each energy service be represented by

$$j_i = \left\{ j \mid P_j / z_{ij} = \min(P_k / z_{ik} \mid k \in A_i) \right\},\ \ i = H, C, L,$$

where A_i represents the availability set of energy choices for energy service i at a given point in time. Where the utility function $\tilde{U}$ and each of the energy service production functions, h, c, and l, have typical properties, the utility maximization problem can thus be represented as

$$\max_{Xij_H, Xij_C, Xij_L, X_0} \tilde{U}(h(z_{Hj_H} X_{Hj_H}), c(z_{Cj_C} X_{Cj_C}), h(z_{Lj_L} X_{Lj_L}), X_0) \equiv U(z_{Hj_H} X_{Hj_H}, z_{Cj_C} X_{Cj_C}, z_{Lj_L} X_{Lj_L}, X_0)$$

subject to

$$P_{j_H} X_{Hj_H} + P_{j_C} X_{Cj_C} + P_{j_L} X_{Lj_L} + X_0 = Y$$

where U includes both preference parameters of the household and parameters of the household energy service production functions, and X_{ij_i} is the quantity chosen of service i from fuel j. First-order conditions for the associated Lagrangian,

$$L = U(z_{Hj_H}X_{Hj_H}, z_{Cj_C}X_{Cj_C}, z_{Lj_L}X_{Lj_L}, X_0) - \lambda(P_{j_H}X_{Hj_H} + P_{j_C}X_{Cj_C} + P_{j_L}X_{Lj_L} + X_0 - Y),$$

are thus

$$\frac{\partial U}{\partial i}\frac{\partial i}{\partial X_{ij_i}} - \lambda P_{j_i} = \frac{\partial U}{\partial i} z_{ij_i} - \lambda P_{j_i} = 0,\ \ i = H, C, L, \text{ and } \frac{\partial U}{\partial X_0} - \lambda = 0,$$

the former of which can be expressed as

$$\frac{\partial U}{\partial i} - \lambda P_{j_i} / z_{ij_i} = 0,\ \ i = H, C, L.$$

Thus, using typical duality results, the associated indirect utility function can be written as $V(p_H, p_C, p_L, Y) = V(P_{j_H} / z_{Hj_H}, P_{j_C} / z_{Cj_C}, P_{j_L} / z_{Lj_L}, Y)$ where V is a function with the standard properties of an indirect utility function and the prices of the respective home goods, heat, cooking, and lighting, are defined by $p_H = P_{j_H} / z_{Hj_H}$, $p_C = P_{j_C} / z_{Cj_C}$, and $p_L = P_{j_L} / z_{Lj_L}$. This function can take typical forms used for modeling indirect utility functions and can generate the associated demand specifications via Roy's identity.

For example, suppose prices satisfy $P_G / z_{iG} < P_E / z_{iE} < P_W / z_{iW} < P_K / z_{iK}$, $i = H, C, L$, and gas and electricity are available, in which case $A_H = \{G,E,W\}$, $A_C = \{G,E,W\}$, and $A_L = \{E,K\}$. Then this problem becomes

$$\max_{G_H, G_C, E_L, X} U(z_{HG}G_H, z_{CG}G_C, z_{LE}E_L, X_0) \text{ s.t. } P_G G_H + P_G G_C + P_E E_L + X_0 = Y,$$

for which the indirect utility function is $V(P_G / z_{HG}, P_G / z_{CG}, P_E / z_{LE}, Y)$. In this case with both gas and electricity available, the household chooses gas for heating and cooking, and electricity for lighting. Other fuels are not used.

If gas is unavailable but electricity is available, then $A_H = \{E,W\}$, $A_C = \{E,W\}$, and $A_L = \{E,K\}$ so the problem becomes

$$\max_{E_H, E_C, E_L, X_0} U(z_{HE}E_H, z_{CE}E_C, z_{LE}E_L, X_0) \text{ s.t. } P_E E_H + P_E E_C + P_E E_L + X_0 = Y,$$

for which the indirect utility function is $V(P_E / z_{HE}, P_E / z_{CE}, P_E / z_{LE}, Y).$ In this case with gas unavailable but electricity available, the household chooses electricity for heating, cooking, and lighting. Other fuels are not used.

If neither gas nor electricity are available, then $A_H = \{W\}$, $A_C = \{W\}$, and $A_L = \{K\}$ so the problem becomes

$$\max_{W_H, W_C, K_L, X_0} U(z_{HW}W_H, z_{CW}W_C, z_{LK}K_L, X_0) \text{ s.t. } P_E E_H + P_E E_C + P_E E_L + X_0 = Y,$$

for which the indirect utility function is $V(P_W / z_{HW}, P_W / z_{CW}, P_K / z_{LK}, Y).$ In this case, the household chooses wood for heating and cooking and kerosene for lighting. Thus, where input fuels substitute in fixed proportions given technical efficiency of current appliances, fuel choices depend on current fuel availability.

In this model, the rates at which a household trades off any two types of energy services are sufficient to determine the rates at which the household trades off any two types of fuels. For example, where electricity is used for lighting and gas is used for heating, the tradeoff is

$$\frac{\dfrac{\partial U}{\partial G_H}}{\dfrac{\partial U}{\partial E_L}} = \frac{\dfrac{\partial U}{\partial H} \cdot \dfrac{\partial (z_{HG} G_H)}{\partial G_H}}{\dfrac{\partial U}{\partial L} \cdot \dfrac{\partial (z_{LE} E_L)}{\partial E_L}} = \frac{\partial U / \partial H}{\partial U / \partial L} \cdot \frac{z_{HG}}{z_{LE}} = \frac{\lambda \cdot P_G}{\lambda \cdot P_E} = \frac{P_G}{P_E}, \text{ i.e., } \frac{\partial U / \partial H}{\partial U / \partial L} = \frac{p_G / z_{HG}}{p_E / z_{LE}},$$

which is the familiar condition equating the marginal rate of substitution to the price ratio. Similar conditions can be derived for all other combinations of the energy services and types of input fuels. This optimality condition states simply that the ratio of marginal utilities of the heating and lighting services should be equal to the price ratio, with the prices adjusted by the respective energy conversion coefficients.

Similarly, comparing tradeoffs of energy consumption for consumption of the numeraire, first-order conditions imply, for example, that

$$\frac{\frac{\partial U}{\partial G_H}}{\frac{\partial U}{\partial X}} = \frac{\frac{\partial U}{\partial H} \cdot z_{HG}}{\frac{\partial U}{\partial X}} = \frac{P_G}{1}, \text{ i.e., } \frac{\partial U / \partial H}{\partial U / \partial X} = \frac{P_G / z_{HG}}{1},$$

which equates the marginal rate of substitution of energy consumption for the least-cost fuel and consumption of the numeraire to the associated price ratio.

In this model, fuel demands will be a function of the effective prices of energy services, income and fuel availability. Effective prices of energy services can be represented as

$$p_i = \left\{ P_j / z_{ij} \mid P_j / z_{ij} = \min(P_k / z_{ik} \mid k \in A_i) \right\}, \; i = H, C, L.$$

Thus, the demands for energy services are of the form

$$\begin{aligned} H &= z_{HG} G_H + z_{HE} E_H + z_{HW} W_H = H(p_H, p_C, p_L, Y) \\ C &= z_{CG} G_C + z_{CE} E_C + z_{CW} W_C = C(p_H, p_C, p_L, Y) \\ L &= z_{LE} E_L + z_{LK} K = L(p_H, p_C, p_L, Y). \end{aligned}$$

With this formulation, relatively few parameters require estimation so the structure of the technology permits estimation with some missing data. For example, if prices satisfy $P_G / z_{iG} < P_E / z_{iE} < P_W / z_{iW} < P_K / z_{iK}$, $i = H, C, L,$ and gas and electricity are available, then these equations imply that energy demands are

$$\begin{aligned} G &= G_H + G_C = H(p_H, p_C, p_L, Y) / z_{HG} + C(p_{H,} p_C, p_L, Y) / z_{CG} \\ E &= E_L = L(p_H, p_C, p_L, Y) / z_{LE} \end{aligned}$$

$$W = 0, \quad K = 0.$$

If gas is not available but electricity is, then energy demands are

$$G = 0$$
$$E = E_H + E_C + E_L = H(p_H, p_C, p_L, Y)/z_{HE} + C(p_H, p_C, p_L, Y)/z_{CE} + L(p_H, p_C, p_L, Y)/z_{LE}$$
$$W = 0,\ \ K = 0.$$

If neither gas nor electricity is available, then energy demands are

$$G = 0,\ \ E = 0,$$

$$W = W_H + W_C = H(p_H, p_C, p_L, Y)/z_{HW} + C(p_H, p_C, p_L, Y)/z_{CW}$$

$$K = L(p_H, p_C, p_L, Y)/z_{LK.}$$

Expanding the model to more fuel choices

For purposes of empirical application, this model is expanded to consider additional fuel choices where they are available. Expanding the fuel set to include LPG, four typical regimes can be defined depending on the availability of natural gas, electricity, and LPG assuming that either wood or dung are always available as a backup energy source for heating or cooking, and that kerosene is always available to purchase for lighting. Other combinations are also possible, but they are rarely observed in practice.

Assuming that cross-sectional variation in fuel availability is indicative of variation across time, calculations reveal that 49 percent of the time households in the 2003 HES sample are in regime 1, 21 percent of the time they are in regime 2, 12 percent of the time in regime 3a, and 11 percent of the time in regime 3b.[37] They are in the additional regime of fuel availability, when gas supply is available but electricity is not, approximately 2 percent of the time. Thus, I have chosen to ignore this minor regime with a good gas supply but a poor electricity supply in the model.

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[37] In order to make this calculation, I assumed that electricity supply with an average of more than 10 hours per day is sufficiently reliable to use electricity for heating and cooking; if it is less reliable, then electricity supply was assumed not to be available for heating and cooking use for the purposes of calculating these figures.

Therefore we limit the number of choice sets to four regimes. Each household can face up to four regimes depending on local circumstances. Some households live in areas where LPG is supplied, while others do not. Because these conditions are largely determined by locality, we assume that households do not switch between having access to LPG and not having it over time. To the extent that this switching occurs, consumption of fuel wood and LPG was aggregated into a single category of transitional (LPG) and fossil (fuel wood) fuels converted into oil equivalents of energy consumption for estimation purposes. Other factors that influence fuel choice, such as the preferences for a clean or convenient fuel, are ignored for the moment.[38]

The energy service production functions, direct and indirect utility functions, and income evaluated at the optimum in each availability regime are provided in Table 6.1.

Table 6.1 Fuel availability regimes and household service production functions.

Regime	Available fuels	Heating, cooking and lighting services	Maximized utility function and energy service expenditures	Indirect utility function
1	*G, E, LPG, K, W*	$H = h(z_{HG}G)$ $C = c(z_{CG}G)$ $L = l(z_{LE}E)$	$U(H,C,L,X) =$ $U\ (z_{HG}G_H, z_{CG}G_C, z_{LE}E_L,X_0)$ $Y = P_G\ (G_H+G_C) + P_E\ E_L+X_0$	$V(p_H,p_C,p_L,Y) =$ $V(P_G/z_{HG}, P_G/z_{CG}, P_E/z_{LE},,Y)$
2	*E, LPG, K, W*	$H = h(z_{HE}E)$ $C = c(z_{CE}E)$ $L = l(z_{LE}E)$	$U(H,C,L,X_0) =$ $U\ (z_{HE}E_H, z_{CE}E_C, z_{LE}E_L,X_0)$ $Y = P_E\ (E_H+E_C+E_L) +X_0$	$V(p_H,p_C,p_L,Y) =$ $V(P_E/z_{HE}, P_E/z_{CE}, P_E/z_{LE}, Y)$
3a (with LPG)	*LPG* (denoted by *B*), *K, W*	$H = h(z_{HW}W)$ $C = c(z_{CB}B)$ $L =l(z_{LK}K)$	$U(H,C,L,X_0) =$ $U\ (z_{HW}W_H, z_{CB}B_C, z_{LK}K_L,X_0)$ $Y = P_W\ W_H + P_B\ B_C+P_KK_L+X_0$	$V(p_H,p_C,p_L,Y) =$ $V(P_W/z_{HW}, P_B/z_{CB}, P_K/z_{LK},Y)$
3b (no LPG)	*W, K*	$H = h(z_{HW}W)$ $C = c(z_{CW}W)$ $L = l(z_{LK}K)$	$U(H,C,L,X) =$ $U\ (z_{HW}W_H, z_{CW}W_C, z_{LK}K_L,X_0)$ $Y = P_W\ (W_H + W_C)+ P_KK_L+X_0$	$V(p_H,p_C,p_L,Y) =$ $V(P_W/z_{HW}, P_W/z_{HW}, P_K/z_{LK}, Y)$

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[38] A similar approach is used in practice in project and policy evaluation, when for simplicity households are assumed indifferent among effective units of energy from different substitute fuels. For example, this approach is used in the World Bank publication that provides guidance on cost benefit analysis of electrification projects (Energy Sector Management Assistance Program, 2002).

Intertemporal weighting of energy availability regimes

The model as outlined thus far generates a switching regression framework as regimes of fuel availability are changed. In practice, however, the regimes change frequently and thus within the monthly time periods of observation. Because switching among the various availability regimes cannot be anticipated and occurs randomly within the time periods of observation, the problem must be modeled as an aggregation over sub-time periods within various regimes. Thus, the intratemporal budget allocation process requires discussion. The vast majority of household consumption models assumes constant conditions within the time period of observation. Thus, the vast majority of the literature on intertemporal budget allocation considers how households allocate income among observed time periods. A principal implication of this literature is that households allocate expenditures over time to keep the marginal utility of wealth constant. This results in consumption smoothing, for example, when households are saving money for retirement (Blundell et. al. 1994).

Certain features of this problem are also present in the intratemporal budget allocation problem here. Over time, real income during periods when households are in high cost energy regimes falls, and the marginal utility of income rises. Optimal consumption thus falls. In order to simplify the derivation of the intratemporal expected indirect utility function, I treat income as an instantaneous rate of income at each point in time, which remains constant over the monthly time period. Then the monthly model represents an aggregation over the monthly time period in a manner that would be consistent with typical modeling where the time period of observation is sufficiently short to have constant conditions within each time period. I assume that expectations of gas and electricity reliability are constant so changes in expectations do not affect behavior.

Making these two assumptions, it is possible to specify an aggregate expected indirect utility function over a monthly period of observation as a weighted average of the indirect utility functions over shorter time periods in each regime. The weights are the shares of time that households are in each energy availability regime over the course of a month. Thus, the term "expected" as used in this chapter describes expected or average conditions over a one-month period considering the average share of time spent in each energy availability regime. It does not suggest any risk aversion response on the part of the household has been incorporated into the model. Thus, with the time shares of each regime merely serve as the weights in computing the average. Making these assumptions, fuel use over the course of a month can be modeled in terms of fuel availability as follows. Assuming that only one fuel is used at a time for producing each household good, the amount of heating, cooking and lighting services is a weighted average of the services obtained from the different inputs:

$$E(H) = \theta(G_H z_{HG}) + \phi(E_H z_{HE}) + (1-\theta-\phi)(W_H z_{HW}),$$
$$E(C) = \theta(G_C z_{CG}) + \phi(E_C z_{CE}) + (1-\theta-\phi)(W_C z_{CW}),$$
$$E(L) = (\theta+\phi)(E_L z_{LE}) + (1-\theta-\phi)(K_L z_{LK}),$$

where θ denotes the share of time a household is in Regime 1, ϕ is the share of time in Regime 2, and $(1-\theta-\phi)$ is the share of time in Regime 3a or 3b, depending on location. The frequency and duration of gas and electricity service interruptions vary over time. Thus, θ and ϕ vary over time and households. Survey data provides information on the average number of the daily hours of supply for each energy source in the previous month, which are used as data for θ and ϕ.

The instantaneous input fuel demands in this approach are implicitly assumed to be independent of the weights θ, ϕ, and $(1-\theta-\phi)$ in the short-run. In addition, the decision problem is assumed to be the same in each monthly time period aside from factors that can be controlled in estimation (such as fuel prices, outages, household characteristics, weather, etc.). In other words, instantaneous fuel use at time t_2 is independent of fuel availability and choice at time t_1 and of the expected instantaneous availability and choice in time t_3. If there is a dependence on other periods, then the aggregate fuel demands need to be modeled as a dynamic problem. These assumptions seem plausible over relatively short periods of time where appliances are fixed.

Thus, the expected utility function over the course of a month takes the following form (for households in areas where LPG is not available) where expectations are over fuel availability regimes:

$$E(V)=\theta V\left(\frac{P_G}{z_{HG}},\frac{P_G}{z_{CG}},\frac{P_E}{z_{LE}},Y\right)+\phi V\left(\frac{P_E}{z_{HE}},\frac{P_E}{z_{CE}},\frac{P_E}{z_{LE}},Y\right)+(1-\theta-\phi)V\left(\frac{P_W}{z_{HW}},\frac{P_W}{z_{CW}},\frac{P_K}{z_{LK}},Y\right).$$

Implementation with an explicit indirect utility function

A flexible functional form can be used to model the indirect utility function of household energy services because the energy services can be regarded as essential. However, every household energy service can be produced from a variety of fuels, so each individual fuel can be appropriately modeled as a non-essential good. Flexible functional forms have been used in numerous applications in the last three decades because more flexible functional forms are tractable compared to earlier primal demand systems. The most well-known flexible functional forms for demand systems are the translog proposed by Christensen et. al. (1975) and the almost ideal demands system (AIDS) proposed by Deaton and Muellbauer (1980). In the literature, these models are used to test theoretical conditions derived from consumer demand theory and provide estimated price and income elasticities (Pollak and Wales 1992, Selvanathan and Clements 1995, Edgerton et. al. 1996).

In Deaton and Muellbauer's (1980, p. 312) words, the AIDS model has several advantages over alternative functional forms: it "gives an arbitrary first-order approximation to any demand system; it satisfies the axioms of choice exactly; it aggregates perfectly over consumers without invoking parallel linear Engel curves; it has a functional form which is consistent with known household-budget data; it is simple to estimate, largely avoiding the need for nonlinear estimation; and it can be used to test the restrictions of homogeneity and symmetry through linear restrictions on fixed parameters." The remaining limitation of the AIDS model is that individual budget shares are not guaranteed to lie globally in the unit interval. Modifications have been proposed to increase the flexibility of the AIDS model. Examples are the dynamic specification of the model (described in Edgerton et. al. 1996), the quadratic generalization of Engel curves in the quadratic AIDS model (Banks et. al. 1997), and the modified almost ideal demand system (MAIDS), which guarantees budget shares in the unit interval (Cooper and McLaren 1988; Agrawal and Powell 1992).

Similarly, Jorgenson, Lau and Stoker (1982) strongly argue in favor of the translog over the AIDS model on the basis of the translog model's flexibility. Although this issue has generated considerable debate in the literature, Lewbel (1989) demonstrates that both models are not only very similar in terms of the theoretical restrictions they impose on consumer behavior, but also in terms of estimation results. Thus, Lewbel (1989) proposed a general model that nests both the AIDS and translog forms and estimated it using consumer expenditure surveys produced by the U.S. Bureau of Labor Statistics. He shows that estimation of the generalized form and estimation of the AIDS and translog models separately produce very similar parameter and price elasticity estimates and both models are about equal in terms of the explanatory power. Thus, in his own words, "the controversy over the relative merits of the AIDS and translog systems appears to be unnecessary, since both yield very similar elasticity estimates" (Lewbel 1989).

Both the AIDS model and the translog functional forms belong to the so-called price-independent generalized logarithmic (PIGLOG) class of preferences proposed by Muellbauer (1976). The key feature of the AIDS model is linearity of budget shares with respect to the logarithm of total expenditures. The budget shares are specified as

$$w_i(P,Y) = \alpha_i + \sum_j \beta_{ij} \log p_j + \vartheta_i \log\{Y/P\},$$

where w_i = denotes the budget share of fuel i, and P is a price index defined by

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + 1/2 \sum_j \sum_k \beta_{kj} \log p_k \log p_j,$$

and where α, β, and ϑ are estimated parameters satisfying

$$\beta_{ij} = \beta_{ji} \quad \forall i,j, \quad \sum_j \beta_{ij} = 0 \quad \forall i, \text{ and } \sum_i \alpha_i = 1, \quad i,j = H,C,L.$$

In contrast, the Christensen et. al. (1975) translog model generates budget shares of the form

$$w_i = \frac{\alpha_i + \sum_j \beta_{ij} \log(p_j / Y)}{1 + \sum_k \sum_j \beta_{kj} \log(p_j / Y)},$$

where

$\beta_{ij} = \beta_{ji}$, and $\sum_k \alpha_k = 1$.

Data constraints present problems for application of either of these approaches. As discussed in chapter 3, total expenditures had to be imputed for two-thirds of the sample for this study. However, using an imputed total expenditures variable on the right hand side of the budget share equations is likely to generate biased parameter estimates. While an instrumental variables approach could be used, all of the variables on which instruments could be based are already in the regressions. Alternatively, I have chosen to use a homothetic specification. The homothetic translog model is the simplest specification in the translog family and is also the special case of the AIDS model implied by homotheticity. By assuming that $\vartheta = 0$, the AIDS model reduces to the homothetic translog. As argued in chapter 4, household income (total expenditures) has little correlation with budget shares. Hence, the assumption underlying the homothetic translog model that total income does not affect expenditure shares does not appear very restrictive in the case of Azerbaijan.

The homothetic translog indirect utility function is given by

$$V(p,Y) = \log Y - \sum_i \alpha_i \log p_i - 1/2 \sum_i \sum_j \beta_{ij} \log p_i \log p_j,$$

where

$$\beta_{ij} = \beta_{ji} \quad \forall i,j, \quad \sum_j \beta_{ij} = 0 \quad \forall i, \text{ and } \sum_i \alpha_i = 1, \quad i,j = H,C,L.$$

By Roy’s identity in the budget share form, the budget share for fuel *i* that would apply if fuel *i* where the preferred fuel and were available throughout the observed time period would be given by the following expression:

$$w_i = -\frac{\partial E(V)/\partial \log p_i}{\partial E(V)/\partial \log Y} = \alpha_i + \sum_j \beta_{ij} \log p_j$$

where w_i denotes the budget share of fuel i. Applying this to the expected indirect utility, $E(V)$, above using the homothetic translog indirect utility function form obtains the following expression for the expected budget shares:

$$w_i = \theta(\alpha_i + \sum_j \beta_{ij} \log p_{j_1}) + \phi(\alpha_i + \sum_j \beta_{ij} \log p_{j_2}) + (1-\theta-\phi)(\alpha_i + \sum_j \beta_{ij} \log p_{j_3}),$$

where p_{j_1}, p_{j_2}, and p_{j_3} denote the prices of heating, cooking and lighting fuels in each of the three regimes.

Substituting the prices that correspond to each of the regimes obtains the following expression for the expected indirect utility function:

$$\begin{aligned}
E(V) = \theta\{&\log Y - \alpha_H \log(P_G / z_{HG}) - \alpha_C \log(P_G / z_{CG}) - \alpha_L \log(P_E / z_{LE}) - 0.5\beta_{HH} \log^2(P_G / z_{HG}) \\
&- 0.5\beta_{CC} \log^2(P_G / z_{CG}) - 0.5\beta_{LL} \log^2(P_E / z_{LE}) - 0.5\beta_{HC} \log(P_G / z_{HG})\log(P_G / z_{CG}) \\
&- 0.5\beta_{HL} \log(P_G / z_{HG})\log(P_E / z_{LE}) - 0.5\beta_{CL} \log(P_G / z_{CG})\log(P_E / z_{LE})\} \\
&+ \phi\{\log Y - \alpha_H \log(P_E / z_{HE}) - \alpha_C \log(P_E / z_{CE}) - \alpha_E \log(P_E / z_{LE}) - 0.5\beta_{HH} \log^2(P_E / z_{HE}) \\
&- 0.5\beta_{CC} \log^2(P_E / z_{CE}) - 0.5\beta_{LL} \log^2(P_E / z_{LE}) - 0.5\beta_{HC} \log(P_E / z_{HE})\log(P_E / z_{CE}) \\
&- 0.5\beta_{HL} \log(P_E / z_{HE})\log(P_E / z_{LE}) - 0.5\beta_{CL} \log(P_E / z_{CE})\log(P_E / z_{LE})\} + (1-\theta-\phi) \\
&\{\log Y - \alpha_{HW} \log(P_W / z_{HW}) - \alpha_{CW} \log(P_W / z_{CW}) - \alpha_{LK} \log(P_K / z_{LK}) - 0.5\beta_{HH} \log^2(P_W / z_{HW}) \\
&- 0.5\beta_{CC} \log^2(P_W / z_{CW}) - 0.5\beta_{LL} \log^2(P_K / z_{LK}) - 0.5\beta_{HC} \log(P_W / z_{HW})\log(P_W / z_{CW}) \\
&- 0.5\beta_{HL} \log(P_W / z_{HW})\log(P_K / z_{LK}) - 0.5\beta_{CL} \log(P_W / z_{CW})\log(P_K / z_{LK})\},
\end{aligned}$$

where the α's and β's are unknown coefficients, and the z's are the known energy conversion coefficients.

Rewriting the model in terms of price indexes obtains a relatively simple model for estimation purposes,

$$E(V) = \log Y - \alpha_H \log p_H^* - \alpha_C \log p_C^* - \alpha_L \log p_L^* - 0.5\beta_{HH} \log p_{HH}^{**} - 0.5\beta_{CC} \log p_{CC}^{**}$$
$$- 0.5\beta_{LL} \log p_{LL}^{**} - 0.5\beta_{HC} \log p_{HC}^{**} - 0.5\beta_{HL} \log p_{HL}^{**} - 0.5\beta_{CL} \log p_{CL}^{**},$$

where the p_i^*'s are price indexes defined by

$$\log p_i^* = \theta \log\left(P_G / z_{iG}\right) + \phi \log\left(P_E / z_{iE}\right) + (1 - \theta - \phi) \log\left(P_W / z_{iW}\right), \; i = H, C, L,$$

$$\log p_{ij}^{**} = \theta \log\left(P_G / z_{iG}\right) \log\left(P_G / z_{jG}\right) + \theta \log\left(P_E / z_{iE}\right) \log\left(P_E / z_{jE}\right) + \phi \log\left(P_E / z_{iE}\right) \log\left(P_E / z_{jE}\right)$$
$$+ (1 - \theta - \phi) \log\left(P_W / z_{iW}\right) \log\left(P_W / z_{jW}\right),$$

$i, j = H, C, L,$

except that *G* and *W* are replaced by *E* and *K*, respectively, in the case where *i* = *L* and/or *j* = *L*.

The application of Roy's identity in the budget share form thus results in the following set of conditions:

$$w_G = -\partial E(V) / \partial \log P_G = \theta \left\{ \alpha_H + \alpha_C + \beta_{HH} \log\left(P_G / z_{HG}\right) + \beta_{CC} \log\left(P_G / z_{CG}\right) + 0.5\beta_{HC} \right.$$
$$\left. \left(\log\left(P_G / z_{HG}\right) + \log\left(P_G / z_{CG}\right)\right) + 0.5\beta_{HL} \log\left(P_E / z_{LE}\right) + 0.5\beta_{CL} \log\left(P_E / z_{LE}\right) \right\},$$
$$w_E = -\partial E(V) / \partial \log P_E = \theta \left\{ \alpha_{LE} + \beta_{EE} \log\left(P_E / z_{LE}\right) + \beta_{HL} \log\left(P_G / z_{HG}\right) + \beta_{CL} \log\left(P_G / z_{CG}\right) \right\}$$
$$+ \phi \left\{ \alpha_{HE} + \alpha_{CE} + \alpha_{LE} + \beta_{HH} \log\left(P_E / z_{HE}\right) + \beta_{CC} \log\left(P_E / z_{CE}\right) + \beta_{LL} \log\left(P_E / z_{LE}\right) \right.$$
$$+ 0.5\beta_{HC} \log\left(P_E / z_{HE}\right) + 0.5\beta_{HC} \log\left(P_E / z_{CE}\right) + 0.5\beta_{HL} \left(\log\left(P_E / z_{HE}\right) + \log\left(P_E / z_{LE}\right)\right)$$
$$\left. + 0.5\beta_{CL} \left(\log\left(P_E / z_{CE}\right) + \log\left(P_E / z_{LE}\right)\right) \right\},$$
$$w_W = -\partial E(V) / \partial \log P_W = (1 - \theta - \phi) \left\{ \alpha_H + \alpha_C + \beta_{HH} \log\left(P_W / z_{HW}\right) + \beta_{CC} \log\left(P_W / z_{CW}\right) \right.$$
$$+ 0.5\beta_{HC} \left(\log\left(P_W / z_{HW}\right) + \log\left(P_W / z_{CW}\right)\right) + 0.5\beta_{HL} \log\left(P_E / z_{LE}\right)$$
$$\left. + 0.5\beta_{CL} \log\left(P_E / z_{LE}\right) \right\},$$
$$w_K = -\partial E(V) / \partial \log P_K = (1 - \theta - \phi) \left\{ \alpha_L + \beta_{LL} \log\left(P_K / z_{LK}\right) + 0.5\beta_{HL} \log\left(P_W / z_{HW}\right) \right.$$
$$\left. + 0.5\beta_{CL} \log\left(P_W / z_{CW}\right) \right\}.$$

Since $\partial E(V) / \partial \log Y = 1$ in each of the regimes, the above four equations provide the expected budget share expressions for different fuel types.

Fuel prices are transformed by the data on network energy supply hours, denoted by θ and ϕ, which vary over households in the survey sample. Therefore, the lack of electricity price variation does not pose an estimation problem. Price variability is introduced alternatively by the changing regimes of availability, which thus permits estimation of the demand for household services, and which can then be translated into market demands under various price and availability scenarios using the observed household technology parameters.

These equations suggest some possible identification problems for estimation. For example, β_{HH} and β_{CC} are always multiplied by the same terms so that only their sum, $\beta_{HH} + \beta_{CC}$, is identified. This problem can be resolved by disaggregating electricity demand into demand for electricity used for heating, cooking and lighting, which is possible because the 2003 HES data contain information on usage hours of different electric appliances in the present and in the reform scenario. Disaggregated demand equations can be obtained by taking the derivative of the indirect utility function with respect to electricity prices related to specific uses, as if those prices were different. The resulting budget shares of electricity are:

$$\begin{aligned}
w_{HE} &= -\partial E(V)/\partial \log P_{HE} = \theta\left\{\alpha_H + \beta_{HH}\log\left(P_E/z_{HE}\right) + 0.5\beta_{HC}\log\left(P_E/z_{CE}\right)\right.\\
&\qquad \left. + 0.5\beta_{HL}\log\left(P_E/z_{LE}\right)\right\},\\
w_{CE} &= -\partial E(V)/\partial \log P_{CE} = \theta\left\{\alpha_C + \beta_{CC}\log\left(P_E/z_{CE}\right) + 0.5\beta_{HC}\log\left(P_E/z_{CE}\right)\right.\\
&\qquad \left. + 0.5\beta_{CL}\log\left(P_E/z_{LE}\right)\right\},\\
w_{LE} &= -\partial E(V)/\partial \log P_{LE} = \theta\left\{\alpha_L + \beta_{LL}\log\left(P_E/z_{LE}\right) + 0.5\beta_{HL}\log\left(P_G/z_{HG}\right)\right.\\
&\qquad \left. + 0.5\beta_{CL}\log\left(P_G/z_{CG}\right)\right\} + \phi\left\{\alpha_L + \beta_{LL}\log\left(P_E/z_{LE}\right) + 0.5\beta_{HL}\log\left(P_E/z_{HE}\right)\right.\\
&\qquad \left. + 0.5\beta_{CL}\log\left(P_E/z_{CE}\right)\right\},
\end{aligned}$$

where P_{iE} denotes the market price of electricity used for heating, cooking and lighting, and $i = H$, C, and L. Using appropriate prices for electricity used for heating, cooking and lighting is a theoretically valid means of facilitating estimation of demand by fuel type and are used theoretically to derive specifications of estimated equations even though the observed prices for electricity are always the same for all uses. Identification is made possible because the effective price of home energy services differs by use when due to switching among fuel availability regimes. In the remainder of this dissertation, however, I do not differentiate between electricity prices for different end-uses of electricity.

Conclusion about the advantages of the intermittent supply model

The modeling approach proposed in this chapter takes into account the specific nature of energy supply and demand conditions in Azerbaijan. By explicitly modeling household energy demand in different fuel availability regimes, this model circumvents the heavy data requirements of the discrete choice approach as well as other shortcomings of other models reviewed in chapter 5. The model developed in this chapter aggregates demand for fuels over time to correspond with observed time periods in revealed preference data, enabling estimation of parameters of interest for policy analysis notwithstanding the missing gas consumption data and a lack of variability in electricity prices. Rather, the variation in fuel availability regimes induces variability in the prices of home energy services that permits identification of preference parameters. This permits a standard second-order flexible functional form to be used to generate demands for essential household energy services while reflecting non-essentiality of specific fuels. In order to enable this structure, households are assumed to minimize the cost of producing household energy services with a rigid structure of fixed-proportions household production technology without specific preferences for fuel type. This generates a clear hierarchy of fuel choice based on relative fuel prices and fuel availability in each regime.

The approach proposed in this chapter does not model the choice of appliances, and so it should be interpreted as a model of short-run behavior. However, as evident from chapters 2 and 4, ownership of household appliances does not appear to be an important factor affecting fuel switching in Azerbaijan compared to the importance of fuel availability and prices.

7 Results of Model Estimation for Azerbaijan

This chapter presents estimates of the model developed in chapter 6 using the survey data for Azerbaijan. The model is estimated by combining both the revealed preference data and stated preference data of the surveys discussed in chapter 3. Specifically, the model was estimated using the actual consumption data and prices for gas, wood/LPG and kerosene budget share equations and contingent behavioral data for the heating, cooking and lighting share equations for electricity.[39] Thus, electricity price varies only in the three electricity budget share equations and not in the gas, wood/LPG and kerosene equations. Use of stated preference data was regarded as essential for identifying electricity demand because the policy scenarios of interest are far outside of observed prices in the revealed preference data.

The estimated model

In this chapter I modify the notation of the previous chapter and denote the share of time in Regimes 1, 2 and 3 by R_1, R_2 and R_3, respectively, instead of the earlier notation to emphasize the fact that these shares of time are variables rather than parameters. In the contingent behavior scenario, the share of time households are in Regime 3, when neither network gas nor electricity is available, is zero. Thus, the share of time in Regime 1 is obtained as 1 – R2 and the shares of time in Regimes 1 and 2 sum to one.

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[39] An ideal approach would have been to construct a panel data set with observations on actual and hypothetical behavior for each household. Estimation of a system of fuel demands would have been facilitated by having both types of data for each demand equation. Unfortunately, the data on hypothetical consumption of any fuels other than electricity are very poor in the 2003 HES and could not be used in estimation. Hence, I have used stated preference data (with electricity price variation) for electricity and revealed preference data for other budget shares of other fuels. As shown in chapter 8, I compare the distribution of electricity consumption predicted by the model with actual electricity consumption data to verify validity of the model's predictions.

Additionally, the parameters of the indirect utility function were, in effect, made a function of household demographic variables. Thus, for example, a term such as $\gamma_1 R_1$ was replaced by $\gamma_1 R_1 + \omega_1 H R_1$ where ω_1 represents a parameter vector and H represents a vector of household demographic variables.

The resulting empirical model after this transformation consists of the following six budget shares:

$$w_{Gn} = c_1 + \gamma_1 R_{1n} + \omega_1 H R_{1n} + \varepsilon_{Gn}, \tag{1}$$

$$w_{HEn} = c_2 + \gamma_2 R_{2n} + \gamma_3 R_{2n} \log P_{En} + \omega_2 H R_{2n} + \omega_3 H R_{2n} \log P_{En} + \varepsilon_{HEn}, \tag{2}$$

$$w_{CEn} = c_3 + \gamma_4 R_{2n} + \gamma_5 R_{2n} \log P_{En} + \omega_2 H R_{2n} + \omega_3 H R_{2n} \log P_{En} + \varepsilon_{CEn}, \tag{3}$$

$$\begin{aligned} w_{LEn} = {} & \left(c_4 + \gamma_6\right) + \gamma_7 R_{2n} + \gamma_8 R_{2n} \log P_{En} + \beta_{LL}\left[\log P_{En}\left(1 - R_{2n}\right)\right] + \omega_2 H R_{2n} + \\ & \omega_3 H R_{2n} \log P_{En} + \omega_4 \left[H\left(\log P_{En}\left(1 - R_{2n}\right)\right)\right]_n + \varepsilon_{LEn}, \end{aligned} \tag{4}$$

$$w_{Wn} = c_5 + \gamma_9 R_{3n} + \gamma_{10} R_{3n} \log P_{Wn} + \omega_5 H R_{3n} + \omega_6 H R_{3n} \log P_{Wn} + \varepsilon_{Wn}, \tag{5}$$

$$\begin{aligned} w_{Kn} = {} & c_6 + \gamma_{11} R_{3n} + \beta_{LL} R_{3n} \log P_{Kn} + \gamma_{12} R_{3n} \log P_{Wn} + \omega_5 H R_{3n} + \omega_7 H R_{3n} \log P_{Kn} + \\ & \omega_6 H R_{3n} \log P_{Wn} + \varepsilon_{Kn}, \end{aligned} \tag{6}$$

where w denotes the budget share of each fuel by household $n = 1,\ldots,N$; G, E, W, and K denote network gas, electricity, wood/LPG and kerosene, respectively; R1 and R2 are the data on the share of time spent in each electricity regime, based on the average village hours of gas and electricity supply, ε denotes the error term in each budget share equation, and parameters to be estimated are denoted by c, γ, β, and ω, and the γ's consist of the following combination of the model's structural parameters:

$$
\begin{aligned}
\gamma_1 &= \alpha_H + \alpha_C + \beta_{HH} \log\left(P_G / z_{HG}\right) + \beta_{CC} \log\left(P_G / z_{CG}\right) + 0.5\beta_{HC}\left(\log\left(P_G / z_{HG}\right) + \log\left(P_G / z_{CG}\right)\right) \\
&\quad + \left(0.5\beta_{HL} + 0.5\beta_{CL}\right)\log\left(P_E / z_{LE}\right), \\
\gamma_2 &= \alpha_H - \beta_{HH} \log z_{HE} - 0.5\beta_{HC} \log z_{CE} - 0.5\beta_{HL} \log z_{LE}, \\
\gamma_3 &= \beta_{HH} + 0.5\beta_{HC} + 0.5\beta_{HL}, \\
\gamma_4 &= \alpha_C - \beta_{CC} \log z_{CE} - 0.5\beta_{HC} \log z_{CE} - 0.5\beta_{CL} \log z_{LE}, \\
\gamma_5 &= \beta_{CC} + 0.5\beta_{HC} + 0.5\beta_{CL}, \\
\gamma_6 &= \alpha_L - \beta_{LL} \log z_{LE} + 0.5\beta_{HL} \log\left(P_G / z_{HG}\right) + 0.5\beta_{CL} \log\left(P_G / z_{CG}\right), \\
\gamma_7 &= -\left(0.5\beta_{HL} \log z_{LE} + 0.5\beta_{CL} \log z_{LE} + 0.5\beta_{HL} \log\left(P_G / z_{HG}\right) + 0.5\beta_{CL} \log\left(P_G / z_{HG}\right)\right), \\
\gamma_8 &= \beta_{LL} + 0.5\beta_{HL} + 0.5\beta_{CL}, \\
\gamma_9 &= \alpha_H + \alpha_C - \beta_{HH} \log z_{HW} - \beta_{cc} \log z_{cw} - 0.5\beta_{HC}\left(\log z_{HW} + \log z_{CW}\right) \\
&\quad + 0.5\beta_{HL} \log\left(P_E / z_{LE}\right) + 0.5\beta_{CL} \log\left(P_E / z_{LE}\right), \\
\gamma_{10} &= \beta_{HH} + \beta_{CC} + \beta_{HC}, \\
\gamma_{11} &= \alpha_L - \beta_{LL} \log z_{LK} - 0.5\beta_{HL} \log z_{HW} - 0.5\beta_{CL} \log z_{CW}, \\
\gamma_{12} &= 0.5\beta_{HL} + 0.5\beta_{CL}.
\end{aligned}
$$

Cross-equation restrictions were imposed in this system, so that whenever the same parameters appear in different equations, they are restricted to be equal. The estimated equations are shown in the Appendix to chapter 7 with the estimated γ's expressed in terms of the structural parameters.

Ideally, the system of budget share equations should be estimated separately, once using the actual data and once using the contingent behavior data. Then the equivalence of these two models could be tested and, if not rejected, the data could be combined into an estimated system in which each household contributes two observations to the overall likelihood function. Thus, present and reform scenario consumption at the corresponding prices would be included for all fuels. However, the data on reform scenario consumption of traditional fuels is missing for most households in the 2003 HES. Available data permit estimation of actual and reform scenario consumption levels only for the electricity budget shares. Only actual consumption shares are available for traditional fuels and network gas. Due to the specific conditions of metering and rationing in Azerbaijan, this comparison based on electricity shares alone was not feasible. Outages occur outside Baku and Sumgayit, which are the only areas with metered electricity supply and fairly strong payment enforcement. Thus, in these areas where household electricity consumption is responsive to prices few substitute fuels are used. Conversely, in the areas with frequent supply interruptions supply is not metered. Therefore, current electricity consumption levels could not be used in model estimation. Instead, I use electricity consumption in the reform scenario and consumption of other fuels in the current case scenario.

In Azerbaijan, payment arrears and non-payment of electricity bills is wide-spread. The average payment ratio of monthly electricity bills by households is only 56 percent, when it is calculated at the village/town level and slightly lower when calculated at the individual level according to the 2003 HES data. Further, there is significant heterogeneity of payment enforcement by location. In order to account for the effect of heterogeneity in the enforcement of payment discipline, electricity prices were multiplied by the average village/town payment ratio of the electricity bill, and prices were transformed in this way both on the left-hand and the right-hand sides.[40] Since the payment ratios are not at the individual but rather at the settlement level, they are not endogenous variables.

The dependent variables are budget shares, which I calculated as expenditures on each type of energy divided by total expenditures. As discussed in chapter 3, total

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[40] Another form of the budget share equations without transforming the left-hand and right-hand side by the payment ratio variable was tested and rejected on the basis of the likelihood ratio test at a one-percent significance level (the log likelihood in that model was 27,791 compared to the log likelihood of 29,388 in the chosen model).

expenditures were not available in the 2003 HES and were imputed for three-quarters of the sample using information on the other one-quarter of the 2003 HES sample households included in both the 2002 HBS and 2003 HES. Results reported in this chapter thus use imputed total expenditures for households for whom actual expenditures were not available, and actual expenditures otherwise. Using imputed total expenditures for the entire sample may have some advantages as using the imputed measure purges possible joint endogeneity between total expenditures and energy expenditures. To investigate this possibility, I have re-estimated the model using imputed total expenditures for the entire sample and did not find any substantive differences between the two sets of results (as reported subsequently in this chapter).

Results of estimation

Assuming that the vector of error terms has a zero mean and that the error terms are identically and independently distributed, this demand system can be regarded as a seemingly unrelated regression (SUR) problem. All independent variables in SUR systems must be exogenous and the equations in such a system must be linked only by their disturbances (Greene 2000: 615). These conditions are assumed to be satisfied. Specifically, the model is estimated using the direct maximum likelihood method by simply inserting the special form of the variance-covariance matrix in the log-likelihood function. Using this method enabled imposition of cross-equation restrictions on the vector of structural parameters including the α's and β's.

The log likelihood for the *n*th observation is

$$\ln L_n = -\frac{1}{2}\left\{ p\ln\left(2\pi\right) + \ln\left|\Sigma\right| + \left(y_n - \beta' x_n\right)' \Sigma^{-1}\left(y_n - \beta' x_n\right)\right\},$$

where $|\Sigma|$ is the determinant of the error covariance matrix, p is the number of equations, y is a vector of budget shares (dependent variables of the demand system), x is a vector of independent variables, and β is a vector of parameters to be estimated (Gould et.al. 2003). Each of these parameters is a linear combination of the structural parameters, which were estimated directly using the method of direct maximum likelihood imposing cross-equation constraints. The estimation was implemented in STATA. The code used for the model's estimation is reported in the Appendix of this chapter.

The results of model estimation are reported in Table 7.1 (Model A). The model's parameters are highly statistically significant, due to the relatively small number of parameters that require estimation after imposing the specific household technology form, and to the rather wide variation in prices made possible by representing prices for household services given variability in energy availability.

Table 7.1 Maximum likelihood estimation results.

		Model A (without IMR terms)		Model B (with IMR terms)		Model C (with IMR terms and region dummies)	
		Coeff.	z	Coeff.	Z	Coeff.	z
α_H		0.038**	4.2	0.040**	4.5	0.040**	4.4
α_C		-0.036**	-3.6	-0.035**	-3.5	-0.034**	-3.4
α_L		-0.006	-1.0	-0.008	-1.4	-0.005	-0.9
β_{HH}		-0.022*	-2.1	-0.020	-1.9	-0.022*	-2.1
β_{CC}		-0.004	-0.4	-0.008	-0.8	-0.005	-0.6
β_{LL}		-0.004**	-6.7	-0.004**	-7.1	-0.004**	-6.9
β_{HC}		0.029**	6.5	0.031**	6.9	0.030**	6.8
β_{CL}		-0.007	-0.4	0.000	0.0	-0.005	-0.3
β_{HL}		0.010	0.5	0.004	0.2	0.008	0.4
c_1	constant term in eq. (1)	0.005**	14.5	0.005**	14.5	0.008**	11.0
c_2	constant term in eq. (2)	0.005*	2.2	0.005*	2.2	0.009**	3.7
c_3	constant term in eq. (3)	0.019**	10.2	0.019**	10.3	0.022**	11.8

c_4	constant term in eq. (4)	0.048**	6.3	0.050**	6.6	0.050**	6.6
c_5	constant term in eq. (5)	0.017**	7.5	0.017**	7.5	0.020**	8.8
c_6	constant term in eq. (6)	0.007**	5.3	0.007**	5.4	0.011**	7.2
ω_1	household size*R1	-0.000	-0.1	-0.000	-0.1	-0.000	-0.2
ω_2	household size *R2	-0.012**	-5.4	-0.012**	-5.3	-0.012**	-5.4
ω_3	household size *R2* $\log P_{Ei}$	0.002**	4.7	0.002**	4.6	0.002**	4.7
ω_4	household size *R1* $\log P_{Ei}$	-0.000**	-3.0	-0.000**	-3.0	-0.000**	-3.0
ω_5	household size *R3	0.001	0.8	0.001	0.8	0.001	0.7
ω_6	household size *R3* $\log P_{Wi}$	-0.000	-0.7	-0.000	-0.6	-0.000	-0.6
ω_7	household size *R3* $\log P_{Ki}$	-0.000	-1.0	-0.000	-1.1	-0.000	-1.3
s_1	house*R1	0.007**	4.0	0.007**	4.0	0.006**	3.2
s_2	house *R2	0.017	1.5	0.016	1.4	0.012	1.0
s_3	house *R2* $\log P_{Ei}$	-0.003*	-2.0	-0.003	-1.9	-0.003	-1.5
s_4	house *R1* $\log P_{Ei}$	-0.000	-0.7	-0.000	-0.6	-0.000	-1.0
s_5	house *R3	0.009	1.9	0.009*	2.0	0.008	1.8
s_6	house *R3* $\log P_{Wi}$	0.003**	4.4	0.003**	4.3	0.003**	4.4
s_7	house *R3* $\log P_{Ki}$	-0.002**	-4.4	-0.002**	-4.3	-0.002**	-4.3
m_1	metered*R2	-0.025*	-2.1	-0.028*	-2.4	-0.023	-2.0
m_2	metered*R2* $\log P_{Ei}$	0.003	1.9	0.004*	2.2	0.003	1.9
m_3	metered*R1* $\log P_{Ei}$	0.001**	2.5	0.001*	2.4	0.001**	3.2
h_1	children*R2	0.007	0.8	0.007	0.8	0.007	0.8
h_2	children*R2* $\log P_{Ei}$	-0.001	-0.7	-0.001	-0.7	-0.001	-0.7
r_1	rural*R2	0.059**	3.6	0.061**	3.7	0.053**	3.2
r_2	rural*R2* $\log P_{Ei}$	-0.010**	-4.1	-0.010**	-4.3	-0.009**	-3.8
z_1	IMR for heating*R2			0.017**	7.3	0.017**	7.4
z_2	IMR for cooking*R2			0.012**	6.2	0.011**	6.2
r_1	Region 1					-0.005**	-6.1
r_2	Region 2					-0.000	-0.4
r_3	Region 3					-0.004**	-5.4
Log likelihood		29,318		29,356		29,388	
Observations		1,797		1,797		1,797	

Note: “House” is a dummy variable equal to 1 if a household resides in a house rather than an apartment, “children” is the number of children in a household, “rural” is a dummy variable equal to 1 for households living in rural areas, “metered” is a dummy variable equal to 1 if electricity consumption is metered, “IMR1” is the Inverse Mills Ratio term in the heating equation (2), “IMR2” is the Inverse Mills Ratio term in the cooking equation (3). The omitted regional dummy variable is “region 4.” Significance at the 5% level is indicated by ‘*’ and significance at the 1% level is indicated by ‘**’.

In order to evaluate whether the estimates are economically meaningful, it is necessary to first derive the expressions for price elasticities. Since the research focus of this dissertation is on electricity reforms, most attention will be devoted to the elasticity of demand for heating, cooking and lighting with electricity.

The system of budget share equations estimated here results in different price elasticities of electricity by use for heating, cooking and lighting. Taking the derivatives of the budget share equations, shown earlier in this chapter, with respect to the price of electricity results in the following expressions:

$$\eta_{En} = \frac{\partial Q_{EHn}}{\partial P_{En}} \cdot \frac{P_{En}}{Q_{EHn}} = \gamma_3 \frac{R_{2n} - R_{2n} \log P_{En}}{S_{EHi}} + \omega_3 \frac{H_n R_{2n} (1 - \log P_{En})}{S_{EHn}},$$

where η_{EHn} denotes the own price elasticity of electricity used for heating,

$$\eta_{ECn} = \frac{\partial Q_{En}}{\partial P_{Ei}} \cdot \frac{P_{En}}{Q_{EHn}} = \gamma_5 \frac{R_{2n} - R_{2n} \log P_{En}}{S_{ECi}} + \omega_3 \frac{H_n R_{2n} * (1 - \log P_{En})}{S_{ECn}},$$

where η_{ECn} denotes own price elasticity of electricity used for cooking, and

$$\eta_{ELn} = \frac{\partial Q_{EHn}}{\partial P_{En}} \cdot \frac{P_{En}}{Q_{EHn}} = \frac{\gamma_8 \left[R_{2n} - R_{2n} \log P_{En}\right] + \beta_{LL} \left[R_{1n} - \log P_{En} R_{1n}\right]}{S_{ELi}}$$
$$+ \frac{\omega_3 \left[H_n R_{2n} (1 - \log P_{En})\right] + \omega_4 \left[H_n R_{1n} \left(1 - \log P_{En}\right)\right]}{S_{ELn}},$$

where η_{ELn} denotes own price elasticity of electricity used for lighting. Although not shown in the above expressions, other terms that are multiplied by the variables that contain an electricity price result in additional expressions that are equivalent to the last term in each of the expressions above, but multiplied by a different but corresponding estimated parameter.

The estimates of own price elasticities for heating, cooking and lighting with electricity were calculated using the coefficients from the estimated model as shown in Table 7.2.

Table 7.2 Estimated own electricity price elasticities of heating, cooking and lighting.

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Heating	-0.27	0.14	-1.98	0.05	-0.53	0.00
Cooking	-0.75	0.13	-5.67	0.00	-1.01	-0.49
Lighting and refrigeration	-0.25	0.07	-3.54	0.00	-0.40	-0.11

Note: evaluated at the mean of the data for all households.

In general, estimates of the overall price elasticity of electricity demand reported in the literature range from -0.34 to -1.2, and they appear to be lower in Europe than in the U.S. (Reiss and White 2005, Freund and Wallich 1996, Dahl 1992). Although the evidence for developing countries is scarce, the long-run price elasticity of residential electricity demand in some developing countries has been estimated at about -0.88 (Dahl, 1992). In the countries in Eastern Europe and the former Soviet Union, price elasticities of electricity demand are likely to be lower because, as pointed out by Freund and Wallich (1996), the stock of appliances tends to be very inefficient in those countries compared to appliance stocks in the U.S. and Western Europe. It will take time to replace existing appliances with a more efficient appliance stock in Azerbaijan. Most households use very inefficient electric appliances, so it is not surprising that price elasticities estimated in this dissertation for Azerbaijan are lower, averaging between -0.25 and -0.75 depending on whether electricity is used for heating, cooking or lighting.

All price elasticity estimates in Table 7.2 are statistically significant at 5 percent level. The 95 percent confidence intervals for price elasticities estimated here is a range from 0 to -1 even though the confidence intervals for specific uses are half that size. The ranges are reasonable for long-run price elasticities that have been reported in the literature for the U.S., Europe, and developing countries. The distinction between long-run and short-run price elasticities is important as households can adjust their stock of appliances in the long-run, thereby increasing the magnitude of the household response to a change in price. However, as revealed by estimation of electricity demand in Norway, the difference in the elasticities is small when alternative sources of energy are not available, minimizing the substitution effect and thereby the discrepancy between the short-run and long-run response (Halvorsen and Larsen 2001). As shown in chapter 4, at least one alternative source of energy (LPG, fuel wood or dung) is available in Azerbaijan even when the network energy sources are not available. Since short-run elasticities are likely to be smaller than long-run elasticities because the stock of appliances is fixed in the short run, the estimates reported thus far in this dissertation appear very reasonable.

Testing for sample selection bias and location-specific omitted variables bias

The first set of results reported earlier in Table 7.2 could be prone to sample selection bias because chosen budget shares are bounded from below by zero as in the classic Tobit model. That is, when electricity is available, some households may still choose to use fuel wood for heating and cooking for several reasons. First, if the reliability of electricity is sufficiently low, some households may choose fuel wood even when they could use electricity. Second, fuel wood collection costs are very low for some households with a low opportunity cost of time or abundant availability of wood sources nearby. Third, there could be other reasons behind the choice of fuel wood even when electricity supply is reliable such as switching costs, appliance unavailability, or personal preferences.

Sample selection bias could arise in each individual regime of fuel availability. But the dependent variable in the model of this dissertation is a weighted average budget share rather than an instantaneous budget share relating to a single regime of fuel availability. Since the model is not a standard Tobit or other type of a discrete/continuous model, the sample selection problem in this model does not correspond directly to the sample selection bias problem in the literature. Therefore, the necessary correction for a particular regime would only apply to the time share associated with that regime.

To test for the presence of this type of sample selection bias, I re-estimated the model correcting for sample selection bias only for the share of response associated with the corresponding regime. As shown in the literature, the problem of zero budget shares associated with selection bias can be corrected by using a two-step procedure first proposed by Heckman (1979). The first step in this procedure can be modeled as a probability of participating in a market:

$$P_{nj}^{*} = b' p_{nj} + \upsilon_{nj},$$

where p_{nj} is a vector of variables that affect the probability P_{nj}^{*} of participation in a market for fuels $j = 1,\ldots, J$; b is a vector of associated coefficients, υ_{nj} is a vector of error terms for households $n = 1,\ldots, N$. The budget share of fuel j is modeled as a continuous choice:

$$w_{nj}^{*} = \gamma' x_{nj} + \varepsilon_{nj},$$

where x_{nj} is a vector of variables that affect the level of consumption. The asterisk ("*") denotes that these are equations in the latent model, underlying the observed model given by

$$P_{nj} = \begin{cases} 1 & if \quad P_{nj}^* > 0 \\ 0 & if \quad P_{nj}^* \leq 0, \end{cases}$$

and

$$w_{nj} = P_{nj} w_{nj}^* .$$

The first step in the estimation procedure obtains the probability of market participation

$$\Pr\left(P_{nj} = 1 \mid b, p_{nj}\right) = \Phi\left(h\left(b, p_{nj}\right)\right),$$

where Φ denotes the standard normal cumulative density function. This probability is estimated in my model by using observations for all households that can choose between electricity and fuel wood and omitting observations for households that have such a poor electricity supply that they can never use their electric heating and cooking appliances because of frequent interruptions and low voltage. The inverse Mills ratio (IMR) can then be calculated using the estimated probability of market participation and included in the second step to estimate the demand system. Since I am including observations with positive and zero expenditures in the estimation of the continuous portion of the model in the second step, the Inverse Mills Ratio is calculated differently for the households with positive and zero observations. It has been shown (Lazaridis 2004, Cheng and Capps 1988, Nayga 1998) that, when all households are included in the second step, for households with positive expenditures the IMR should be computed as

$$IMR = \frac{\varphi\left(h\left(b, p_{nj}\right)\right)}{\Phi\left(b, p_{nj}\right)},$$

and for households with zero expenditures as

$$IMR = -\frac{\varphi\left(h\left(b, p_{nj}\right)\right)}{1-\Phi\left(b, p_{nj}\right)},$$

where $\varphi(\cdot)$ denotes standard normal probability density function.

Households with very poor electricity supply do not in reality face a choice between using electricity and fuel wood. Thus, for households with less than the average of 18 hours per day of electricity during a typical winter day, the *IMR* term was replaced with zero because these households are not likely candidates to switch to electricity. As a result, the *IMR* term is non-zero for 40 percent of the sample. After multiplying it by R2, it ranges between -1.4 and 0.8. Results of the probit models that separately predict the probability of using electricity for cooking and heating are reported in Table 7.3.

In order to test whether sample selection bias could be affecting the earlier results, the model is re-estimated including the computed *IMR* for households with zero and positive expenditures on electricity used for heating and cooking. In the model estimated in the first part of Table 7.1 (Model A), sample selection bias could arise in regime 2 when electricity is available. Therefore, the computed *IMR* term is multiplied by the share of time in regime 2 and entered additively. The selection bias correction term, equal to $IMR*R_2$, was added to the cooking and heating electricity budget share equations as an additional covariate.

Table 7.3 Probit model results for heating and cooking with electricity.

	Heating with electricity	Cooking with electricity
Household size	-0.052	0.029
	(1.84)	(1.03)
Total living area (sq. m)	0.003*	0
	(2.06)	-0.35
Dummy =1 if live in a house	-0.458**	-0.51**
	(2.84)	(2.89)
Share of children (<10 yrs old)	-0.08	-0.317
	(0.32)	(1.25)
Price of electricity (Manat/oe)	0	0
	(0.63)	(1.47)
Dummy =1 if rural	-0.938**	-0.246
	(4.92)	-1.34
Share of time in regime 2	0.962	2.205**
	(1.92)	(4.13)
Share of time in regime 3	-0.145	-1.206**
	(0.34)	(2.92)
Total monthly expenditures	0	0*
	(0.72)	(2.41)
Dummy =1 if use gas for heating	-0.721	-0.198
	(1.82)	(0.47)
Dummy =1 if metered	0.284*	0.518**
	(2.11)	(3.72)
Average village pay ratio	-1.146**	-0.712*
	(3.53)	(2.19)
<u>Regional dummy variables (Zone 4 omitted):</u>		
Zone 1	-0.805**	-1.206**
	(2.88)	(4.30)
Zone 2	-0.588*	-0.393
	(2.10)	-1.43
Zone 3	-1.249**	-1.553**
	(4.54)	(5.78)
Constant	1.31	0.023
	(1.9)	(0.03)
Observations	1,274	1,274
Pseudo R-squared	19.5	21.3

Note: The absolute values of t statistics are given in parentheses. Significance at the 5% level is indicated by '*' and significance at the 1% level is indicated by '**'.

The presence of sample selection bias due to these factors is not likely in any of the budget share equations because, as revealed by the discussion and evidence presented in chapter 4, the hierarchy of fuel choices is clearly dictated by fuel availability, which is controlled for in this model. In addition, when either gas supply or electricity supply is reliable, households do not choose fuel wood as a primary source of heating, although some still use it as a back-up source when supply is not perfectly reliable and they may use it as a secondary source.

As shown in Table 7.4, the vast majority of the households that never have a reliable supply of gas (i.e., they are never in Regime 1) use wood as the primary heating source. In fact, only one household with a reliable gas supply, with gas over 41 percent of the time, still uses wood as a primary heating source. The situation is rather similar with electricity, where 234 out of 377 households that never have reliable electricity (or gas) supply use wood as a primary heating source. Only 20 households out of a total of 274 who are in the electricity regime more than 91 percent of the time still choose to rely on fuel wood for heating. Hence, it is very unusual for people to choose wood as their primary heating source when they have a sufficiently reliable gas or electricity supply. Thus, it is not surprising that the Inverse Mills Ratio correction terms earlier in this chapter did not have an appreciable effect on the model's coefficients and price elasticities.

Table 7.4 Use of fuel wood as primary source of heating (number of households).

	Do not use wood	Use wood
Share of time in regime 1		
0	856	756
0.01 to 0.4	0	2
0.41 to 1	385	1
Share of time in regime 2		
0	377	234
0.01 to 0.8	506	460
0.81 to 0.9	84	45
0.91 to 0.98	133	20
0.99 to 1	141	0

Source: 2003 Household Energy Survey

The estimated model does not account for differences in average winter temperatures and other climatic conditions by location, because weather-related data at the level of the sampling unit were not available. The omission of weather patterns and other location-specific variables that affect energy demand could result in omitted variables bias. In an attempt to control for this bias caused by location-specific omitted variables, I used a fixed-effects specification and included regional dummy variables in all six estimated equations.[41]

Estimation results that include the *IMR* term are reported in the central two columns of Table 7.1 (Model B). While the *IMR* term is positive and significant, it is small in magnitude. The results of Model C which includes the regional dummy variables in addition to the *IMR* terms are reported in the last two columns of Table 7.1. The inclusion of regional dummy variables does not significantly affect the magnitude of other parameters and they are only slightly different from the estimates in Models A and B. Since two of the three regional dummy variables are statistically significant, I use this model specification as a basis for policy simulations in the following chapter.

Finally, I have investigated the robustness of Model C with respect to the definition of the total expenditures variable which, as described in chapter 3, was imputed for three-quarters of the sample. While Model C used actual total expenditures for the households for which this variable was available and imputed total expenditures otherwise, Model D uses imputed total expenditures for all households. The results of Model D are nearly identical to Model C with differences in the coefficients only in the

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[41] In order to control for possible clustering, I have also attempted to use the robust maximum likelihood estimation procedure of the variance-covariance matrix, but maximum likelihood estimation of Models A and B with this option could not be implemented due to some missing data in the calculation of the robust score matrix.

second decimal point and with little difference in significance levels (see Appendix Table 7.1).

Testing plausibility of the assumption of perfect substitutability of fuels

As discussed in chapter 5, in conclusion to the discussion of the direct demand estimation method, the assumption of perfect substitutability of energy from different sources in the production of household energy services may not necessarily be satisfied in practice. In particular, the most likely reason for failure of this assumption is the adverse health effects of kerosene or wood fuels, which are well recognized in some other countries. For this reason, I conduct a statistical test about whether an additional multiplicative discount factor should be attached to kerosene or fuel wood (and LPG) to represent their inferior quality compared to energy from network sources. Thus, energy conversion coefficients of kerosene into lighting and fuel wood (and LPG) into cooking and heating were divided by a discount factor ϖ, as shown in the Appendix to chapter 7. The resulting system to be estimated is unchanged except for the fuel wood/LPG and kerosene budget share equations, which include additional additive terms containing the discount factor. Every term that includes ϖ is a constant aside from variation in the energy regime, e.g., the term $0.5\log\varpi(\beta_{HL}+\beta_{CL})$ is a constant in the kerosene budget share equation multiplied by the share of time kerosene is in the chosen fuel mix. If those constants are zero, which corresponds to $\varpi=1$, then there is no discounting associated with non-network energy sources. While adding these terms to the estimated budget shares caused convergence problems indicative of identification issues, no improvement in the log likelihood could be achieved.[42] Thus, I conclude that households are primarily interested in the cost of household services rather than any health side effects, which provides some evidence to validate the estimates in Table 7.1.

Testing equality of parameters of indirect utility function by regime

Finally, I have considered a test to see if the parameters of the estimated indirect utility function are the same across availability regimes. This test investigates whether the model adequately captures the role of preferences in fuel choice, or whether households have non-financial preferences over heating fuel choice. For this purpose, the expected indirect utility function from chapter 6 can be rewritten as

$$E(V) = \theta V_1\left(\frac{P_G}{z_{HG}}, \frac{P_G}{z_{CG}}, \frac{P_E}{z_{LE}}, Y\right) + \phi V_2\left(\frac{P_E}{z_{HE}}, \frac{P_E}{z_{CE}}, \frac{P_E}{z_{LE}}, Y\right) + (1-\theta-\phi)V_3\left(\frac{P_W}{z_{HW}}, \frac{P_W}{z_{CW}}, \frac{P_K}{z_{LK}}, Y\right).$$

where the indirect utility functions, V_1, V_2, and V_3 have different parameters in each availability regime. Associated demands were derived from each equation by Roy's identity to obtain the system of observable demand equations for estimation. The functional form of the resulting budget share equations is the same as previously, but instead of a total of 9 structural parameters the model has 27 structural parameters. In other words, the structural parameters in the first regime are not assumed to be equal to the corresponding parameters in the second and third regimes etc. Unfortunately, convergence could not be achieved in this model when coefficients were allowed to be different in each individual regime. Although the data are not sufficient to fully implement this general test that allows parameters to differ in each individual energy availability regime, results could be achieved when allowing the indirect utility

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[42] Admittedly, however, this is not a powerful test, because the difference in discount factors ϖ could partly reflect a difference in appliance efficiency across households.

parameters of one regime to differ from the others. In these cases, the hypothesis of identical coefficients could not be rejected. Thus, the results provide some confirmation of, and no evidence against, the structural assumption whereby a common indirect utility function applies for household energy services across energy availability regimes, and where differences among regimes are fully represented by the assumed Leontief household production technology and its implications for cost minimization.

Estimated price elasticities and conclusions about their plausibility

Price elasticities calculated on the basis of estimates from Model C are shown in Table 7.5 (for Model D they are shown in Appendix Table 7.2.) The comparison of estimated elasticities with the earlier results indicates that the inclusion of the IMR term and the regional dummy variables does not appreciably affect the results. The new price elasticity estimates fall within the confidence intervals of the estimates obtained in Table 7.2.

Table 7.5 Estimated own price elasticities of heating, cooking and lighting (with correction of sample selection bias).

	Coefficient	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
All households						
Heating	-0.30	0.14	-2.22	0.03	-0.56	-0.03
Cooking	-0.83	0.13	-6.22	0	-1.09	-0.57
Lighting	-0.30	0.07	-4.15	0	-0.44	-0.16
Rural						
Heating	-0.31	0.19	-1.63	0.10	-0.67	0.06
Cooking	-0.36	0.32	-1.12	0.26	-0.99	0.27
Lighting	-0.41	0.11	-3.59	0	-0.64	-0.19
Urban						
Heating	-0.28	0.12	-2.39	0.02	-0.51	-0.05
Cooking	-0.97	0.11	-8.77	0	-1.19	-0.75
Lighting	-0.24	0.07	-3.3	0	-0.38	-0.10
Poor						
Heating	-0.27	0.11	-2.55	0.01	-0.48	-0.06
Cooking	-0.50	0.12	-4.12	0	-0.74	-0.26
Lighting	-0.31	0.06	-5.15	0	-0.44	-0.20
Nonpoor						
Heating	-0.31	0.15	-2.07	0.04	-0.62	-0.01
Cooking	-0.98	0.15	-6.58	0	-1.27	-0.69
Lighting	-0.30	0.09	-3.53	0	-0.47	-0.13

Note: evaluated at the mean of the data and at the mean of each category.

Price elasticities of electricity demand vary by the type of appliances, household location, and demographic characteristics, as recognized by the early literature that conditioned electricity demand on the stock of household appliances (e.g., Dubin and McFadden 1984, Chern et. al. 1983, Parti and Parti 1980). In a recent study of California households, Reiss and White (2005) once again point out significant heterogeneity in household elasticities of demand for electricity and emphasize the importance of taking it into account in an evaluation of the social impact of energy policies and alternative tariff designs. The model of residential electricity demand, developed in their study, is an attempt to allow price and income elasticities to vary with consumption level and appliance holdings and estimate price elasticities disaggregated by the type of end-use.

Estimation results reveal much higher elasticities for households with electric space heating or air conditioning than for households without such equipment. For households that do not use electricity for either of these two purposes, the study found elasticities to be very close to zero. Accordingly, households could be divided in two types: those who use electricity for space heating or air conditioning and are price sensitive, and those who do not and who are price insensitive (Reiss and White 2005). Thus, for households with electric space heating, the average price elasticity was estimated at -1.02, and only at -0.20 for households without it. For households without electric space heating and air conditioning, the price elasticity was estimated at merely -0.08. Clearly, welfare consequences of tariff reform policies are very different for these household categories.

In Azerbaijan supply constraints play an important role in determining how sensitive households will be to an electricity price increase. Furthermore, one would expect much lower elasticities when electricity prices are very low as they are in Azerbaijan. Overall, the estimated price elasticities of heating and lighting are very low at around -0.30, and higher for cooking at around -0.83 (Table 7.5). Electricity demand is more elastic for urban than rural households. This is not surprising, given that the supply quality is higher and demand rather than supply constraints are a more important factor that influences the level of electricity consumption in urban areas. In rural areas, estimated price elasticities for heating and cooking are statistically insignificant, probably for the same reason.

Two findings are somewhat puzzling. First, price elasticities are lower for the poor than for the nonpoor. Second, the price elasticity of heating tends to be lower than for cooking. Low elasticity estimates may point to a higher welfare impact of a change in the price of electricity on households that use it for the base load (lighting and cooking), and a lower impact on households who use it for heating.

The finding that the elasticity of heating is as low as lighting, while the elasticity of cooking is more than three times as high as the heating elasticity for urban households is striking. Space heaters have high wattage and are typically operated for more hours every day than ovens and stoves. So one would expect that the immediate response to a price increase would be to reduce electricity consumption for heating more than for cooking. This response would be consistent with what Reiss and White (2005) have found in California.

There are several possible explanations for this surprising result. Price elasticities tend to be higher when households are able to reduce their electricity consumption fairly easily, for example, by improving efficiency of current appliances, reducing the heated area, or switching to substitute sources of energy. Notwithstanding the low cost of homemade electric appliances that are commonly available, fewer households own electric space heaters than electric ovens or stoves in Azerbaijan. Traditional homemade ovens are simply tin boxes with a spiral, which are traditionally used for baking bread and other purposes. Compared to homemade space heaters, ovens are safer in operation. The difference in the relative appliance costs and their safety could explain the discrepancy in the estimated price elasticities of electricity used for heating and cooking.

Conclusions

To conclude, the model estimated in this chapter produces reasonable results for a problem of intermittent supply and thus intermittent data availability. The elasticity estimates, made possible by introducing variability in the imputed prices of essential household energy services through switching energy availability regimes, are consistent with the literature, even though variability in prices of specific fuels is lacking. The model incorporates the key economic variables that affect energy demand and results in highly significant coefficient estimates. As expected, there is a significant difference in the estimated elasticities depending on whether electricity is used for heating, cooking, or lighting. Although why the estimated elasticity of cooking is substantially higher than heating is not entirely clear, some possible explanations related to the stock of appliances and the ease of fuel substitution. Since the appliance purchase decision is not included in the model, the elasticity estimates should be interpreted as short-run elasticities.

Appendix to chapter 7:
Budget share equations with the model's structural parameters

Network gas:

$$w_{Gi} = c_1 + \{\alpha_H + \alpha_C + \beta_{HH} \log P_G / z_{HG} + \beta_{CC} \log P_G / z_{CG} + 0.5\beta_{HC} \left(\log P_G / z_{HG} + \log P_G / z_{CG}\right)$$

$$+ 0.5\beta_{HL} \log P_E / z_{LE} + 0.5\beta_{CL} \log P_E / z_{LE}\} * R1_i + \varepsilon_{Gi},$$

Electricity for heating:

$$w_{HEi} = c_2 + \{\alpha_H - \beta_{HH} \log z_{HE} - 0.5\beta_{HC} \log z_{CE} - 0.5\beta_{HL} \log z_{LE}\} * R2_i$$
$$+ \{\beta_{HH} + 0.5\beta_{HC} + 0.5\beta_{HL}\} * R2 \log P_{Ei} + \varepsilon_{HEi},$$

Electricity for cooking:

$$w_{CEi} = c_3 + \{\alpha_C - \beta_{CC} \log z_{CE} - 0.5\beta_{HC} \log z_{CE} - 0.5\beta_{CL} \log z_{LE}\} * R2_i$$
$$+ \{\beta_{CC} + 0.5\beta_{HC} + 0.5\beta_{CL}\} * R2 \log P_{Ei} + \varepsilon_{CEi},$$

Electricity for lighting:

$$w_{LEi} = \{c_4 + \alpha_L - \beta_{LL} \log z_{LE} + 0.5\beta_{HL} \log P_G / z_{HG} + 0.5\beta_{CL} \log P_G / z_{CG}\} * 1$$
$$- \{0.5\beta_{HL} \log z_{LE} + 0.5\beta_{CL} \log z_{LE} + 0.5\beta_{HL} \log P_G / z_{HG} + 0.5\beta_{CL} \log P_G / z_{HG}\} * R2_i$$
$$+ \{\beta_{LL} + 0.5\beta_{HL} + 0.5\beta_{CL}\} * R2 \log P_{Ei} + \beta_{LL} \left(\log P_E - R2 \log P_E\right) + \varepsilon_{LEi},$$

Fuel wood and LPG:

$$w_{Wi} = c_5 + \left(\alpha_H + \alpha_C - \beta_{HH} \log z_{HW} - \beta_{CC} \log z_{CW} - 0.5\beta_{HC} \left(\log z_{HW} + \log z_{CW}\right) + 0.5\beta_{HL} \log P_E / z_{LE}\right.$$
$$\left. + 0.5\beta_{CL} \log P_E / z_{LE}\right\} * R3_i + \{\beta_{HH} + \beta_{CC} + \beta_{HC}\} * R3 \log P_{Wi} + \varepsilon_{Wi},$$

Kerosene:

$$w_{Ki} = c_6 + \{\alpha_L - \beta_{LL} \log z_{LK} - 0.5\beta_{HL} \log z_{HW} - 0.5\beta_{CL} \log z_{CW}\} * R3_i$$
$$+ \beta_{LL} * R3 \log P_{Ki} + \{0.5\beta_{HL} + 0.5\beta_{CL}\} * R3 \log P_{Wi} + \varepsilon_{Ki}.$$

Modification of the fuel wood/LPG and kerosene budget shares to test whether households are indifferent between the sources of energy services

Fuel wood/LPG:

$$
\begin{aligned}
w_{Wi} = c_5 &+ \left(\alpha_H + \alpha_C - \beta_{HH} \log z_{HW} - \beta_{CC} \log z_{CW} - 0.5\beta_{HC} \left(\log z_{HW} + \log z_{CW}\right) + 0.5\beta_{HL} \log P_E / z_{LE}\right. \\
&\left. +0.5\beta_{CL} \log P_E / z_{LE} - \log \varpi (\beta_{HH} + \beta_{CC} - \beta_{HC})\right\} * R3_i + \left\{\beta_{HH} + \beta_{CC} + \beta_{HC}\right\} * R3 \log P_{Wi} + \varepsilon_{Wi},
\end{aligned}
$$

Kerosene:

$$
\begin{aligned}
w_{Ki} = c_6 &+ \left\{\alpha_L - \beta_{LL} \log z_{LK} - 0.5\beta_{HL} \log z_{HW} - 0.5\beta_{CL} \log z_{CW} - 0.5 \log \varpi (\beta_{HL} + \beta_{CL})\right\} * R3_i \\
&+ \beta_{LL} * R3 \log P_{Ki} + \left\{0.5\beta_{HL} + 0.5\beta_{CL}\right\} * R3 \log P_{Wi} + \varepsilon_{Ki},
\end{aligned}
$$

where ϖ is the discount factor associated with the use of traditional (fuel wood and kerosene) and transitional (LPG) fuels instead of electricity and network gas.

Appendix Table 7.1 Estimation results using predicted and actual versus all predicted budget shares.

		Model C (predicted and actual budget shares)		Model D (predicted budget shares for the whole sample)	
		Coeff.	z	Coeff.	z
α_H		0.040**	4.4	0.041**	4.9
α_C		-0.034**	-3.4	-0.036**	-3.9
α_L		-0.005	-0.9	-0.004	-0.7
β_{HH}		-0.022*	-2.1	-0.025**	-2.5
β_{CC}		-0.005	-0.6	-0.002	-0.3
β_{LL}		-0.004**	-6.9	-0.004**	-7.1
β_{HC}		0.030**	6.8	0.031**	7.2
β_{CL}		-0.005	-0.3	-0.011	-0.6
β_{HL}		0.008	0.4	0.015	0.8
c_1	constant term in eq. (1)	0.008**	11.0	0.007**	10.4
c_2	constant term in eq. (2)	0.009**	3.7	0.008**	3.8
c_3	constant term in eq. (3)	0.022**	11.8	0.022**	12.3
c_4	constant term in eq. (4)	0.050**	6.6	0.047**	6.5
c_5	constant term in eq. (5)	0.020**	8.8	0.019**	8.6
c_6	constant term in eq. (6)	0.011**	7.2	0.009**	6.9
ω_1	household size*R1	0.000	0.2	0.000	0.2
ω_2	household size *R2	-0.012**	-5.4	-0.012**	-5.7
ω_3	household size *R2* $\log P_{Ei}$	0.002**	4.7	0.002**	5.0
ω_4	household size *R1* $\log P_{Ei}$	-0.000**	-3.0	-0.000**	-3.0
ω_5	household size *R3	0.001	0.7	0.001	0.7
ω_6	household size *R3* $\log P_{Wi}$	-0.000	-0.6	-0.000	-0.5
ω_7	household size *R3* $\log P_{Ki}$	-0.000	-1.3	-0.000	-1.3
s_1	house*R1	0.006**	3.2	0.005**	3.0
s_2	house *R2	0.012	1.0	0.010	0.9
s_3	house *R2* $\log P_{Ei}$	-0.003	-1.5	-0.002	-1.5
s_4	house *R1* $\log P_{Ei}$	-0.000	-1.0	-0.000	-0.9
s_5	house *R3	0.008	1.8	0.008	1.9
s_6	house *R3* $\log P_{Wi}$	0.003**	4.4	0.003**	4.3
s_7	house *R3* $\log P_{Ki}$	-0.002**	-4.3	-0.002**	-4.2
m_1	metered*R2	-0.023*	-2.0	-0.022*	-2.0

m_2	metered*R2* $\log P_{Ei}$	0.003	1.9	0.003	1.9
m_3	metered*R1* $\log P_{Ei}$	0.001**	3.2	0.001**	3.6
h_1	children*R2	0.007	0.8	0.017*	2.1
h_2	children*R2* $\log P_{Ei}$	-0.001	-0.7	-0.003*	-2.1
r_1	rural*R2	0.053**	3.2	0.047**	3.1
r_2	rural*R2* $\log P_{Ei}$	-0.009**	-3.8	-0.008**	-3.7
z_1	IMR for heating*R2	0.017**	7.4	0.017**	8.0
z_2	IMR for cooking*R2	0.011**	6.2	0.011**	6.3
r_1	Region 1	-0.005**	-6.1	-0.004**	-5.3
r_2	Region 2	-0.000	-0.4	0.001	0.7
r_3	Region 3	-0.004**	-5.4	-0.004**	-5.2
Log likelihood		29,388		29,938	
Observations		1,797		1,797	

Note: “House” is a dummy variable equal to 1 if a household resides in a house rather than an apartment, “children” is the number of children in a household, “rural” is a dummy variable equal to 1 for households living in rural areas, “metered” is a dummy variable equal to 1 if electricity consumption is metered, “IMR1” is the Inverse Mills Ratio term in the heating equation (2), “IMR2” is the Inverse Mills Ratio term in the cooking equation (3). The omitted regional dummy variable is “region 4.” Significance at the 5% level is indicated by ‘*’ and significance at the 1% level is indicated by ‘**’.

Appendix Table 7.2 Estimated own electricity price elasticities of heating, cooking and lighting.

	Model C		Model D	
	Coefficient	Z	Coefficient	Z
All households				
Heating	-0.30	-2.22	-0.27	-2.24
Cooking	-0.83	-6.22	-0.80	-6.30
Lighting	-0.30	-4.15	-0.31	-4.53
Rural				
Heating	-0.31	-1.63	-0.44	-4.05
Cooking	-0.36	-1.12	-0.26	-2.35
Lighting	-0.41	-3.59	-0.93	-8.86
Urban				
Heating	-0.28	-2.39	-0.26	-2.35
Cooking	-0.97	-8.77	-0.93	-8.86
Lighting	-0.24	-3.30	-0.24	-3.52
Poor				
Heating	-0.27	-2.55	-0.26	-2.70
Cooking	-0.50	-4.12	-0.45	-3.88
Lighting	-0.31	-5.15	-0.33	-5.68
Nonpoor				
Heating	-0.31	-2.07	-0.29	-2.05
Cooking	-0.98	-6.58	-0.96	-6.77
Lighting	-0.30	-3.53	-0.31	-3.85

Note: evaluated at the mean of the data and at the mean of each category.

STATA code used to implement direct maximum likelihood estimation of the model.

```
# delim ;

*capture program drop testdemog_regions_d0;
program define testdemog_regions_d0;
       version 8.2;
       args todo b lnf;
       tempname ah ac al bhh bcc bll bhc bcl bhl
       sigma11 sigma12 sigma22 sigma13 sigma23 sigma33 sigma14 sigma24 sigma34 sigma44
       sigma15 sigma25 sigma35 sigma45 sigma55 sigma16 sigma26 sigma36 sigma46 sigma56
       sigma66
       c1 c2 c3 c4 c5 c6 h1 h2 h3 h4 h5 h6 h7 s1 s2 s3 s4 s5 s6 s7 n1 n2 n3 ch1 ch2 apl1
       apl2 m1 m2 rg1 rg2 rg3;

       tempvar ll;
       tempname isi;
       quietly {;

       local p = 6;

       scalar `ah'      = `b'[1,1];
       scalar `ac'      = `b'[1,2];
       scalar `al'      = `b'[1,3];
       scalar `bhh'     = `b'[1,4];
       scalar `bcc'     = `b'[1,5];
       scalar `bll'     = `b'[1,6];
       scalar `bhc'     = `b'[1,7];
       scalar `bcl'     = `b'[1,8];
       scalar `bhl'     = `b'[1,9];
       scalar `sigma11' = `b'[1,10];
       scalar `sigma12' = `b'[1,11];
       scalar `sigma22' = `b'[1,12];
       scalar `sigma13' = `b'[1,13];
       scalar `sigma23' = `b'[1,14];
       scalar `sigma33' = `b'[1,15];
       scalar `sigma14' = `b'[1,16];
       scalar `sigma24' = `b'[1,17];
       scalar `sigma34' = `b'[1,18];
       scalar `sigma44' = `b'[1,19];
       scalar `sigma15' = `b'[1,20];
       scalar `sigma25' = `b'[1,21];
       scalar `sigma35' = `b'[1,22];
       scalar `sigma45' = `b'[1,23];
       scalar `sigma55' = `b'[1,24];
       scalar `sigma16' = `b'[1,25];
       scalar `sigma26' = `b'[1,26];
       scalar `sigma36' = `b'[1,27];
       scalar `sigma46' = `b'[1,28];
       scalar `sigma56' = `b'[1,29];
       scalar `sigma66' = `b'[1,30];
       scalar `c1'      = `b'[1,31];
       scalar `c2'      = `b'[1,32];
       scalar `c3'      = `b'[1,33];
       scalar `c4'      = `b'[1,34];
       scalar `c5'      = `b'[1,35];
       scalar `c6'      = `b'[1,36];

       scalar `h1'     = `b'[1,37];
       scalar `h2'     = `b'[1,38];
       scalar `h3'     = `b'[1,39];
       scalar `h4'     = `b'[1,40];
       scalar `h5'     = `b'[1,41];
       scalar `h6'     = `b'[1,42];
       scalar `h7'     = `b'[1,43];

       scalar `s1'     = `b'[1,44];
       scalar `s2'     = `b'[1,45];
       scalar `s3'     = `b'[1,46];
       scalar `s4'     = `b'[1,47];
```

```
scalar `s5'     = `b'[1,48];
scalar `s6'     = `b'[1,49];
scalar `s7'     = `b'[1,50];

scalar `n1'     = `b'[1,51];
scalar `n2'     = `b'[1,52];
scalar `n3'     = `b'[1,53];

scalar `ch1'    = `b'[1,54];
scalar `ch2'    = `b'[1,55];
scalar `apl1'   = `b'[1,56];
scalar `apl2'   = `b'[1,57];

scalar `m1'     = `b'[1,58];
scalar `m2'     = `b'[1,59];

scalar `rg1'    = `b'[1,60];
scalar `rg2'    = `b'[1,61];
scalar `rg3'    = `b'[1,62];


matrix CHOL =  (`sigma11',        0,     0,       0,         0,       0) \
                      (`sigma12',`sigma22',     0,       0,         0,       0) \
                      (`sigma13',`sigma23',`sigma33',    0,         0,       0) \
                      (`sigma14',`sigma24',`sigma34',`sigma44',     0,       0) \
                      (`sigma15',`sigma25',`sigma35',`sigma45',  `sigma55',  0) \
                      (`sigma16',`sigma26',`sigma36',`sigma46',  `sigma56', `sigma66');
matrix S =CHOL*CHOL';

*noi matrix list CHOL;

/*
capture matrix CHECK = cholesky(S);
if (_rc != 0) {;
        display in red "Matrix is not positive semidefinite";
       // exit;
};
*/

matrix iS= syminv(S);

// get residuals;

scalar pg = 42.68907563;
scalar pe = 1129.412;
scalar zhg = 0.85;
scalar zcg = 0.60;
scalar zhe = 0.89;
scalar zce = 0.75;
scalar zle = 0.90;
scalar zhw = 0.40;
scalar zcw = 0.25;
scalar zlk = 0.60;

tempname r1 r2 r3 r4 r5 r6;

generate double `r1'=
ish_CG-(`ah'+`ac'+`bhh'*ln(pg/zhg)+`bcc'*ln(pg/zcg)+0.5*`bhc'*(ln(pg/zhg)+ ln(pg/zcg))-
0.5*`bhl'*ln(pe/zle)-0.5*`bcl'*ln(pe/zle))*r1 -`c1' -`h1'*h_r1 - `s1'*s_r1 - `rg1'*region1 -
`rg2'*region2 - `rg3'*region3;

generate double `r2'=
ish_ELEh- (`ah'-`bhh'*ln(zhe)-0.5*`bhc'*ln(zce)-0.5*`bhl'*ln(zle))*r2 -
(`bhh'+0.5*`bhc'+0.5*`bhl')*r2p_ele-`c2' - `h2'*h_r2 -  `h3'*h_r2p_ele
- `s2'*s_r2 -  `s3'*s_r2p_ele -`n1'*n_r2 - `n2'*n_r2p_ele - `m1'*mills_heat
- `rg1'*region1 - `rg2'*region2 - `rg3'*region3;

generate double `r3'=
ish_ELEc- (`ac'-`bcc'*ln(zce)-0.5*`bhc'*ln(zce)-
```

```
        0.5*`bcl'*ln(zle))*r2 -(`bcc'+0.5*`bhc'+0.5*`bcl')*r2p_ele -`c3' -`h2'*h_r2-`h3'*h_r2p_ele  -
        `n1'*n_r2 - `n2'*n_r2p_ele - `ch1'*c_r2 - `ch2'*c_r2p_ele- `apl1'*apl_r2 - `apl2'*apl_r2p_ele
        -`m2'*mills_cook - `rg1'*region1 - `rg2'*region2 - `rg3'*region3;

        generate double `r4'=
        ish_ELEl-(`al'-`bll'*ln(zle)+0.5*`bhl'*ln(pg/zhg)+0.5*`bcl'*ln(pg/zcg)+`c4')-
        ((`al'-`bll'*ln(zle)-`bhl'*ln(zle)-`bcl'*ln(zle))-(`al'-
        `bll'*ln(zle)+0.5*`bhl'*ln(pg/zhg)+0.5*`bcl'*ln(pg/zcg)))*r2 -
        (`bll'+0.5*`bhl'+0.5*`bcl')*r2p_ele - `bll'*(p_ele_p_ele)-`h4'*h_p_ele_p_ele - `h3'*h_r2p_ele
        -`h2'*h_r2 -`s4'*s_p_ele_p_ele - `s3'*s_r2p_ele -`s2'*s_r2-`n1'*n_r2 - `n2'*n_r2p_ele -
        `n3'*n_p_ele_p_ele- `rg1'*region1 - `rg2'*region2 - `rg3'*region3;

        generate double `r5'=ish_WOD-
        (`ac'+`ah'-`bhh'*ln(zhw)-`bcc'*ln(zcw)-0.5*`bhc'*(zhw+zcw)+
        0.5*`bhl'*ln(pe/zle)+0.5*`bcl'*ln(pe/zle))*r3-(`bhh'+`bcc'+`bhc')*r3p_wood -`c5' -
        `h5'*h_r3 - `h6'*h_r3p_wod - `s5'*s_r3 - `s6'*s_r3p_wod - `rg1'*region1 - `rg2'*region2 -
        `rg3'*region3;

        generate double `r6'=ish_KER- (`al'-`bll'*ln(zlk)-0.5*`bhl'*ln(zhw)-0.5*`bcl'*ln(zcw))*r3+
        `bll'*r3p_ker+(0.5*`bhl'+0.5*`bcl')*r3p_wood -`c6' -`h5'*h_r3 - `h7'*h_r3p_ker -
        `h6'*h_r3p_wod -`s5'*s_r3 - `s7'*s_r3p_ker -`s6'*s_r3p_wod - `rg1'*region1 - `rg2'*region2 -
        `rg3'*region3;



        local resids "`r1' `r2' `r3' `r4' `r5' `r6'";
        tempvar g1 g2 g3 g4 g5 g6 ip;
        generate double `ip' = 0;
        forval i = 1/`p' {;
                matrix isi = iS[`i',1...];
                matrix colnames isi = `resids';
                matrix score double `g`i'' = isi;
                replace `ip' = `ip' + `r`i''*`g`i'';
                }; // end forval
        scalar det = det(S);
        mlsum `lnf' =  -0.5*(3*ln(2*c(pi))+ln(det)+ `ip');
        }; // end quietly
 //     display `lnf';
end;
```

8 Welfare analysis and discussion of policy implications

In the past, countries with former centrally planned economies pursued a social pricing policy for electricity. Making electricity services universally accessible and affordable was an important part of a government strategy of making infrastructure services accessible to all. In the last decade, most countries with former central planning have reformed their energy sectors in pursuit of three types of objectives: fiscal, efficiency, and distributional.

Motivation for reforms is mostly fiscal, but the efficiency and distributional objectives are also important considerations in the design of reform programs. A planned increase in electricity tariffs will eliminate the subsidy and raise revenues, freeing up resources for reinvestment in the electricity sector as well as social spending on education, health and other areas in dire need of budgetary financing. An increase of electricity prices will also result in a better resource allocation facilitated by appropriate price signals, thus encouraging more efficient consumption of electricity. Although such reforms can generate substantial efficiency and welfare gains for all sectors, they can also reduce the real income of households, especially the poor.

Residential electricity prices in Azerbaijan are far below the cost-recovery level, and the Government has committed to eliminate all financial support for the provision of electricity and other utility services by 2010. The reform option that appears most plausible envisages a 50 percent increase in wholesale electricity tariffs (from 71 AZM/kWh to 106.5 AZM/kWh) effective in 2006, with equal annual percentage increases thereafter in order to reach full cost recovery, estimated at 174 AZM/kWh, by the end of 2010 (World Bank 2005).[43] In spite of the apparently poor reliability of electricity supply in many parts of the country, the government has not set clear targets for reliability improvement.

The main purpose of this chapter, and ultimately of this dissertation, is to explore the magnitude of the welfare impact of the likely price increase scenario, potential reliability improvements, and potential combined price increase and reliability improvement scenarios on Azeri households. The analysis proceeds in three steps. First, I use the model estimated in the previous chapter to predict the level of electricity consumption in each policy scenario and to investigate household response to price and reliability changes. The assumptions about price increases and supply reliability levels are summarized in Table 8.1 for five scenarios. Scenario 1 is a baseline scenario with current price and reliability levels. Scenario 2 considers a 50 percent higher electricity price and the current reliability level. Scenario 3 assumes a reliability improvement with no price change. And Scenario 4 involves a combined 50 percent price increase and reliability improvement from the current level to uninterrupted 24-hour-per-day supply. Scenario 5 is a 100 percent price increase and a 50 percent improvement in reliability. If current electricity supply exceeds an average of 12 hours a day, then this scenario assumes perfect supply (24 hours a day).

Table 8.1 Scenario descriptions.

	Scenario 1 (baseline)	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Electricity price	Current	50% increase	Current	50% increase	100% increase
Supply reliability	Current	Current	24 hr supply	24 hr supply	50% improvement

---

[43] Residential prices are expected to increase in similar proportion to wholesale electricity prices and reach the full cost recovery level of about 4.5-5.5 US cents/kWh by 2010.

Second, I calculate the welfare gains and losses for each policy scenario compared to the baseline and explore how the direction and magnitude of the welfare impact of reforms varies with household location, access to substitutes, and demographic characteristics. Third, I identify the most vulnerable households and propose strategies to mitigate the adverse welfare impact of reforms on these groups.

An approach for economic welfare analysis of policy reform

Electricity consumption levels in alternative reform scenarios can be predicted using the three estimated budget shares for electricity reported in chapter 7:

$$w_{HEn} = c_2 + \gamma_2 R_{2n} + \gamma_3 R_2 \log P_{En} + \omega_2 HR_{2n} + \omega_3 HR_2 \log P_{En} + \varepsilon_{HEn}, \tag{2}$$

$$w_{CEn} = c_3 + \gamma_4 R_{2n} + \gamma_5 R_2 \log P_{En} + \omega_2 HR_{2n} + \omega_3 HR_2 \log P_{En} + \varepsilon_{CEn}, \tag{3}$$

$$\begin{aligned} w_{LEn} = {} & \left(c_4 + \gamma_6\right) + \gamma_7 R_{2n} + \gamma_8 R_2 \log P_{En} + \beta_{LL}\left[\log P_{En}\left(1 - R_{2n}\right)\right] + \omega_2 HR_{2n} + \\ & \omega_3 HR_2 \log P_{En} + \omega_4 \left[H\left(\log P_{En}\left(1 - R_{2n}\right)\right)\right]_n + \varepsilon_{LEn}, \end{aligned} \tag{4}$$

The level of electricity consumption for heating, cooking, and lighting in kWh per month is calculated as the product of the corresponding budget share and total income divided by electricity price. Consumption quantities are calculated for each household taking into account each household’s demographic characteristics. The resulting predicted consumption levels are reported in Table 8.2.

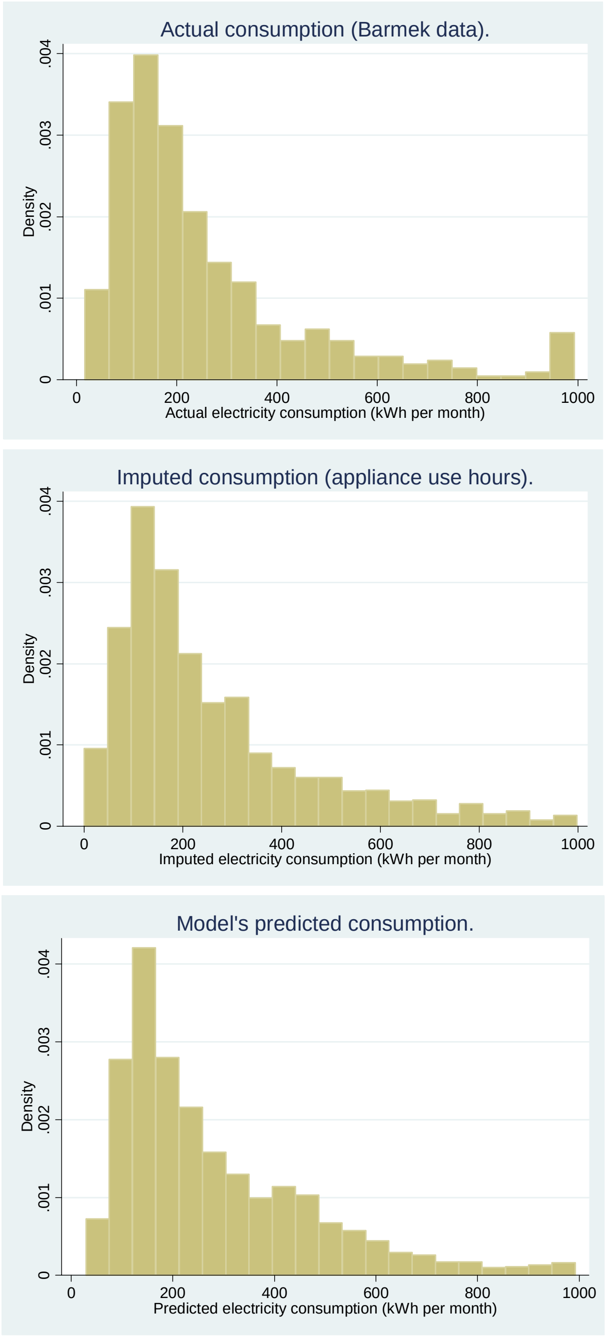
As predicted by the model, current electricity consumption during the winter is an average of 308 kWh per month, and it would increase to 482 kWh per month if electricity were supplied at the current price without interruptions. The predicted level of electricity consumption in the reform scenario that combines a 50% price increase and a reliability improvement is about 323 kWh per month, which is slightly above the current consumption level predicted by the model. As indicated in Table 8.2, predicted electricity consumption for the nonpoor is substantially higher than for poor households in all scenarios. Similarly, it is higher for unmetered than for metered households. The change in electricity consumption predicted by the model implies an average overall arc price elasticity of -0.69.

Table 8.2 Predicted winter electricity consumption by scenario (kWh/month).

	Scenario 1: Current price and current reliability	Scenario 2: 50% higher price and current reliability	Scenario 3: Current price and 24-hour/day supply	Scenario 4: 50% higher price and 24-hour/day supply	Scenario 5: 100% higher price and 50% higher reliability
Urban	260	168	424	283	151
Rural	374	246	564	379	251
Nonpoor	332	216	516	346	204
Poor	217	142	355	239	149
Unmetered	317	207	498	335	207
Metered	294	191	459	307	171
Total	308	201	482	323	193

Distribution of electricity consumption predicted by the model for all households, assuming all households are metered, is similar to the distribution of actual electricity consumption from Barmek company records for metered households in Baku as well as imputed electricity consumption based on reported hourly usage of electricity (Figure 8.1). Thus, although actual electricity consumption data were not included in model estimation in chapter 7, the model's predictions are comparable to revealed preference data.

Figure 8.1 Comparison of model’s predictions with actual electricity consumption.



Note: The first histogram describes the distribution of actual electricity consumption from Barmek utility company records for metered households in Baku (calculated as the monthly utility company’s bill divided by electricity price). The second histogram describes the distribution of imputed electricity consumption using information on reported hourly usage of electric appliances in the current price and reliability scenario. The third histogram describes the distribution of predicted electricity consumption in current price and reliability scenario. Predictions are based on Model C estimated in chapter 7. Source: 2003 Household Energy Survey and Barmek utility company billing records for metered households in Baku.

The key policy issue in the process of designing the reform strategy is to identify households that would gain and lose from the reforms. In general, households are unequivocally worse-off from a price increase, and they are universally better-off with an improvement in the supply quality. But overall, some categories of households may experience welfare gains while others experience losses from a reform that combines a price increase with a reliability improvement. Since political concerns for the poor are an important factor in implementing reforms, it is important for the government to understand the distribution of gains and losses in order to design an effective mitigation strategy.

The welfare effect of a change in electricity price and reliability levels can be measured by compensating variation (*CV*). It is implicitly defined in terms of the indirect utility function as

$$V(p'', r'', Y - CV) = V(p', r', Y),$$

where *p* is electricity price and *r* is reliability of electricity supply. The left-hand side of this expression is expected indirect utility after the reform after extracting the *CV*, and the right-hand side is expected indirect utility before the reform.

Following Just et. al. (2004), the analytical expression for *CV* can be derived by solving the equation that implicitly defines *CV* in terms of the indirect utility function. The level of expected indirect utility before the price and quality change is defined by the expression for the homothetic translog indirect utility function derived in chapter 6, with electricity price and shares of time in each regime evaluated at their pre- and post-reform levels using parameter estimates reported in chapter 7. This derivation, as detailed in the

Appendix to this chapter, results in the following definition of *CV* as a percent of total consumption expenditures:[44]

$$CV / Y = 1 - e^{Z1 - Z2},$$

where

$$\begin{aligned} Z1 = \theta' \{ & -\alpha_H \log(P_G / z_{HG}) - \alpha_C \log(P_G / z_{CG}) - \alpha_L \log(P_E' / z_{LE}) - 0.5\beta_{HH} \log^2(P_G / z_{HG}) - 0.5\beta_{CC} \log^2(P_G / z_{CG}) \\ & - 0.5\beta_{LL} \log^2(P_E' / z_{LE}) - 0.5\beta_{HC} \log(P_G / z_{HG}) \log(P_G / z_{CG}) - 0.5\beta_{HL} \log(P_G / z_{HG}) \log(P_E' / z_{LE}) \\ & - 0.5\beta_{CL} \log(P_G / z_{CG}) \log(P_E' / z_{LE}) \} + \phi' \{ -\alpha_H \log(P_E' / z_{HE}) - \alpha_C \log(P_E' / z_{CE}) - \alpha_E \log(P_E' / z_{LE}) \\ & - 0.5\beta_{HH} \log^2(P_E' / z_{HE}) - 0.5\beta_{CC} \log^2(P_E' / z_{CE}) - 0.5\beta_{LL} \log^2(P_E' / z_{LE}) - 0.5\beta_{HC} \log(P_E' / z_{HE}) \\ & \log(P_E' / z_{CE}) - 0.5\beta_{HL} \log(P_E' / z_{HE}) \log(P_E' / z_{LE}) - 0.5\beta_{CL} \log(P_E' / z_{CE}) \log(P_E' / z_{LE}) \} + (1 - \theta' - \phi') \\ & \{ -\alpha_{HW} \log(P_W / z_{HW}) - \alpha_{CW} \log(P_W / z_{CW}) - \alpha_{LK} \log(P_K / z_{LK}) - 0.5\beta_{HH} \log^2(P_W / z_{HW}) \\ & - 0.5\beta_{CC} \log^2(P_W / z_{CW}) - 0.5\beta_{LL} \log^2(P_K / z_{LK}) - 0.5\beta_{HC} \log(P_W / z_{HW}) \log(P_W / z_{CW}) \\ & - 0.5\beta_{HL} \log(P_W / z_{HW}) \log(P_K / z_{LK}) - 0.5\beta_{CL} \log(P_W / z_{CW}) \log(P_K / z_{LK}) \}, \end{aligned}$$

and

$$\begin{aligned} Z2 = \theta'' \{ & -\alpha_H \log(P_G / z_{HG}) - \alpha_C \log(P_G / z_{CG}) - \alpha_L \log(P_E'' / z_{LE}) - 0.5\beta_{HH} \log^2(P_G / z_{HG}) - 0.5\beta_{CC} \log^2(P_G / z_{CG}) \\ & - 0.5\beta_{LL} \log^2(P_E'' / z_{LE}) - 0.5\beta_{HC} \log(P_G / z_{HG}) \log(P_G / z_{CG}) - 0.5\beta_{HL} \log(P_G / z_{HG}) \log(P_E'' / z_{LE}) \\ & - 0.5\beta_{CL} \log(P_G / z_{CG}) \log(P_E'' / z_{LE}) \} + \phi'' \{ -\alpha_H \log(P_E'' / z_{HE}) - \alpha_C \log(P_E'' / z_{CE}) - \alpha_E \log(P_E'' / z_{LE}) \\ & - 0.5\beta_{HH} \log^2(P_E'' / z_{HE}) - 0.5\beta_{CC} \log^2(P_E'' / z_{CE}) - 0.5\beta_{LL} \log^2(P_E'' / z_{LE}) - 0.5\beta_{HC} \log(P_E'' / z_{HE}) \\ & \log(P_E'' / z_{CE}) - 0.5\beta_{HL} \log(P_E'' / z_{HE}) \log(P_E'' / z_{LE}) - 0.5\beta_{CL} \log(P_E'' / z_{CE}) \log(P_E'' / z_{LE}) \} + (1 - \theta'' - \phi'') \\ & \{ -\alpha_{HW} \log(P_W / z_{HW}) - \alpha_{CW} \log(P_W / z_{CW}) - \alpha_{LK} \log(P_K / z_{LK}) - 0.5\beta_{HH} \log^2(P_W / z_{HW}) \\ & - 0.5\beta_{CC} \log^2(P_W / z_{CW}) - 0.5\beta_{LL} \log^2(P_K / z_{LK}) - 0.5\beta_{HC} \log(P_W / z_{HW}) \log(P_W / z_{CW}) \\ & - 0.5\beta_{HL} \log(P_W / z_{HW}) \log(P_K / z_{LK}) - 0.5\beta_{CL} \log(P_W / z_{CW}) \log(P_K / z_{LK}) \}. \end{aligned}$$

Economic welfare implications of reform

As shown in Figures 8.2-8.5, welfare effects are heterogeneous. It appears that higher income households stand to have the highest losses from a price increase that is unaccompanied by a quality improvement. At a first glance, gains from an improvement in reliability seem to be slightly higher for the poor households. In every instance the gains and losses are widely dispersed even for households at the same income level. The

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[44] A more detailed derivation of this result is shown the Appendix.

gains from the restoration of perfect supply by far outweigh the losses from a 50 percent price increase (Figure 8.4), although there are some losers in the scenario of a higher price increase and lower reliability improvement (Figure 8.5).

In every reform scenario, the welfare level of some households is not affected by the electricity price change and reliability improvement. It is likely that these households have a reliable gas supply and for this and other reasons their electricity consumption was very low and would continue to remain low in the reform scenario. The simulated positive or negative welfare impact on the remaining households is not very large. The losses never exceed 1 percent of total expenditures. The gains have a greater range of variation and some households gain almost as much as 3 percent of total expenditures (Figure 8.4), even though the scenario of perfect supply reliability and no price increase is not realistic. The relatively low magnitude of the gains and losses is plausible, because, as shown in chapter 4, electricity expenditures also constitute a small share of total expenditures. However, the findings with respect to the losses and gains of the poor versus non-poor should be interpreted with some caution, keeping in mind that the procedure for the imputation of total expenditures, as discussed in chapter 3, is less accurate for the poor than for other household categories.

Figure 8.2 Compensating variation (*CV*) of a 50 percent price increase.

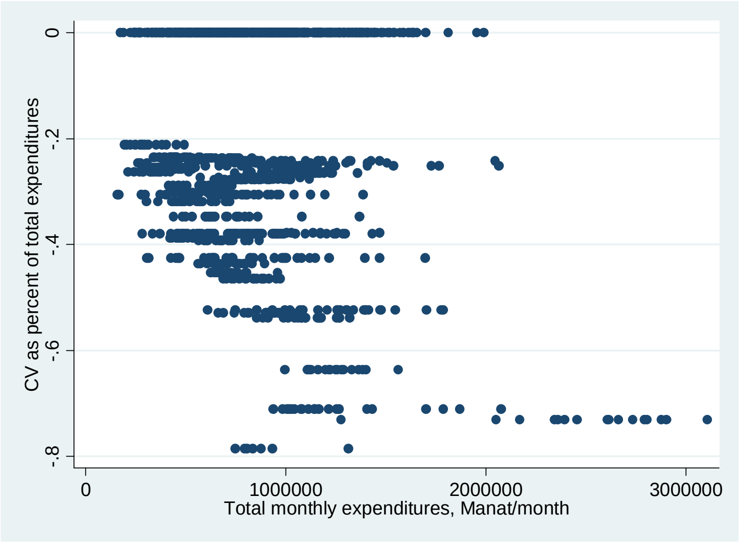
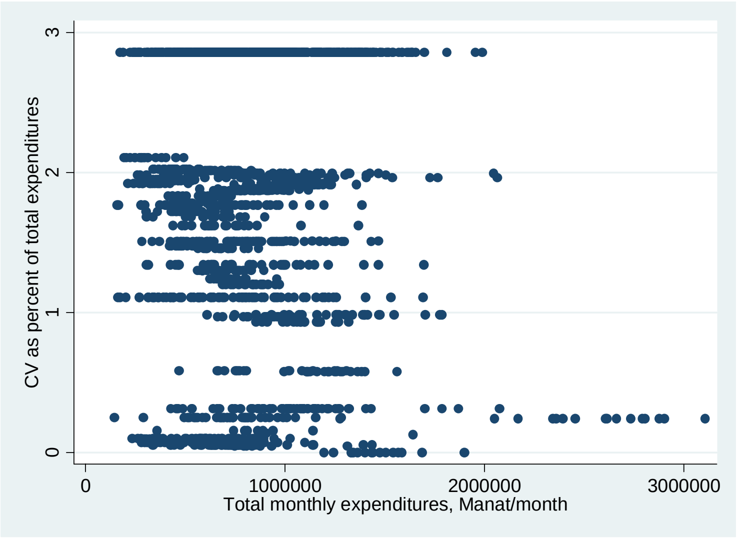


Figure 8.3 *CV* of a reliability improvement.



Source: calculated from 2003 Household Energy Survey.

Figure 8.4 *CV* of a 50 percent price increase and a reliability improvement.

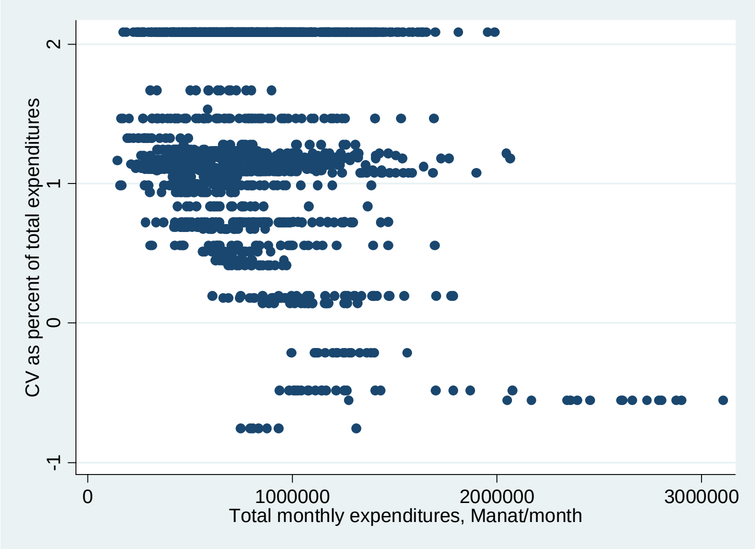
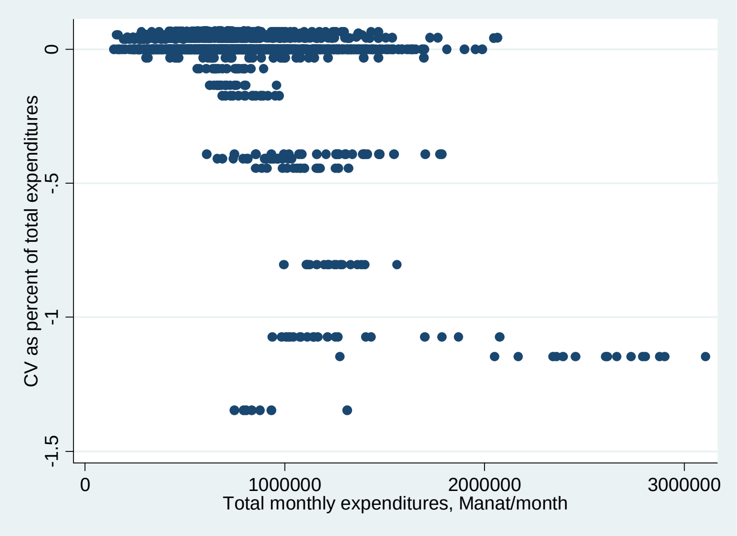


Figure 8.5 *CV* of a 100 percent price increase and a 50 percent improvement in reliability.



Source: calculated from 2003 Household Energy Survey.

As shown in Table 8.3, in Scenario 2 of a 50 percent electricity price increase all households experience welfare losses. The absolute value of the losses is below one percent of total household income. The losses are somewhat higher for rural households compared to urban households and there are strong regional differences. The differences by income level, for example, across income quintiles, are very small. The most distinct differences in welfare impacts are among the categories that reflect supply quality.[45] As expected, households in category 3, which never receive network gas and receive very little electricity, are unaffected by the price change of electricity. Conversely, households in category 1 (with a reliable gas supply), and in category 2 (without a reliable supply of gas but a reliable supply of electricity) experience losses form a price increase, and there are mitigated by the quality improvement in Scenario 4 but not in Scenario 5.

Table 8.3 Compensating variation of three reform scenarios (% of household budget)

	Scenario 2: 50% price increase	Scenario 3: quality improvement to perfect reliability	Scenario 4: 50% price increase and quality improvement to perfect reliability	Scenario 5: 100% price increase and 50 percent quality improvement
Urban	-0.08	1.89	1.62	-0.03
Rural	-0.33	1.64	0.9	-0.05
Nonpoor	-0.2	1.74	1.34	-0.06
Poor	-0.24	1.94	1.24	0.03
Unmetered	-0.26	1.82	1.19	-0.04
Metered	-0.11	1.74	1.51	-0.05
Zone 1 (Absheron Peninsula)	-0.06	1.7	1.59	-0.05
Zone 2 (North)	-0.3	1.77	1.01	-0.03
Zone 3 (South)	-0.28	1.79	1.09	-0.05
Zone 4 (Mingechevir and Ganja)	-0.09	2.05	1.66	0.01
Poorest 20%	-0.24	1.94	1.24	0.03
Quintile 2	-0.21	1.75	1.31	-0.01
Quintile 3	-0.19	1.62	1.34	-0.02
Quintile 4	-0.16	1.9	1.44	-0.08
Richest 20%	-0.23	1.7	1.26	-0.12
Category 1	-0.75	0.39	1.1	-0.07
Category 2	-0.35	1.61	0.83	-0.05
Category 3	0	2.86	2.08	0
Total	-0.21	1.79	1.32	-0.04

---

[45] Three categories were defined to reflect the reliability of network energy. Households in category 1 have gas supply at least some of the time or they had electricity supply more than 90 percent of the time before the reform. Households in category 2 never have gas supply, and have electricity supply between 20 and 90 percent of the time. Households in category 3 never have gas supply and have electricity supply less than 20 percent of the time.

On average, all households experience welfare gains of about 1.79 percent of total income as supply interruptions are eliminated (Scenario 3). A combined price increase and reliability improvement in Scenario 4 results in a welfare gains for all household categories, although they are clearly lower in magnitude than the gains from a supply improvement in the absence of a price increase. Households in category 3, who presently have a very poor supply of electricity, experience the highest welfare gains from a reliability improvement, and therefore also the highest gains from the combined price and reliability change.

A particularly important question in the course of a welfare evaluation of alternative reform scenarios is identification of households who will be adversely affected by the reforms (Table 8.4).

Table 8.4 Number of households that gain and lose from the reform, by district.

	Scenario 4		Scenario 5	
	Gain (or no effect) 1/	Lose	Gain (or no effect) 1/	Lose
<u>Zone 1: Absheron Peninsula</u>				
Alibayramly	99	0	90	9
Baku	361	24	361	24
Sumgayit	145	1	145	1
<u>Zone 2: Guba, Ismailly and Goycay</u>				
Guba	201	0	201	0
Ismailly	191	1	118	74
Goycay	175	23	116	82
<u>Zone 3: Sabirabad and Imishly</u>				
Imishly	155	15	155	15
Sabirabad	185	0	166	19
<u>Zone 4: Mingechevir and Ganja City</u>				
Mingechevir	73	0	73	0
Ganja City	148	0	148	0
Total	1,733	64	1,573	224

Note: The category of "gainers" in this table also includes households with zero *CV*.

As shown in Table 8.4, only 63 households experience welfare losses in Scenario 4 of a combined price and reliability change, but the number of losers triples in Scenario

5 of a higher price increase and a lower reliability improvement. Although according to the model nearly all households would experience welfare gains in the reform scenario, small changes in the assumptions about the magnitude of the price increase, supply reliability and payment enforcement can result in welfare losses for the vulnerable group, as indicated by Scenario 5.

In both scenarios the adversely affected households tend to be located in a few areas: Goycay, Ismailly and Baku. However, the 2003 HES does not include households from all districts in Azerbaijan. Therefore, I proceed with detailing a profile of the vulnerable households according to their demographic characteristics and energy supply conditions. For the purposes of this analysis, households that experience losses in Scenario 5 are defined here as vulnerable. As shown in Table 8.5, vulnerable households are equally likely to be located in rural and urban areas, but they tend to be located in fuel wood scarce areas in the South, with 70 percent of all the losers living in this part of the country.

Table 8.5 Mean values for households who gain and lose from the reform (Scenario 5). 1/

	Lose from the reform N=224	Gain N=970	No effect N=603
Demographic characteristics and income structure:			
Household size**	4.4	4.8	3.8
Number of children in a family*	0.65	0.72	0.39
Children under 10 as a share of household size	0.13	0.13	0.08
Employed persons as a share of household size	0.07	0.05	0.20
House (dummy)**	0.90	0.98	0.32
Living area (total m2)**	68	75	53
Share of income from salaries**	0.18	0.10	0.41
Share of income from pensions	0.26	0.27	0.22
Share of income from remittances (private transfers)**	0.05	0.13	0.11
Total monthly consumption expenditures**	1,089,644	717,745	807,735
Energy use and appliance ownership:			
Electric stove (dummy)*	0.10	0.05	0.11
Electric oven (dummy)	0.35	0.38	0.20

Electric space heater (dummy)	0.25	0.29	0.33
Wood stove (dummy)*	0.75	0.88	0.12
Heat with electricity (dummy)	0.26	0.31	0.36
Cook with electricity (dummy)	0.32	0.34	0.22
Heat with gas (dummy)*	0.02	0.00	0.97
Heat with wood (dummy)**	0.75	0.88	0.12
Use dummy variables:			
LPG	0.50	0.54	0.13
Kerosene**	0.87	0.98	0.51
Dung**	0.10	0.25	0.00
Network gas	-	-	1.00
Electricity	0.99	0.99	1.00
Wood**	0.76	0.89	0.13
Location (dummy variables):			
Rural	0.83	0.85	0.05
Region 1 (Absheron Peninsula: includes main cities)**	0.15	-	0.61
Region 2 (Northern areas: rich in forest cover)**	0.15	0.50	0.02
Region 3 (South: fuel wood scarce areas)**	0.70	0.43	0.18
Region 4 (West: Ganja and Mingechev cities)**	-	0.07	0.18
Quality of energy supply and other indicators:			
Payment ratio (previous month's payment/bill)	0.49	0.55	0.51
Average village/town payment ratio	0.59	0.60	0.54
Metered (dummy)**	0.22	0.12	0.63
Average hours of gas supply (winter)	-	-	20
Average hours of electricity supply (winter)**	16	9	19
Electricity price (Manat per oil equivalent)	953	1,033	1,051
Pre-reform share of time in regime 1 (gas regime)	-	-	0.31
Pre-reform share of time in regime 2 (electricity regime)**	0.68	0.37	-
Share of time in regime 2 in Scenario 5**	1.00	0.74	-
Other:			
Imputed**	0.82	0.70	0.73
Compensating variation as percent of total expenditures**	-0.46	0.05	-
Total energy expenditures (Manat/month)**	50,147	61,485	24,946
Energy as a share of total expenditures*	0.05	0.10	0.04
Poor (dummy)**	0.08	0.43	0.10

Note: 1/ The results are for a total of 1,797 households for whom the model was estimated. Compensating variation is missing for the remaining 203 households with missing data. Significant difference between summary statistics for the losers and gainers categories is indicated by “**” if different at one percent level, and by “*” if different at five percent level.

One of the most significant findings is that the average income level in the vulnerable group (1,089,644 Manat per month) is substantially higher than that of the non-vulnerable group (717,745 Manat per month), and this income difference is statistically significant. The finding that the share of the poor among the losers is low is also confirmed by a much lower poverty rate among the losers (8 percent) than among the gainers (43 percent).

Other distinguishing characteristics of the adversely affected group of households include lower incidence of fuel wood and dung. There is a higher share of metered households in the group of vulnerable households, and all of them are in the electricity regime (Regime 2) after a 50 percent reliability improvement in Scenario 5 in contrast to the group of the gainers. Prior to the reform, the losers' group also had a higher average reliability level and daily hours of electricity supply (16 versus 9 hours on a typical winter day). Interestingly, the average (hypothetical) electricity price is lower for the losers than for the gainers, so their losses do not appear to be related to the magnitude of the stated price increase alone. On average, the losers have a lower share of energy in total expenditures than the gainers. There are very few differences in the income structure of the two groups. The only exceptions are the lower share of remittances (private transfers from friends and household members) and a slightly higher share of income from salaries. Last, the loser category includes a slightly lower share of households living in houses and slightly smaller living area than in the gainer category.

To sum up these findings, the losers from the reforms tend to be households who have relatively poor access to substitutes (gas, wood and dung) and/or households who had relatively reliable electricity supply before the reforms. Contrary to expectations, households that incur welfare losses from the reforms are not located solely in Baku (Table 8.4). Only 15 percent of all the losers are located on the Absheron Peninsula (including Baku), while another 15 percent are in the forest-rich areas in the North and 70 percent in forest-poor areas in the South.

Overall, this comparison of the losers and gains from the reform with the most extreme price increase scenario indicates that there is a strong locational determinant in the direction and magnitude of the welfare impact, but losers will not be confined to one geographic area, even though losses appear to be borne mainly by the relatively richer households.

An earlier ex-ante evaluation of the same reforms by the World Bank (2005), that did not attempt to quantify welfare gains from a reliability improvement in Azerbaijan, concluded that poor households would be particularly vulnerable to the adverse impact of pricing reforms. One of the policy recommendations was for the Government of Azerbaijan to design a well-targeted social assistance scheme to mitigate the adverse effects of the price increase. Welfare gains from improvements in supply reliability were deemed to be important for Azeri households but they were not quantified because of a lack of clarity about the appropriate methodology. Inclusion of the positive welfare impact of these gains using the intermittent supply model reveals that the poor are more likely to be the gainers even if a moderate price increase accompanies service quality improvements. Furthermore, households that will be adversely affected are more likely to be non-poor. Thus, in this particular situation, a strong policy emphasis and targeted investments in improving service reliability can be more effective at protecting vulnerable households than income transfers through a social protection scheme.

The results of these policy simulations demonstrate the need to account for the welfare impact of improvements in service quality in the course of cost-benefit analysis of infrastructure reforms in situations where reforms are expected to result in both a price increase and a reliability improvement.

The actual welfare impact may diverge from the simulations presented here to some extent. With uninterrupted supply some of these households, especially those who are in the vulnerable category, may adjust to the price change by purchasing more efficient appliances. Higher average income in the loser group suggests that this is a likely outcome because appliance costs may not represent a significant obstacle for this household category. Investigating this possibility calls for further analysis but it requires further data on appliance costs and purchase decisions, which were not available in the surveys used in this dissertation.

Payment enforcement

No scenario of stricter payment enforcement is included in this chapter because raising payment enforcement by a certain percentage of the historical enforcement rate is equivalent to raising price by the same percentage in this model. For example, improving payment enforcement by 50 percent is equivalent to raising the nominal price by 50 percent, which is a policy outcome that is modeled in Scenario 2. In practice, the decision to accumulate payment arrears is endogeneous. Thorough analysis of this issue would require detailed information on payment rates with sufficient variability for a representative sample of metered households in each geographic zone. These data were not available, as metering for electricity has been introduced mainly in the Barmek service area on the Absheron Peninsula. Household behavior with respect to bill payment is an important issue of policy concern that could be revisited after detailed data on electricity consumption for metered households become available.

Conclusions

Policy simulations in this chapter clearly show that gains from an improvement in the reliability of electricity supply outweigh the losses in a range of possible policy scenarios. Combining pricing reforms with an improvement in service quality is a very effective way of mitigating the losses that would result from implementing pricing reforms without a concurrent quality improvement.

Even in an extreme case of a partial improvement in reliability and doubling of electricity prices, there are few losers. Contrary to expectations, only a small share of them are located in Baku and other large cities. The main finding of the policy simulations is that the reform's losers tend to be the nonpoor, who can be broadly divided into two categories. The first category consists of households residing in areas with good supply of gas and relatively good electricity supply prior to the reforms. The second category includes the majority of the losers, and consists of households who have poor access to substitutes, such as in the forest-poor areas in the South of Azerbaijan. Since the group of adversely affected households includes very few poor households, targeted social protection measures may not need to accompany the reforms. However, it is crucial that the supply quality improve substantially in order to ensure that there are few losers.

The provision of network gas will be an effective mitigation strategy. As seen in this analysis, the loser category does not include any households with reliable gas supply. To the extent that the residential gas prices will also rise in the course of the reforms, the simulations in this chapter present a partial view of the reform's welfare impact. Policy makers will need to evaluate the availability of electricity and substitute sources of energy as well as their cost relative to household income in order to select areas for targeted investments to improve the quality of energy services. A strong location-specific determinant that underlies the observed energy consumption patterns of Azeri households and defines the magnitude of the welfare effect of reforms could facilitate effective targeting.

Appendix to chapter 8:
Derivation of the expression for compensating variation (*CV*) using the indirect utility function

CV can be implicitly defined in terms of the expected indirect utility function before and after the change in price and reliability as follows:

$$V(p'',\phi'',\theta'',Y-CV)=V(p',\phi',\theta',Y),$$

In the model in this thesis, the right hand side of this expression is defined as

$$\begin{aligned}
V(p',\phi',\theta',Y) &= \theta'\left\{\log Y-\alpha_H\log P_G/z_{HG}-\alpha_C\log P_G/z_{CG}-\alpha_L\log P_E'/z_{LE}-0.5\beta_{HH}\log^2\left(P_G/z_{HG}\right)-0.5\beta_{CC}\log^2\left(P_G/z_{CG}\right)\right.\\
&\quad -0.5\beta_{LL}\log^2\left(P_E'/z_{LE}\right)-0.5\beta_{HC}\log\left(P_G/z_{HG}\right)\log\left(P_G/z_{CG}\right)-0.5\beta_{HL}\log\left(P_G/z_{HG}\right)\log\left(P_E'/z_{LE}\right)\\
&\quad \left.-0.5\beta_{CL}\log\left(P_G/z_{CG}\right)\log\left(P_E'/z_{LE}\right)\right\}+\phi'\left\{\log Y-\alpha_H\log\left(P_E'/z_{HE}\right)-\alpha_C\log\left(P_E'/z_{CE}\right)-\alpha_E\log\left(P_E'/z_{LE}\right)\right.\\
&\quad -0.5\beta_{HH}\log^2\left(P_E'/z_{HE}\right)-0.5\beta_{CC}\log^2\left(P_E'/z_{CE}\right)-0.5\beta_{LL}\log^2\left(P_E'/z_{LE}\right)-0.5\beta_{HC}\log\left(P_E'/z_{HE}\right)\log\left(P_E'/z_{CE}\right)\\
&\quad \left.-0.5\beta_{HL}\log\left(P_E'/z_{HE}\right)\log\left(P_E'/z_{LE}\right)-0.5\beta_{CL}\log\left(P_E'/z_{CE}\right)\log\left(P_E'/z_{LE}\right)\right\}+(1-\theta'-\phi')\left\{\log Y-\alpha_{HW}\log\left(P_W/z_{HW}\right)\right.\\
&\quad -\alpha_{CW}\log\left(P_W/z_{CW}\right)-\alpha_{LK}\log\left(P_K/z_{LK}\right)-0.5\beta_{HH}\log^2\left(P_W/z_{HW}\right)-0.5\beta_{CC}\log^2\left(P_W/z_{CW}\right)-0.5\beta_{LL}\log^2\left(P_K/z_{LK}\right)\\
&\quad \left.-0.5\beta_{HC}\log\left(P_W/z_{HW}\right)\log\left(P_W/z_{CW}\right)-0.5\beta_{HL}\log\left(P_W/z_{HW}\right)\log\left(P_K/z_{LK}\right)-0.5\beta_{CL}\log\left(P_W/z_{CW}\right)\log\left(P_K/z_{LK}\right)\right\},
\end{aligned}$$

and the left-hand side of the earlier expression is defined as

$$\begin{aligned}
V(p',\phi'',\theta'',Y) &= \theta''\left\{\log Y-\alpha_H\log P_G/z_{HG}-\alpha_C\log P_G/z_{CG}-\alpha_L\log P_E''/z_{LE}-0.5\beta_{HH}\log^2\left(P_G/z_{HG}\right)-0.5\beta_{CC}\log^2\left(P_G/z_{CG}\right)\right.\\
&\quad -0.5\beta_{LL}\log^2\left(P_E''/z_{LE}\right)-0.5\beta_{HC}\log\left(P_G/z_{HG}\right)\log\left(P_G/z_{CG}\right)-0.5\beta_{HL}\log\left(P_G/z_{HG}\right)\log\left(P_E''/z_{LE}\right)\\
&\quad \left.-0.5\beta_{CL}\log\left(P_G/z_{CG}\right)\log\left(P_E''/z_{LE}\right)\right\}+\phi''\left\{\log Y-\alpha_H\log\left(P_E''/z_{HE}\right)-\alpha_C\log\left(P_E''/z_{CE}\right)-\alpha_E\log\left(P_E''/z_{LE}\right)\right.\\
&\quad -0.5\beta_{HH}\log^2\left(P_E''/z_{HE}\right)-0.5\beta_{CC}\log^2\left(P_E''/z_{CE}\right)-0.5\beta_{LL}\log^2\left(P_E''/z_{LE}\right)-0.5\beta_{HC}\log\left(P_E''/z_{HE}\right)\log\left(P_E''/z_{CE}\right)\\
&\quad \left.-0.5\beta_{HL}\log\left(P_E''/z_{HE}\right)\log\left(P_E''/z_{LE}\right)-0.5\beta_{CL}\log\left(P_E''/z_{CE}\right)\log\left(P_E''/z_{LE}\right)\right\}+(1-\theta''-\phi'')\left\{\log Y-\alpha_{HW}\log\left(P_W/z_{HW}\right)\right.\\
&\quad -\alpha_{CW}\log\left(P_W/z_{CW}\right)-\alpha_{LK}\log\left(P_K/z_{LK}\right)-0.5\beta_{HH}\log^2\left(P_W/z_{HW}\right)-0.5\beta_{CC}\log^2\left(P_W/z_{CW}\right)-0.5\beta_{LL}\log^2\left(P_K/z_{LK}\right)\\
&\quad \left.-0.5\beta_{HC}\log\left(P_W/z_{HW}\right)\log\left(P_W/z_{CW}\right)-0.5\beta_{HL}\log\left(P_W/z_{HW}\right)\log\left(P_K/z_{LK}\right)-0.5\beta_{CL}\log\left(P_W/z_{CW}\right)\log\left(P_K/z_{LK}\right)\right\},
\end{aligned}$$

Using the definition of *CV* in terms of the indirect utility function results in the following expression:

$$CV/Y=1-e^{Z1-Z2},$$

where

$$
\begin{aligned}
Z1 = \theta' \{ & -\alpha_H \log P_G / z_{HG} - \alpha_C \log P_G / z_{CG} - \alpha_L \log P_E' / z_{LE} - 0.5\beta_{HH} \log^2 (P_G / z_{HG}) - 0.5\beta_{CC} \log^2 (P_G / z_{CG}) \\
& - 0.5\beta_{CL} \log(P_G / z_{CG}) \log(P_E' / z_{LE}) \} - 0.5\beta_{LL} \log^2 (P_E' / z_{LE}) - 0.5\beta_{HC} \log(P_G / z_{HG}) \log(P_G / z_{CG}) \\
& - 0.5\beta_{HL} \log(P_G / z_{HG}) \log(P_E' / z_{LE}) + \phi' \{ -\alpha_H \log(P_E' / z_{HE}) - \alpha_C \log(P_E' / z_{CE}) - \alpha_E \log(P_E' / z_{LE}) \\
& - 0.5\beta_{HH} \log^2 (P_E' / z_{HE}) - 0.5\beta_{CC} \log^2 (P_E' / z_{CE}) - 0.5\beta_{LL} \log^2 (P_E' / z_{LE}) - 0.5\beta_{HC} \log(P_E' / z_{HE}) \log(P_E' / z_{CE}) \\
& - 0.5\beta_{HL} \log(P_E' / z_{HE}) \log(P_E' / z_{LE}) - 0.5\beta_{CL} \log(P_E' / z_{CE}) \log(P_E' / z_{LE}) \} + (1 - \theta' - \phi') \\
& \{ -\alpha_{HW} \log(P_W / z_{HW}) - \alpha_{CW} \log(P_W / z_{CW}) - \alpha_{LK} \log(P_K / z_{LK}) - 0.5\beta_{HH} \log^2 (P_W / z_{HW}) \\
& - 0.5\beta_{CC} \log^2 (P_W / z_{CW}) - 0.5\beta_{LL} \log^2 (P_K / z_{LK}) - 0.5\beta_{HC} \log(P_W / z_{HW}) \log(P_W / z_{CW}) \\
& - 0.5\beta_{HL} \log(P_W / z_{HW}) \log(P_K / z_{LK}) - 0.5\beta_{CL} \log(P_W / z_{CW}) \log(P_K / z_{LK}) \}.
\end{aligned}
$$

and

$$
\begin{aligned}
Z2 = \theta'' \{ & -\alpha_H \log P_G / z_{HG} - \alpha_C \log P_G / z_{CG} - \alpha_L \log P_E'' / z_{LE} - 0.5\beta_{HH} \log^2 (P_G / z_{HG}) - 0.5\beta_{CC} \log^2 (P_G / z_{CG}) \\
& - 0.5\beta_{LL} \log^2 (P_E'' / z_{LE}) - 0.5\beta_{HC} \log(P_G / z_{HG}) \log(P_G / z_{CG}) - 0.5\beta_{HL} \log(P_G / z_{HG}) \log(P_E'' / z_{LE}) \\
& - 0.5\beta_{CL} \log(P_G / z_{CG}) \log(P_E'' / z_{LE}) \} + \phi'' \{ -\alpha_H \log(P_E'' / z_{HE}) - \alpha_C \log(P_E'' / z_{CE}) - \alpha_E \log(P_E'' / z_{LE}) \\
& - 0.5\beta_{HH} \log^2 (P_E'' / z_{HE}) - 0.5\beta_{CC} \log^2 (P_E'' / z_{CE}) - 0.5\beta_{LL} \log^2 (P_E'' / z_{LE}) - 0.5\beta_{HC} \log(P_E'' / z_{HE}) \log(P_E'' / z_{CE}) \\
& - 0.5\beta_{HL} \log(P_E'' / z_{HE}) \log(P_E'' / z_{LE}) - 0.5\beta_{CL} \log(P_E'' / z_{CE}) \log(P_E'' / z_{LE}) \} + (1 - \theta'' - \phi'') \{ -\alpha_{HW} \log(P_W / z_{HW}) \\
& - \alpha_{CW} \log(P_W / z_{CW}) - \alpha_{LK} \log(P_K / z_{LK}) - 0.5\beta_{HH} \log^2 (P_W / z_{HW}) - 0.5\beta_{CC} \log^2 (P_W / z_{CW}) \\
& - 0.5\beta_{LL} \log^2 (P_K / z_{LK}) - 0.5\beta_{HC} \log(P_W / z_{HW}) \log(P_W / z_{CW}) - 0.5\beta_{HL} \log(P_W / z_{HW}) \log(P_K / z_{LK}) \\
& - 0.5\beta_{CL} \log(P_W / z_{CW}) \log(P_K / z_{LK}) \}.
\end{aligned}
$$

By definition, *CV* is negative for a welfare loss and positive for a welfare gain.

This expression is used in chapter 8 to calculate compensating variation of a price and/or reliability change.

9 Conclusion

This dissertation has developed a new approach to enable policy-makers to analyze welfare gains from improvements in the quality of public water and energy supply in developing countries. With the tight budgetary constraints that usually exist, it is important to be able to prioritize public sector investments on the basis of expected benefits. However, policy analysts are rarely able to measure the benefits of improving the quality of infrastructure services, even though they are a large component of the overall welfare impact. The most frequently cited reason for failures to carry out such welfare analysis is the scarcity of data on service quality.

Major contributions

The main contribution of this dissertation is a new model of welfare evaluation of changes in the quality of infrastructure services for the case of limited data availability. The model can be estimated using existing data from household energy surveys or data from the energy sections of multi-purpose household surveys. It uses a structural approach that fits the common case of intermittent supply in developing countries and accommodates missing data that is commonly generated by intermittent supply. It permits the use of common second-order flexible forms for estimating the demand for the essential household services of utilities. But it also permits the sensible modeling of weak complementarity for specific market goods used to produce household services by explicitly modeling the household technology. This approach makes possible the use of engineering data on household energy conversion coefficients, which enable more precise estimation of the key economic parameters that reflect tastes (note the superior significance of estimated coefficients).

Potential applications of this model range from ex-ante reform evaluation to ex-post monitoring of policy outcomes. Broad applicability and modest data requirements make this approach a useful contribution to policy analysis and to the literature on welfare evaluation of quality changes in infrastructure.

An application of the proposed model in the former Soviet Republic of Azerbaijan demonstrates how this approach can be used in welfare assessment of energy sector reforms. Another novelty of the approach used in this dissertation is the combined use of revealed and stated preference data in order to examine the welfare implications of price and reliability changes that differ drastically from observed historical data. The reforms that have recently been initiated will have far-reaching poverty and distributional consequences for the country because they result in both an improvement in supply reliability and an increase in energy prices. Similar reforms in Armenia and Georgia, the other two countries in the Caucasus region, have largely failed and resulted in social unrest when electricity prices hikes were not matched by an improvement in the quality of electricity supply. This underscores the importance of including welfare evaluation of quality changes in the overall assessment of reforms before their implementation.

Estimation results in this dissertation strongly indicate that households in the areas with poor supply quality have a high willingness to pay for reliability improvements. However, low income households with little access to substitute energy sources stand to incur substantial welfare losses from an electricity price increase, and poverty in the country may rise. A reform scenario with a modest 50 percent price increase would result in average welfare losses of less than one percent of total household expenditures. However, they would be higher for further price increases as shown by the scenario of a partial reliability improvement and the doubling of electricity prices.

In reality the reforms are likely to result in a substantially higher price increase over time to reach the cost recovery level, so that the estimate of the losses in this thesis is a conservative estimate. The best way to mitigate the adverse effect of the price increase will be to improve reliability. Although this is an obvious fact, policy makers have not set clear reform targets for improving service quality. For political reasons, the political establishment is still hesitant to admit to what extent supply interruptions are a problem in many parts of Azerbaijan and to set quality targets. As shown in this dissertation, the welfare gains to households from a reliability improvement would be in the range of 1.5 to 2 percent of total household expenditures.

Qualifications and further research

The estimated welfare effects in this dissertation are likely conservative estimates of the gains for many reasons. The estimates exclude the secondary benefits that households would experience from a more favorable business environment, improved reliability of water supply where pumped irrigation is used, better health services, education and the positive environmental externalities. To some extent the losses will be mitigated by income growth in the economy if the quality of electricity supply improves and the gains are higher than estimated in this dissertation. Such gains may result from the general equilibrium effects that were not included in the overall welfare measure in this approach. For example, a series of recent case studies reveal that the gains from improving supply reliability for energy services are likely to significantly outweigh the losses from a price increase in the agricultural sector in Azerbaijan (World Bank 2004). In addition, households will experience gains from improvements in the quality of health services and education. Gains of this type were shown to be very high for electrification projects in other parts of the world (World Bank 2002).

Further, environmental benefits will result from a decreasing pressure on forest resources and an improvement in indoor and outdoor air pollution in the areas that heavily rely on fuel wood and kerosene. As discussed in chapter 4, households in Azerbaijan do not appear to be aware of the extent to which fuel wood consumption increases the risk of respiratory illness in children. Thus, improved health outcomes would be an additional positive externality of a more reliable electricity or gas supply. Since all of these components were omitted in the calculation of the welfare gains from a reliability improvement, the estimate of the welfare gains should be interpreted as a conservative estimate of the overall gains of a reform program that would result from establishing a reliable electricity supply.

Survey evidence also shows that, although households may incur sizable welfare losses from indoor air pollution when they rely on traditional fuels, they do not recognize indoor air pollution as a strong factor contributing to the high incidence of respiratory illness among fuel wood users. Therefore, policy interventions that improve the reliability of modern energy sources should be combined with an information campaign about the health effects of fuel wood use if they are to result in significant benefits in this country.

Two further aspects of the modeling approach in this dissertation should be pointed out in conclusion. First, the appliance base was assumed to be fixed, so the analysis is short-run analysis. Any scenario that substantially increases the electricity price is likely to induce a change in appliances over time. In turn, that could lead to increased use of more efficient appliances that will reduce the welfare effects of the higher prices. Furthermore, increasing reliability of electricity is also likely to induce switching to more efficient appliances and eliminate the need to have backup appliances. Any complete, longer-run analysis of reforms must consider these factors, but such analysis will require further surveys designed to generate data on appliance purchases.

Second, there is a tradeoff between flexibility versus specificity in modeling the household technology and the ability to identify the economic behavioral parameters. The modeling approach adopted in this dissertation imposes a very specific structure on the household technology. The rigid modeling structure allows proceeding with model estimation even in the presence of missing data on prices and consumption levels of some fuels. While this approach enables identification of the parameters that are important for policy analysis, it limits the applicability of the model to situations where the model's assumptions are inappropriate. For example, this model could not be used if there were no clear hierarchy of fuel choice dictated by fuel prices and availability as in Azerbaijan, or in a situation where appliances are expensive and the need to purchase new appliances represents a significant burden to fuel switching. Future modeling efforts of the intermittent supply problem would need to take into account household adjustment of the stock of appliances and collect comprehensive data to permit welfare evaluation in these situations.

Finally, the policy conclusions based on the empirical findings in this dissertation need to be interpreted with some caution as the reliability of the poverty measure have been limited by data availability. The information on total household expenditures, which has been used in the model estimation and to define the poor and nonpoor households whenever the 2003 HES data were used, were not available in the survey and had to be imputed. Thus, for one-quarter of the sample, information on total expenditures was available from an earlier 2002 HBS survey, and for three-quarters of the households no information was available. The imputation procedure required to predict this variable for households with missing information necessarily makes the prediction less accurate for the poor than for all other welfare categories. Although we observe very significant differences in total expenditures of the reform's losers and winners, the conclusions could be either less or more definitive if some of the households classified as non-poor were actually poor. The fact that overall there are very few losers from a reform that ensures a reliability improvement reinforces the key conclusion of the policy analysis in this dissertation: there is a high willingness to pay for quality improvements in Azerbaijan, and as long as the reforms result in a substantial reliability improvement even combined with a price increase of the magnitude considered, households will experience welfare gains.

References

Abdalla, Charles, Brian Roach, and Donald Epp (1989). "Valuing Environmental Quality Changes Using Averting Expenditures: an Application to Groundwater Contamination." *Land Economics* 68, no.2: 163-69.

Agrawal, Nisha and Alan Powell (1992). "MAIDS Under Additive Preferences: Some Early Estimates." In: Bewley, Ronald and Tran Van Hoa, eds. *Contributions to Consumer Demand and Econometrics.* New York: St. Martin's Press.

Ahmed, Kulsum, Yewande Awe, Douglas Barnes, Maureen Cropper, and Masami Kojima (2005). *Environmental Health and Traditional Fuel Use in Guatemala.* Washington, D.C.: The World Bank.

Alam, A., M. Murthi, R. Yemtsov, E. Murrugarra, N. Dudwick, E. Hamilton, and E. Tiogson (2005). *Growth, Poverty, and Inequality: Eastern Europe and the Former Soviet Union.* Washington, D.C., World Bank.

An, Li, Frank Lupi, Jianguo Liu, Marc Linderman, and Jinyan Huang (2002). "Modeling the Choice to Switch from Fuel wood to Electricity: Implications for Giant Panda Habitat Conservation." *Ecological Economics* 42, no. 3: 445-57.

Azevedo, Christopher, Joseph Herriges and Catherine Kling (2003). "Combining Revealed and Stated Preferences: Consistency Tests and Their Interpretations." *American Journal of Agricultural Economics* 85, no. 3: 325-37.

Banks, James, Richard Blundell and Arthur Lewbel (1997). "Quadratic Engel Curves and Consumer Demand." *The Review of Economics and Statistics* 79, no. 4: 527-539.

Barnes, Douglas, Kerry Krutilla and William Hyde (2005). *The Urban Household Energy Transition.* Washington, D.C: Resources for the Future.

Barreix, Alberto, Glenn Jenkins, and Mario Marchesini (2003). "Restructuring the Water and Sewer Utility in Panama." Department of Economics. Queen's University. Canada: Kingston. Mimeographed.

Bartik, Timothy (1988). "Evaluating the Benefits of Non-marginal Reductions in Pollution Using Information on Defensive Expenditures." *Journal of Environmental Economics and Management* 15, no. 1: 111-27.

Becker, Gary (1965). "A Theory of the Allocation of Time." *Economic Journal* 75, no. 299: 493-517.

Bergstrom, John, Kevin Boyle, and Gregory Poe, eds. (2001). *The Economic Value of Water Quality.* New Horizons in Environmental Economics Series. Cheltenham, UK, and Northampton, MA: Edward Elgar Publishing.

Bernard, Jean-Thomas, Denis Bolduc, and Donald Bélanger (1996). "Quebec Residential Electricity Demand: A Microeconometric Approach." *Canadian Journal of Economics* 29, no 1: 92-113.

Blundell, Richard, Martin Browning and Costas Meghir (1994). "Consumer Demand and the Life-Cycle Allocation of Household Expenditures." *Review of Economic Studies.* Vol. 61. pp. 57-80.

Bockstael, Nancy and Kenneth McConnell (1993). "Public Goods as Characteristics of Non-Market Commodities." *The Economic Journal* 103, no. 420: 1244-57.

Bockstael, Nancy and Kenneth McConnell (1999). "The Behavioral Basis of Non-Market Valuation." In: Herriges and Kling, eds. *Valuing Recreation and the Environment: Revealed Preference Methods in Theory and Practice*. New

Horizons in Environmental Economics. Cheltenham, UK and Northampton, MA: Edward Elgar Publishing.

Briscoe, John, Paul Furtado de Castro, Charles Griffin, James North, and Orjan Olsen (1990). “Toward Equitable and Sustainable Rural Water Supplies: A Contingent Valuation Study in Brazil.” *The World Bank Economic Review* 4, no. 2: 115-34.

Cai, Yongxin, Iraj Deilami, and Kenneth Train (1998). "Customer Retention in a Competitive Power Market: Analysis of a 'Double-Bounded Plus Follow-ups' Questionnaire." *The Energy Journal* 19, no. 2: 191-215.

Carpentier, Alain and Dominique Vermersch (1997). “Measuring Willingness to Pay for Drinking Water Quality Using the Econometrics of Equivalence Scales.” Fondazione Eni Enrico Mattei Working Paper, no. 92/97. Venice.

Carson, Richard, Nicholas Flores, and Norman Meade (2001). “Contingent Valuation: Controversies and Evidence.” *Environmental and Resource Economics* 19, no. 2: 173-210.

Carson, Richard, Theodore Groves, and Mark Machina (2000). “Incentive and Informational Properties of Preference Questions.” Department of Economics. University of California, San Diego.

Caves, Douglas, Joseph Herriges, and Robert Windle (1990). “Customer Demand for Service Reliability in the Electric Power Industry: A Synthesis of the Outage Cost Literature.” *Bulletin of Economic Research* 42, no. 2: 79-119.

Chaudhuri, S. and Alexander Pfaff (2003) "Fuel Choice and Indoor Air Quality: a household-level perspective on economic growth and the environment". Columbia University Working Paper.

Cheng, Hsiang-tai. and Oral Capps, Jr. (1988). “Demand Analysis of Fresh and Frozen Finfish and Shellfish in the United States.” *American Journal of Agricultural Economics* 70: 533-42.

Chern, W.S., R.E. Just, and H.S. Chang (1983). “A Varying Elasticity Model of Residential Electricity Demand with Given Appliance Saturation,” *Proceedings of the American Statistical Association*, Business and Economics Section.

Choynowski, Peter (2002). “Measuring Willingness to Pay for Electricity.” Asian Development Bank Economics and Research Department Technical Note Series, no. 3. Manila.

Christensen, Laurits, Dale Jorgenson and Lawrence Lau (1975). “Transcendental Logarithmic Utility Functions.” *American Economic Review* 65, no. 3: 367-83.

Collins, Alan and Scott Steinback (1993). “Rural Household Response to Water Contamination in West Virginia.” *Water Resources Bulletin* 29, no. 2: 199-209.

Dahl, Carol (1992). “A Survey of Energy Demand Elasticities for the Developing World.” *Journal of Energy and Development* 18, no. 1: 1-47.

Deaton, Angus (1981). “Theoretical and Empirical Approaches to Consumer Demand under Rationing.” In: *Essays in the Theory and Measurement of Consumer Behavior.* Cambridge University Press. Cambridge, U.K.

Deaton, Angus (1997). *The Analysis of Household Surveys. A Microeconometric Approach to Development Policy.* The Johns Hopkins University Press. Baltimore and London.

Deaton, Angus and John Muellbauer (1980). “An Almost Ideal Demand System.” *The American Economic Review* 70, no. 3: 312-26.

Deaton, Angus and Margaret Grosh (1999). “Chapter 17: Consumption,” in Margaret Grosh and Paul Glewwe, eds., *Designing Household Survey Questionnaires for Developing Countries: Lessons from Ten Years of LSMS Experience.* Washington, D.C.: The World Bank.

Devicienti, Francesco, Irina Klytchnikova, and Stefano Paternostro (2005). “Willingness to Pay for Water and Energy. An Introductory Guide to Contingent Valuation and Coping Cost Techniques.” Energy and Mining Sector Board Working Notes, no. 3. Washington, D.C.: The World Bank.

Diamond, Peter and Jery Hausman (1994). “Contingent Valuation: Is Some Number Better Than No Number.” *Journal of Economic Perspectives* 8, no. 4: 45-64.

Dias-Bandaranaike, Romesh and Mohan Munasinghe (1983). “The Demand for Electricity Services and the Quality of Supply.” *The Energy Journal* 4, no. 2: 49-71.

Dodonov, Boris, Petra Opitz, and Wolfgang Pfaffenberger (2004). “How Much Do Electricity Tariff Increases in Ukraine Hurt the Poor?” *Energy Policy* 32: 855-863.

Dubin, J. and Daniel McFadden (1984). “An Econometric Analysis of Residential Electric Appliance Holdings and Consumption.” *Econometrica* 52: 118-131.

Edgerton, David, Bengt Assarsson, Anders Hummelmose, Ilkka Laurila, Kyrre Rickertsen and Per Halvor Vale (1997). *The Econometrics of Demand Systems. With Applications to Food Demand in the Nordic Countries*. Kulwer Academic Publishers.

Environmental Resources Management (2002). “Preliminary Document – Environmental Resources Management.” TACIS/World Bank Joint Report.

Foster, Vivien and Jean-Philippe Tré (2003). “Measuring the Impact of Energy Interventions on the Poor – an Illustration from Guatemala.” In: Brook, Penelope and Timothy Irwin, eds. *Infrastructure for Poor People. Public Policy for Private Provision.* World Bank, Washington, D.C.

Foster, William and Richard Just (1989). “Measuring Welfare Effects of Product Contamination with Consumer Uncertainty.” *Journal of Enivronmental Economics and Management* 17, no. 3: 266-83.

Freeman, Myrick III (2003). *The Measurement of Environmental and Resource Values. Theory and Methods.* Washington, D.C: Resources for the Future.

Freund, Caroline and Christine Wallich (1996). “The Welfare Effect of Raising Household Energy Prices in Poland.” *Energy Journal* 17, no. 1: 53-78.

Goett, Andrew, Kathleen Hudson, and Kenneth Train (2000). “Customers’ Choice Among Retail Energy Suppliers: the Willingness-to-Pay for Service Attributes.” *The Energy Journal* 21, no. 4: 1-28.

Gould, William, Jeffrey Pitblado and William Sribney (2003). *Maximum Likelihood Estimation with Stata*. Stata Corporation. College Station, Texas.

Gorman, William (1980). “A Possible Procedure for Analyzing Quality Differentials in the Egg Market.” *Review of Economic Studies* 47, no. 5: 843-856.

Greene, William (2000). *Econometric Analysis.* New Jersey: Prentice Hall, Inc.

Griffin, Charles, John Briscoe, Bhanwar Singh, Radhika Ramasubban, and Ramesh Bhatia (1995). “Contingent Valuation and Actual Behavior: Predicting

Connections to New Water Systems in the State of Kerala, India." *The World Bank Economic Review* 9, no. 3: 373-95.

Grosh, Margaret and Paul Glewwe (1998). "The World Bank's Living Standards Measurement Study Household Surveys." *Journal of Economic Perspectives* 12, no. 1: 187-96.

Haab, Timothy and Kenneth McConnell (2002). *Valuing Environmental and Natural Resources. The Econometrics of Non-Market Valuation.* New Horizons in Environmental Economic Series. Cheltenham, UK and Northampton, MA: Edward Elgar Publishing.

Halvorsen, Bente and Bodil Larsen (2001). "The Flexibility of Household Electricity Demand Over Time." *Resource and Energy Economics* 23, no. 1: 1-18.

Hanemann, Michael (1984). "Discrete/Continuous Models of Consumer Demand." *Econometrica* 52, no. 3: 541-562.

Harrington, Winston, Alan Krupnick, and Walter Spofford, Jr. (1989). "The Economic Losses of a Waterborne Disease Outbreak." *Journal of Urban Economics* 25, no. 1: 116-37.

Heckman, James (1979). "Sample Selection Bias as a Specification Error." *Econometrica* 47, no.1: 153-61.

Heltberg, Rasmus (2005). "Factors Determining Household Fuel Choice in Guatemala." *Environment and Development Economics* 10, no. 3: 337-61.

Heltberg, Rasmus, Thomas Channing Arndt, and Nagothu Udaya Sekhar (2000). "Fuel wood Consumption and Forest Degradation: A Household Model for Domestic Energy Substitution in Rural India." *Land Economics* 76, no. 2: 213-32.

Hensher, David, Nina Shore, and Kenneth Train (2004). "Households' Willingness to Pay for Water Service Attributes." University of Sydney, National Economic Research Associates, and University of California, Berkeley. Mimeographed.

Hentschel, Jesko and Peter Lanjouw (2000). "Household Welfare Measurement and the Pricing of Basic Services." *Journal of International Development* 12, no. 1: 13-27.

Humplick, Frannie, Ayse Kudat, and Samer Madanat (1993). "Modeling Household Responses to Water Supply: A Service Quality Approach." Transport, Water, and Urban Development Department Working Paper, no. 4. Washington, D.C.: The World Bank.

Israel, Debra (2002). "Fuel Choice in Developing Countries: Evidence from Bolivia." *Economic Development and Cultural Change* 50, no. 4: 865-90.

Jorgenson, Dale, Lawrence Lau and Thomas Stoker (1982). "The Transcendental Logarithmic Model of Aggregate Consumer Behavior." In R. Basman and G. Rhodes, eds. *Advances in Econometrics.* Greenwich: JAI Press.

Just, Richard, Darrel Hueth, and Andrew Schmitz (2004). *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation.* Northampton, MA: Edward Elgar Publishing.

Kaiser, Mark (2000). "Pareto-Optimal Electricity Tariff Rates in the Republic of Armenia." *Energy Economics* 22, no. 4: 463-95.

Kling, Catherine (1989). "The Importance of Functional Form in the Estimation of Welfare." *Western Journal of Agricultural Economics* 41, no. 1: 168-174.

Komives, Kristine, Vivien Foster, Jonathan Halpern, and Quentin Wodon (2005). *Water, Electricity, and the Poor. Who Benefits from Utility Subsidies?* Washington, D.C.: World Bank.

Lampietti, Julian, ed. (2004). "Power's Promise. Electricity Reforms in Eastern Europe and Central Asia." World Bank Staff Working Paper, no. 40. Washington D.C.: The World Bank.

Lampietti, Julian, Irina Klytchnikova, and Xun Wu (2003). 2003 Azerbaijan Household Energy Survey. Survey Instrument. Washington D.C.: The World Bank.

Lancaster, Kelvin (1966). "A New Approach to Consumer Theory." *Journal of Political Economy* 74, no. 2: 132-57.

Larson, Bruce and Ekaterina Gnedenko (1990). "Avoiding Health Risks from Drinking Water in Moscow: An Empirical Analysis." *Environment and Development Economics* 4, no. 4: 565-81.

Lazaridis, Panagiotis (2004). "Demand Elasticities Derived from Consistent Estimation of Heckman-Type Models." *Applied Economic Letters* 11, no. 8: 523-27.

Lewbel, Arthur (1989). "Nesting the Aids and Translog Demand Systems." *International Economic Review* 30, no. 2: 349-56.

Louviere, Jordan, David Henscher, and Joffre Swait (2000). *Stated Choice Methods: Analysis and Applications.* New York: Cambridge University Press.

Mäler, Karl-Göran (1974). *Environmental Economics: A Theoretical Inquiry.* Baltimore, MD: The Johns Hopkins University Press for Resources for the Future.

McConnell, Kenneth and Marcia Rosado (2000). "Valuing Discrete Improvements in Drinking Water Quality Through Revealed Preferences." *Water Resources Research* 36, no. 7: 1575-82.

McConnell, Kenneth and Nancy Bockstael (forthcoming). "Valuing the Environment as an Input in Production." *Handbook in Environmental Economics.* Karl-Goran Maler and Jeffrey Vincent, eds. Springer Verlag.

McFadden, Daniel (1974). "Conditional Logit Analysis of Qualitative Choice Behavior," in *Frontiers of Econometrics*. P. Zarembka, ed. New York: Academic Press.

McKenzie, David and Dilip Mookherjee (2003). "The Distributive Impact of Privatization in Latin America: Evidence from Four Countries." *Economia* 3, no.2: 161-218.

Muellbauer, John (1976). "Community Preferences and the Representative Consumer." *Econometrica* 44, no. 5: 525-43.

Munasinghe, Mohan (1978). "The Leisure Cost of Electric Power Failures." World Bank Staff Working Paper, no. 285. Washington D.C.: The World Bank.

Nayga, Rodolfo M. (1998). "A Sample Selection Model for Prepared Food Expenditures." *Applied Economics* 78: 290-300.

Nestor, Deborah (1998). "Policy Evaluation with Combined Actual and Contingent Response Data." *American Journal of Agricultural Economics* 80, no. 2: 264-76.

O'Sullivan, Kyran and Douglas Barnes (2006). "Energy Modules for Multi-topic Household Surveys: Guidelines for LSMS Survey Designers." Energy and Mining Sector Board Discussion Paper. Washington D.C.: The World Bank.

Palmquist, Raymond (2005). "Weak Complementarity, Path Independence, and the Intuition of the Willig Condition." *Journal of Environmental Economics and Management* 49, no. 1: 103-15.

Parti, Michael and Cynthia Parti (1980). "The Total and Appliance-Specific Conditional Demand for Electricity in the Household Sector." *The Bell Journal of Economics* 11, no. 1: 309-321.

Pattanayak, Subhrendu, Caroline van den Berg, Jui-Chen Yang, and George Van Houtven (2005). "Use and Abuse of WTP Experiments: Estimating Demand for Piped Water Connections." RTI International and the World Bank.

Pollak, Robert and Terence Wales (1992). *Demand System Specification and Estimation.* Oxford University Press.

Poyer, David, Lenneal Henderson, and Arvind Teotia (1997). "Residential Energy Consumption Across Different Population Groups: Comparative Analysis for Latino and Non-Latino Households in USA." *Energy Economics* 19: 445-463.

Pudney, Stephen (1989). *Modeling Individual Choice. The Econometrics of Corners, Kinks and Holes.* Oxford. Basil Blackwell.

Reiss, Peter and Matthew White (2005). "Household Electricity Demand, Revisited." *Review of Economic Studies* 72, no. 3: 853-83.

Ribaudo, Marc and Daniel Hellerstein (1992). "Estimating Water Quality Benefits: Theoretical and Methodological Issues." USDA Economic Research Service Bulletin, no. 1808.

Sanghvi, Arun (1982). "Economic Costs of Electricity Supply Interruptions. US and Foreign Experience." *Energy Economics* 4, no. 2: 180-98.

---------. (1983). "Optimal Electricity Supply Reliability Using Customer Shortage Costs." *Energy Economics* 5, no. 2: 129-36.

Scott, Kinnon (2003). "Generating Relevant Household-Level Data: Multitopic Household Surveys." In: eds. Bourguignon, François and Luiz Pereira da Silva. *The Impact of Economic Policies on Poverty and Income Distribution. Evaluation Techniques and Tools.* The World Bank and Oxford University Press: Washington, D.C.

Selvanathan, E. Anthony and Kenneth Clements (1995). *Recent Developments in Applied Demand Analysis. Alcohol, Advertising and Global Consumption.* Springer Verlag.

Silva, Patricia, Irina Klytchnikova and Dragana Radevic (2006). "Poverty and Environmental Consequences of Electricity Pricing Reforms in Montenegro." Environment Department Working Paper. Washington, D.C.: The World Bank.

Tauchmann, Harald (2005). "Efficiency of Two-Step Estimators for Censored Systems of Equations: Shonkwiler and Yen Reconsider." *Applied Economics* 37, no. 4: 367-374.

Train, Kenneth (2003). *Discrete Choice Methods with Simulation.* New York: Cambridge University Press.

Um, Mi-Jung, Seung-Jun Kwak, and Tai-Yoo Kim (2002). "Estimating Willingness to Pay for Improved Drinking Water Quality Using Averting Behavior Method with Perception Measure." *Environmental and Resource Economics* 21, no. 3: 287-302.

Vartia, Yrjo (1983). "Efficient Methods of Measuring Welfare Change and Compensated Income in Terms of Ordinary Demand Functions." *Econometrica* 51, no. 1: 79-98.

Walker, Ian, Serrano Ordoñez, Pedro and Jonathan Halpern (2000).“Pricing, Subsidies and the Poor. Demand for Improved Water Services in Central America.” Policy Research Working Paper, no. 2468. Washington D.C.: The World Bank.

Westley, Glenn (1984). “Electricity Demand in a Developing Country.” *The Review of Economics and Statistics* 66, no. 3: 459-67.

Whittington, Dale, John Briscoe, Xinming Mu, and William Barron (1990). “Estimating Willingness to Pay for Water Services in Developing Countries: A Case Study of the Use of Contingent Valuation Surveys in Southern Haiti.” *Economic Development and Cultural Change* 38, no. 2: 293-311.

Willig, Robert (1976). “Consumer Surplus Without Apology.” *American Economic Review* 66, no.4: 589-97.

World Bank (2005). *Project Appraisal Document on a Proposed Loan to Azerenerji for a Power Transmission Project.* Europe and Central Asia Power Sector Department Report, no. 31485-AZ.

---------. (2004). *Azerbaijan. Raising Rates: Short-Term Implications of Residential Electricity Tariff Rebalancing.* Europe and Central Asia Environmentally and Socially Sustainable Development Department Report, no. 30749-AZ.

---------. (2002). *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits.* Energy Sector Management Assistance Program Report, no. 255/02.

Wu, Xun, Julian Lampietti, and Anke Meyer (2004). “Coping with the Cold: Space Heating and the Urban Poor in Developing Countries.” *Energy Economics* 26: 345-357.

Yang, Jui-Chen, Subhrendu Pattanayak, Reed Johnson, Carol Mansfield, Caroline van den Berg, and Kelly Jones (2005). “Un-packaging Demand for Water Service Quality: Evidence from Conjoint Choice Surveys in Sri Lanka.” RTI International and the World Bank.