The Role of Liquefied Petroleum Gas in Reducing Energy Poverty

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Contents

Figures

Tables

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Turkey
- AYGAZ
- Energy Market Regulatory Authority (EPDK)
- IPRAGAZ
- Milangaz
- Tüpras (Turkish Petroleum Refineries Corporation)
- Turkish LPG Association

Abbreviations

ANP	*Agência Nacional do Petróleo, Gás Natural e Biocombustíveis* (National Agency for Oil, Natural Gas, and Biofuels), Brazil
ANRE	*Agenției Naționale pentru Reglementare în Energetică* (National Energy Regulatory Agency), Moldova
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
Btu	British thermal units
EPDK	*Enerji Piyasası Düzenleme Kurumu* (Energy Market Regulatory Authority), Turkey
EPPO	Energy Policy and Planning Office, Thailand
ERC	Energy Regulatory Commission, Kenya
FOB	free on board
GDP	gross domestic product
IEA	International Energy Agency
ISO	International Organization for Standardization
kg	kilogram(s)
LPG	liquefied petroleum gas
LPGSASA	Liquefied Petroleum Gas Safety Association of Southern Africa
NERSA	National Energy Regulator of South Africa
NFPA	U.S. National Fire Protection Association
NPA	National Petroleum Authority, Ghana
OGRA	Oil and Gas Regulatory Authority, Pakistan
OSINERGMIN	*Organismo Supervisor de la Inversión en Energía y Minería* (Supervisory Agency for Energy and Mining Investment), Peru
PPP	purchasing power parity
UPPF	Uniform Price Petroleum Fund, Ghana

Abstract

Increasing household use of liquefied petroleum gas (LPG) is one of several pathways toward the UN goal of universal access to clean cooking and heating solutions by 2030. This study analyzed national household expenditure surveys in 10 developing countries to assess the factors influencing LPG selection and consumption. It also examined LPG markets in 20 developing countries by collecting information on the regulatory framework, pricing and other policies, the state of supply infrastructure, cylinder management, the amount of information available to the public, and activities designed to promote household use of LPG.

Analysis of national household surveys showed that LPG was used predominantly by the upper half of the income groups in low- and lower-middle-income countries. As expected, household income and fuel prices were the two principal determinants of a household's decision to use LPG and how much to consume. Response to relative prices indicated that prices of firewood would have to rise steeply before a household would consider substituting it with LPG. Consistent with these findings, a survey of data on household fuel use for cooking from 63 developing countries showed that LPG use increased with wealth quintile in 51 countries. Rising LPG use with income would mean that a universal price subsidy for LPG would generally be regressive, and highly so in low- and lower-middle-income countries. This study found that, at today's world LPG prices, regular users of LPG would likely need monthly household income in excess of US$350, but also that many households capable of paying for LPG continued to use solid biomass as the primary cooking fuel, indicating that many more households could potentially switch to LPG without financial assistance under suitable market conditions.

Interestingly, everything else being equal, the higher the education levels attained by household members, the more likely the household was to select LPG. This effect was larger for women than men. Once education levels of women and men were separately accounted for, a household headed by a woman was no more likely to favor LPG selection and consumption than a male-headed household. This suggests that educating the public, especially women, about the costs and benefits of fuel choice could promote a switch to cleaner fuels. Such awareness-raising and public education, however, is lacking in many developing countries, and both governments and LPG marketing companies can do much more on this score using the internet, newspapers, TV, and other media, as well as face-to-face demonstrations by retailers.

Assessment of LPG markets in 20 developing countries showed a wide range of costs of supply, suggesting scope for cost reduction in some markets; weak regulatory framework for safety in most countries and inadequate information provided by LPG marketers and governments to the public on safety issues; weak enforcement of regulations in many countries; and unsustainable subsidy policies in several countries. Where an automotive LPG market exists, any subsidy for LPG is increasingly captured by vehicle owners, making the subsidy even more regressive. The unsustainability of price subsidies for petroleum products (affecting refinery operations) and

for LPG in particular (affecting LPG imports and marketing) was also an important cause of LPG shortages. Taken together, these observations suggest that, on balance, serious consideration should be given to reducing and eventually eliminating price subsidies for LPG.

There are large economies of scale in LPG handling, starting with marine transport and import facilities and down to cylinder management. Although costs are much higher on a unit basis, small cylinders—3 to 6 kilograms (kg) in size—are easier to carry around and cheaper per refill. The study found, however, that small LPG cylinders were common only in two countries with very large LPG price subsidies. Absent large subsidies, market forces have favored cylinders in the range 10–15 kg as a compromise between refill costs and scale economy.

High costs are by far the most important reason households do not switch to LPG. There are ways to lower costs of supply. Hospitality arrangements and third-party access to import terminals and storage tanks—as in Pakistan, Peru, and Turkey—minimize duplication of infrastructure, improve efficiency, and lower barriers to entry. Importing large parcels lowers unit costs, but port infrastructure and storage facilities need to match import parcel sizes.

For households, short-selling, fires and other accidents, and fuel shortages are arguably three other main deterrents to LPG use. Short-selling of LPG is difficult to detect at the point of purchase and requires effective monitoring and enforcement to minimize it. There are several facets to tackling unsafe practices: clear definition of cylinder ownership; assignment of legal responsibility for cylinder maintenance, repair, and replacement; effective enforcement of the ban on cross-filling where such a ban exists; proper training of operators throughout the supply chain; establishing a registry of certified installers and inspectors; extensive education campaigns for end-users; and penalizing companies that refill unsafe cylinders. It would be helpful if training of operators and education of consumers is specifically required in the regulatory framework, as in South Africa and Turkey. Monitoring (by government as well as private certified inspectors) and enforcement may be made self-financing through fees charged to marketing companies, as in Pakistan and Turkey. Ensuring reasonable cost recovery by efficient operators (for example, by removing price subsidies), creating an environment where financially sound companies have incentives to build more storage capacity, and requiring minimum stockholding are among the options for minimizing fuel shortages.

Government can contribute to the access agenda by modernizing the regulatory framework, which may include formal adoption of international standards; ensuring effective enforcement, which also helps promote fair competition; recognizing the limitations of price subsidies; improving roads and port infrastructure and reducing port congestion, which incurs high demurrage charges for LPG imports; and, above all, communicating information widely to the public in nontechnical language. Industry associations can help with operator training and self-monitoring to discourage commercial malpractice as well as public-awareness raising. LPG marketers, micro-finance schemes, and others can lower the barrier to LPG selection by making it easier to finance the cylinder deposit fee and stove purchase.

Executive Summary

The UN "Sustainable Energy for All" initiative, launched in 2011, sets as one of its three objectives universal access to modern energy services—electricity and clean cooking and heating systems—by 2030. About 3 billion people still rely on solid biomass or coal for cooking and heating, and smoke from such fuel use is estimated to cause four deaths every minute. Universal access will require a multi-prong approach: advanced cookstoves for biomass and other solid fuels, natural gas for urban households in countries that have or are developing an extensive gas pipeline network, biogas, and liquefied petroleum gas (LPG). The International Energy Agency estimates that more than 40 percent of those newly gaining access to modern household energy by 2030 in the universal access scenario will do so by switching to LPG. LPG is a transition fuel in some circumstances: households will switch to natural gas as soon as it is made available, primarily in urban areas, and others will switch to electricity for cooking, heating, or both, as electricity supply becomes reliable. But for many who choose to cook or heat with gas and do not have access to natural gas, LPG will be the fuel of choice.

This study examined factors affecting household use of LPG, the state of LPG markets in developing countries, and measures to enable more households to shift away from solid fuels to LPG. Household use of LPG was examined through a survey of household energy data for cooking in 110 developing countries as well as econometric analysis of recent national household surveys in 10 developing countries. In addition, LPG markets in 20 developing countries were analyzed by assessing the industry and market structures and practices, supply arrangements and infrastructure, the legal framework, and pricing policies.

Data from the middle of the last decade collected in 110 countries show that more than half of all households named LPG as the primary cooking fuel in 30 percent of the countries, most of which were upper-middle income. Predictably, the share of households using LPG was higher in urban than in rural areas, except in seven countries where urban households had access to natural gas. In 51 out of 63 countries where information by wealth quintile was available, the share of households using LPG rose with quintile.

World LPG prices have more than doubled in real terms in the last decade, increasing at an annual average rate of 9 percent since 2001. This rate of increase is much higher than that for household income in most developing countries. Prices are now sharply higher than when the above data were collected. Even in an efficient market with light tax on LPG, cooking and heating water with LPG would require upwards of US$15 every month at today's LPG prices. As such, LPG is unlikely to be the fuel of the poor.

Among the three billion who continue to rely on traditional solid fuels, however, there are many who are financially capable of paying US$15–20 a month to purchase LPG. Many factors in addition to income determine LPG use: availability of LPG, reliability of LPG supply, prices of other fuels, the acquisition cost of the LPG cylinder and stove, fears about safety, unfamiliarity

with cooking with LPG, lack of knowledge about the harm caused by smoke from solid fuels, and cultural preferences. Therefore, recent increases in world LPG prices notwithstanding, rising household income accompanying economic development and growing migration from rural to urban areas in developing countries provide ample opportunities for expanding use of LPG as a household fuel.

This study examined surveys in Guatemala, India, Indonesia, Kenya, Pakistan, and Sri Lanka to gain a better understanding of what factors influence households' decision to use LPG (selection) and, for the households that have decided to use it, how much to use (consumption). A two-stage Heckman-type model was set up for this purpose. As expected, income and relative fuel prices were the two most important determinants of fuel use patterns. In all six countries, LPG *selection* increased with household expenditure and the highest levels of education attained by female and male household members, and LPG *consumption* (quantity per household) increased with household expenditure and decreasing price of LPG. Variables serving as proxies for the level of infrastructure development (electricity connection, urban rather than rural residence) increased selection and consumption, while engagement in agriculture (broadly associated with biomass availability) reduced them. Rising prices of firewood and kerosene, which compete with LPG, increased LPG selection. However, cross-price elasticities of firewood in the consumption equation were about an order of magnitude smaller, requiring a very large increase in the price of firewood before a household would consider consuming more LPG in response.

The higher the education level attained by female and male members of a household, the more likely the household was to select LPG, and this effect was larger for women than for men. Education in this context is likely to be a proxy for the level of awareness about the benefits and costs of LPG. It is often speculated that female-headed households are more inclined to choose clean and convenient fuels because women are directly affected by fuel choice. Once education levels of women and men were separately accounted for, however, this study found no evidence that female-headed households were more likely to choose LPG, and, if anything, they were less likely. The latter unexpected finding may simply reflect unmeasured economic disadvantages faced by female-headed households that make less cash available for LPG purchase.

Albania, Brazil, Mexico, and Peru—where household use of LPG was more widespread but for which only national average prices (and not prices paid by individual households) were available—were similarly modeled. Although price effects could not be examined, other findings broadly supported those from the first six countries.

In the six low- and lower-middle-income countries among the 10, LPG was used primarily by those in the upper half of expenditure groups. Analysis of benefit incidence and benefit

targeting of hypothetical universal price subsidies across all 10 countries showed that such subsidies would be regressive to highly regressive.

The present study also assessed LPG markets in Afghanistan, Albania, Brazil, the Dominican Republic, Fiji, Ghana, Guatemala, Jordan, Kenya, Mexico, Moldova, Morocco, Pakistan, Peru, Senegal, South Africa, Sri Lanka, Thailand, Turkey, and Vietnam. Household use of natural gas in urban areas is widespread in Moldova, Pakistan, and Turkey. Peru and South Africa are self-sufficient in LPG supply, and all others are net importers. Turkey, Mexico, and Thailand rank in the top 10 markets globally for automotive LPG.

Retail prices in December 2010 ranged from US$0.40 per kilogram (kg) of LPG in Morocco, where LPG is heavily subsidized, to US$3.26 in Turkey, where the tax on LPG is high. Net-of-tax bottling and distribution costs vary by an order of magnitude, suggesting considerable scope for decreasing costs in some countries. Estimated annual per capita consumption by households in 2009 ranged from about 1 kg in Kenya to nearly 60 kg in Mexico. As expected, when the unit price of LPG was scaled with respect to household income to arrive at a measure of affordability, there was an inverse correlation between the affordability metric and per capita consumption. By this metric, LPG was least affordable in Kenya, followed by Afghanistan, Vietnam, Senegal, and Pakistan. The top four countries for affordability—Mexico, Jordan, Morocco, and Thailand in that order—all subsidize LPG.

LPG requires metal management—LPG is pressurized in metal containers for transport and storage—which adds considerably to the retail price of LPG. Supplying LPG is extremely capital-intensive with high front-end costs. There are large economies of scale, from marine transport down to cylinder sizes. Importers in Turkey contract parcels as large as 20,000 tonnes, enabled in part by joint procurement activities and hospitality (swapping) arrangements for import-terminal storage facilities. This contrasts with parcel sizes of 1,200–5,000 tonnes in Ghana, Kenya, Senegal, and Sri Lanka. Turkey, however, suffers from high demurrage charges due to port congestion. Pakistan has private-sector terminal operators engaged in receiving, storing, and onward shipping LPG for third parties for set fees, potentially lowering the barrier to entry.

Further down the supply chain, there are other opportunities to exploit scale economy, avoid duplication of facilities, or both. In Peru and Turkey, a large company supplies LPG to small operators, thereby minimizing the need to build an import terminal and lowering the barrier to entry. In Pakistan, the regulatory agency encourages hospitality arrangements whereby an operator would trade off storage capacity in one region in exchange for access to another company's storage in another region.

Small cylinders have been suggested as one way of enabling households to start using LPG. The cylinder acquisition and refill costs are both lower, and small cylinders are also easier to transport if residential customers have to take cylinders to retail shops. In the sample of 20

countries, the most commonly used cylinder sizes are 6 kg or smaller in Morocco and Senegal, where LPG in small cylinders are heavily subsidized. In all other countries except Mexico, the most commonly used cylinder sizes are 10–15 kg, which appear to represent a compromise between the benefits of small cylinders and the scale economy enjoyed by larger cylinders together with the convenience of not having to refill as frequently. In Mexico, only half of residential consumers purchase LPG in cylinders, mostly 20 and 30 kg in size, while the remaining households are supplied by very large stationary tanks. The cylinder market in Brazil is also migrating to LPG tanks.

Cylinder ownership and refill arrangements have significant effects on LPG safety. There are two ways by which customers obtain cylinder refills:

1. **Centralized system of filling**, whereby empty company-owned or customer-owned cylinders are exchanged for filled ones. If cylinders are company-owned, the company is responsible for ensuring the safety of cylinders. If customer-owned, the customer does not retain the same cylinder. If cross-filling is prohibited, the brand company from which the customer purchases LPG is responsible for cylinder safety. If there is interchangeability of cylinders across companies, incentives for any given company to repair and replace cylinders are considerably weakened unless there is a way of enforcing rigorous maintenance and replacement across all companies.
2. **Decentralized, bulk-supplied system with mini-filling plants**, whereby customer-owned cylinders are taken by customers to and filled at mini-filling plants. Each cylinder remains in the possession of the owner through its entire life. This modality poses serious safety risks because the only time LPG suppliers come in contact with cylinders is when they are being refilled. Cylinder safety depends critically on the diligence of plant operators in inspecting each cylinder and refusing to refill those that are defective. Globally, this modality is rare.

In both systems, because cylinders remain in the possession of final consumers most of the time, safety education for consumers is essential. Most countries have the centralized system. In the study countries, the second system is the dominant mode only in Ghana. By virtually eliminating commercial transport of cylinders, the decentralized system can substantially slash costs for LPG marketing companies, and conversely increase the indirect costs for consumers who are entirely responsible for cylinder transport.

Lowering the acquisition cost of the cylinder, stove, or both is one way of lowering the barrier to LPG use. Doing so can help the segment of middle-class households who are able to pay for LPG but find it challenging to save enough money to pay for the start-up cost. This segment is likely to be narrow because, unlike electricity, the difference between the start-up cost and monthly LPG fuel cost is not all that large. As a result, many households that struggle to save enough cash to pay for a cylinder and a stove cannot pay for regular use of LPG. As a result,

subsidizing the upfront cost of LPG use may not enable many households to start using LPG in any significant quantity. In some countries, LPG marketing companies promote LPG by setting cylinder deposit fees at levels markedly below cylinder manufacturing costs. The difference is recovered through slightly higher LPG prices than otherwise. If deposit fees are set too low, however, cylinders may be resold on the black market or smuggled out of the country.

LPG has historically attracted subsidies in a number of countries. In the study countries, the government does not intervene in price setting in six. The government keeps retail prices artificially low in Ghana, Jordan, Mexico, Morocco, Peru, Senegal, and Thailand. Brazil and the Dominican Republic have moved away from price subsidies to LPG vouchers for poor families. Where prices are subsidized and a sizable automotive LPG market is present, vehicle owners capture an increasing share of the subsidy, making it all the more regressive. There have been acute LPG shortages in several study countries in recent years, caused by disruptions to refinery operations coupled with inadequate storage capacity, a situation aggravated by financial difficulties arising from fuel price subsidies.

The laws and regulations in some countries are incomplete, outdated, or both. The regulations in nearly all countries are deficient when it comes to requiring consumer education and training and certification of the personnel of LPG suppliers. Because fuel specifications and safety standards for LPG are well established globally, formal adoption of international standards by reference, adapted for the country's climatic and other conditions as needed, is an efficient way of establishing such standards. Several countries in the study have adopted this approach without seemingly writing any of their own.

The amount and type of information provided by governments and LPG marketing companies vary greatly. There is considerable scope for improving the quality of information provided by companies to make it more user-friendly. Pictorial guides to safety risks have been developed by industry associations and governments in a handful of countries, but they tend to be rare. Some governments maintain an extensive database on prices, which would be valuable for consumers and industry analysts alike.

The findings of this study suggest that programs for substitution of biomass with LPG are likely to be more effective if they first focus on areas where biomass is diminishing, the costs of biomass cooking are high, and there is infrastructure for reliable LPG delivery, starting with tarred roads. Conversely, if the shortcomings in the LPG market are such that not even urban middle-class households can be persuaded to switch to LPG, it is unlikely that an LPG promotion program will be successful with the poor or rural households.

Because high costs present the greatest barrier to the adoption of LPG, making the LPG market as efficient as possible and passing efficiency gains to consumers to lower prices is crucial in the effort to expand household use of LPG. Government can contribute in various ways. It can

encourage hospitality arrangements and third-party access to import terminals and storage tanks, thereby reducing duplication of infrastructure and lowering the barrier to entry. Improving roads can reduce transport costs and enable more areas to be reached, while improving ports could reduce congestion. Better port infrastructure may also facilitate LPG imports in larger parcels, again lowering costs. Fair competition—essential for increasing efficiency—requires establishing a modern regulatory framework, which may include formal adoption of international standards so that they are automatically updated, and effective monitoring and enforcement to curb commercial malpractice and ensure safety. Where institutional capacity is still being developed for monitoring and enforcement, one option is to establish a system of certified installers and private inspectors under government supervision. LPG marketers, micro-finance schemes, and others can lower the barrier to LPG adoption by making it easier to finance the cylinder deposit fee and stove purchase. There is a niche market for small cylinders, but global experience to date suggests that their role is likely to remain limited.

Ensuring safety calls for a clear definition of cylinder ownership; assignment of legal responsibility for cylinder maintenance, repair, and replacement; effective enforcement of the ban on cross-filling where such a ban exists; proper training of operators throughout the supply chain; extensive education campaigns for end-users; and penalizing companies that refill unsafe cylinders. The regulatory framework in Turkey offers useful lessons. It requires training of all personnel involved in supplying LPG and educating consumers about proper handling of LPG, and sets strict rules about the conditions under which cylinders can be refilled. It authorizes charging of small fees to marketing companies to finance monitoring and enforcement.

Price subsidies can help those who are otherwise unable to purchase LPG, but are inefficient. Universal price subsidies are regressive, captured largely by middle- and high-income households and vehicle owners. Capping prices at artificially low levels all too often deters investment in the sector by making it difficult even for efficient operators to recover costs, and have led to fuel shortages in some markets. A more equitable approach is to move away from price subsidies and include assistance to the needy for LPG purchase in social safety net programs, as in Brazil and the Dominican Republic. Removing universal price subsidies can help create an environment where financially sound companies have incentives to invest, including in more storage capacity. Construction of adequate storage capacity in turn is essential for enforcing minimum stockholding requirements.

Communicating information widely to the public using different media in nontechnical language is another crucial element in LPG promotion. This study provides evidence that disseminating information to women can be particularly effective. There are several good examples of information sharing in the study countries: pictorial guides on safety in several local languages published by the LPG Safety Association of Southern Africa; newspaper advertisements

sponsored by government agencies in Ghana to alert consumers to the risks associated with LPG cylinders; a calculator for estimating the amount of LPG consumed by different appliances on the Web site of the Mexican energy ministry; prices of LPG by location, company, and cylinder size posted on the Web site of the regulatory agencies in Peru and Turkey; and frequently asked questions on the Web site of an LPG marketing company in Brazil. Well-informed consumers can help efficient and responsible firms to expand their market share at the expense of those engaged in commercial malpractice, and exert relentless pressure on firms to minimize costs, thereby contributing to growth of a vibrant, competitive LPG market.

The Role of Liquefied Petroleum Gas in Reducing Energy Poverty

1. Background

In December 2010, the United Nations General Assembly passed a resolution declaring 2012 the "International Year of Sustainable Energy for All." Following this declaration, UN-Energy, a group coordinating 20 UN agencies, launched a global initiative, "Sustainable Energy for All," in 2011. The first of the three goals set for 2030 under the initiative is universal access to modern energy services: electricity and clean cooking and heating solutions (UN-Energy 2011). Electricity is the universal energy source of choice for lighting, space cooling, and powering household appliances, including electric rice cookers, electric kettles, and microwave ovens for cooking and boiling water. For cooking and heating, some households switch entirely to electricity as income rises and electricity supply becomes reliable. Many, however, choose to use a gaseous fuel for cooking even at the highest income level because gas gives better control over heat. Heating with electricity is the safest option, but because of its expense many households prefer a gaseous fuel while others choose a liquid fuel (heating oil).

World Energy Outlook 2011 by the International Energy Agency (IEA) suggests that, if no new policies are adopted and implemented beyond those that had been proposed by mid-2011, the number of people without access to clean cooking solutions will actually increase slightly between 2009 and 2030 because of the increase in population. To achieve universal access to modern energy services for cooking, an estimated 1.25 billion people, who would otherwise have continued to rely on traditional use of solid biomass, will use advanced biomass cookstoves; 1.2 billion people will use LPG; and 350 million people will use biogas (IEA 2011a).

The importance of gas as part of the efforts to attain universal access and reduce energy poverty—defined by the IEA and others as lack of use of electricity, clean cooking and heating systems, or both—has been increasingly recognized by researchers and policymakers alike. The costs to families of relying on solid fuels are enormous. Indoor air pollution was estimated to have caused 1.9 million premature deaths and many more cases of illnesses in 2004 (UNDP and WHO 2009). Where biomass is collected, the time burden on the collectors—many of whom are women and children—can be considerable, taking children away from attending school and studying at home, depriving parents of time that could otherwise be spent on childcare, and denying adults alternative productive activities, including income generation. Where biomass is not harvested sustainably, its use can lead to degradation or loss of tree resources. While the main driver of deforestation is conversion of tropical forest to agricultural land, concentrated consumption of charcoal and fuelwood—typically in urban areas by residential and industrial users—can also lead to loss of forest cover (FAO 2010).

A recent editorial in *Energy for Sustainable Development* observes that the richer half of the world uses just two types of energy for cooking: gas and electricity. Citing rural women in India

who asked why improved biomass stoves continued to be compared to traditional biomass stoves when the focus should be how closely improved stoves can mimic "the stove everyone wants, gas," the editorial suggests that a gas stove is the "aspirational appliance that every woman knows and would prefer, for convenience, controllability, time savings, and modernity," setting a gold standard against which improved biomass stoves should be measured (Smith and Dutta 2011).

There are three types of gaseous fuels: biogas, natural gas, and LPG. Biogas, made from organic wastes, is the only renewable fuel among the gaseous fuels and therefore ranks high in sustainability. It is typically made from livestock manure in developing countries, limiting its adoption to rural areas with farm animals. Biogas digesters costs are also high; 2010 estimates range from about US$440 in India to US$924 in Sub-Saharan Africa (IEA 2011a). Natural gas burns more cleanly than LPG and, absent subsidies, is typically a (much) cheaper fuel, making it the fuel of choice in areas where both natural gas and LPG are available. For energy-intensive activities such as space heating, natural gas is also typically cheaper than electricity. But laying down a natural gas pipeline network is capital-intensive with very large economies of scale, so that it takes time to develop the gas supply infrastructure. Even when the supply infrastructure is fully developed, as in some high-income countries, natural gas is available only to urban and some peri-urban households where scale economy can be exploited. For these reasons, of the three gaseous fuels, LPG will be the most widely available gaseous fuel in developing countries for the foreseeable future. LPG is marketed in both urban and rural areas, although in developing countries it tends to be more widely available in urban areas where its supply costs are lower.

This study focuses on household use of LPG. To understand the scale of LPG adoption by households, this study examined data from 110 developing countries (Kojima, Bacon, and Zhou 2011). More than half of all households named LPG as the primary cooking fuel in 30 percent of the countries and solid fuels in 49 percent. There were more than a dozen countries where less than half of the households used solid fuels and where forms of energy other than LPG were widely used as cleaner-energy alternatives: kerosene in three countries; natural gas and electricity in eight countries each, mostly in the former Soviet Union. Predictably, the share of households using LPG in most cases is higher in urban than in rural areas, except in seven countries where many urban households had access to natural gas. In 51 of the 63 countries for which information on the primary sources of energy for cooking was available by wealth or income quintile, the percentage of households using LPG rose with quintile. These observations suggest that LPG is indeed likely to play an increasingly important role in the coming years with rising income as well as growing awareness about the convenience and health benefits of LPG.

Households in developing countries, however, do not automatically shift to LPG or an alternative form of clean energy as soon as they can afford it. Some households do not change

their fuel use patterns and may merely increase fuel consumption. Others initially add new sources of energy to the existing ones to suit their budgets and preferences, for example using LPG or electricity for making tea, dung for simmering, and firewood for the bulk of the rest of cooking. The benefits of using modern forms of energy are diminished correspondingly with continuing use of solid fuels. An earlier examination of national household expenditure surveys in nine developing countries in Asia and Sub-Saharan Africa found that more than 60 percent of the households in the top quintile in urban areas in four countries reported using some biomass, and in fact more than 80 percent in two of them. Nor were they the four poorest countries in the sample according to per capita expenditure (Bacon, Bhattacharya, and Kojima 2010). Adequate income is therefore a necessary, but not a sufficient, condition for shifting households away from traditional use of solid fuels. If there are frequent LPG shortages, if LPG delivery is not reliable, if unsafe handling of cylinders has led to publicized fires, or if non-household members are dealing with biomass (for example, a housekeeper), the incentive to consider LPG is weakened.

The global LPG market has also been affected by the steep rise in oil prices since 2004. The price increase for LPG has been nearly as large as that for oil: between 2003 and the first ten months of 2011, LPG prices rose by a factor of 2.9, oil prices by a factor of 3.6. In real terms, the LPG price increase corresponded to 145 percent, or an average annual increase of 10 percent, far above the increase in the income of most households.

This study was undertaken to deepen the understanding of the factors affecting household selection of LPG and its consumption, the state of LPG markets in developing countries, and the scope for improving the regulatory and market conditions to enable more households to shift away from solid fuels to LPG in markets where LPG would be the fuel of choice. This report draws upon two background papers prepared under the study.[1] The first (Kojima, Bacon, and Zhou 2011) used recent national household expenditure surveys in 10 developing countries to conduct econometric analysis of the factors influencing the decision to use LPG and, among users, the quantity consumed per household. The second (Matthews and Zeissig 2011) consisted of a desk study assessing the legal framework, industry and market structures and practices, supply arrangements and infrastructure, and pricing policies in 20 developing countries, and field visits to Ghana and Turkey to gather additional information.

This report begins with a description of the global LPG market and its economics in chapter 2. Chapter 3 summarizes the findings from the first background paper on patterns of LPG use in the ten developing countries and factors affecting them. Chapter 4 discusses the key findings of an analysis of the LPG market in 20 developing countries from the second background paper, supplemented by additional analysis and information collected by World Bank staff. Chapter 5

[1] Unreferenced information in chapters 3 and 4 is from these two background papers.

concludes with observations and recommendations. The details are left to the background papers.

2. LPG Supply, Use, and Economics

LPG is used as a gas but sold as a liquid, and produced in both crude oil refining and natural gas processing. LPG is more costly to distribute than liquid fuels, but less so than natural gas in areas lacking sufficient economies of scale for the latter.

Global supply and demand

A unique feature of LPG supply is that nearly all LPG is generated as a byproduct. About two fifths of LPG supply comes from crude oil refining, a quarter from natural gas associated with crude oil production, and most of the balance from unassociated natural gas. LPG production is governed by refinery throughput, oil production, and unassociated natural gas production, and cannot respond rapidly to changes in demand; instead, demand has to adjust to supply fluctuations. This demand response occurs primarily in the petrochemicals industry (3–7 percent of global LPG demand), which is highly price-sensitive and substitutes feedstocks quickly in response to changes in their relative prices. In contrast, residential and commercial demand for LPG for cooking and heating—which accounts for slightly more than half of global LPG demand—is much less price-sensitive, as are some chemical feedstock applications (20 percent) and industrial use (9 percent). Another 9 percent of demand is for autogas (automotive LPG), substituting primarily gasoline. Low refinery throughput led to the first fall in LPG production in more than 25 years in 2009, but production rebounded strongly in 2010 and this growth trend is expected to continue in the coming years, with the bulk of the increase coming from natural gas processing (Hart, Gist, and Otto 2011).

The world's largest LPG exporter is the Middle East, followed by Africa (North and Sub-Saharan combined). In 2010, the world's largest exporter was Saudi Arabia, followed by Qatar and Algeria; in Sub-Saharan Africa, the largest exporter was Nigeria. In both the Middle East and Africa, LPG production has been threatened by civil unrest, raising the possibility of serious disruptions to LPG trade and pricing. The United States and Canada together form the world's largest LPG producing region and became a net exporter in 2009, largely due to the exploitation of shale gas and oil (Hart, Gist, and Otto 2011). Prices of propane (an important component of LPG) in the United States have been lower than international prices elsewhere by an average of more than 10 percent since October 2008.

The world's largest residential-commercial consumer of LPG is China. Residential and commercial demand accounts for about 95 percent of the total in the Indian subcontinent and Africa (consumption in Africa occurs primarily in North Africa) and three quarters in Latin America and the Caribbean. In terms of per capita consumption, Sub-Saharan Africa and the Indian subcontinent rank the lowest. At the opposite end of the spectrum are countries such as Mexico and Ecuador with very high per capita consumption; in the case of Ecuador, large subsidies for the residential market reduce the retail price to US$0.11 per kilogram (kg), among

the lowest in the world (Hart, Gist, and Otto 2011). The world's largest autogas market is the Republic of Korea. Among developing countries, Turkey, the Russian Federation, Mexico, and Thailand were among the top 10 autogas consumers in 2008 (WLPGA 2010).

Supply chain

LPG is a mixture largely of propane and butane. At atmospheric pressure, propane is a gas above –42 degrees Celsius (^{o}C) and butane is a gas above –0.5^{o}C. The ratio of propane to butane in LPG varies from market to market. Unlike natural gas which rises, LPG settles near the ground if leaked, increasing chances of explosion. LPG is spiked with an odorant to make leak detection easier.

Gaseous propane and butane take up about 250 times as much space as in the liquid state. To conserve space, LPG is pressurized in a metal container at ambient temperature or else refrigerated to transport and store it as a liquid. The need to keep LPG pressurized or refrigerated and associated metal management add considerably to the supply cost of LPG—for example, specialized steels are used to manufacture tanks for LPG ships—and result in large economies of scale. Typically large volumes of LPG greater than 10,000 tonnes are refrigerated during transportation and storage while those under approximately 3,000 tonnes are pressurized. Depending on LPG composition, the largest LPG ships in regular use can carry about 45,000 tonnes, consisting of four tanks of 11,000 tonnes each. Port congestion delaying unloading for importers and a delay in accumulation of the parcel size to be loaded for exporters can incur substantial demurrage costs. Various factors lead to most of the global LPG trade being conducted under term contract arrangements. As a result, compared to other petroleum products such as gasoline and kerosene, the LPG market is not as liquid and has fewer spot deals (Allen Consulting Group 2009).

Commercial participants in the LPG supply chain include the following actors:

- *Producers* sell LPG at the refinery or natural gas processing plant gate.
- *Traders* and *marketers* buy LPG in bulk from producers or from overseas markets, and store in large primary terminals and sell to other marketers, distributors, retailers, and final consumers.
- *Transporters* and *distributors* truck, rail, or pipe bulk LPG to their regional depots where it is stored in large pressure vessels, and then supply LPG to bulk customers by small road tanker. LPG is bottled in cylinders and distributed to retailers.
- *Retailers* sell LPG to small customers, including households. The retail outlets may be retail branches or commission agents of a marketer, or independent resellers who purchase and resell LPG in marketer-owned and branded cylinders. Autogas is sold at filling stations.

Equipment and service industries supporting the supply chain include cylinder manufacturing, testing, repair, and recertification; LPG appliances and equipment such as stoves, valves, hoses, and regulators; and bulk tank manufacturing and installation services. For autogas, associated equipment and services include fuel tanks, valves, hoses, fillers, and conversion of light-duty gasoline vehicles to run on LPG. Autogas is covered in this report because it pricing policy can have a significant effect on the availability and price levels of LPG for household use.

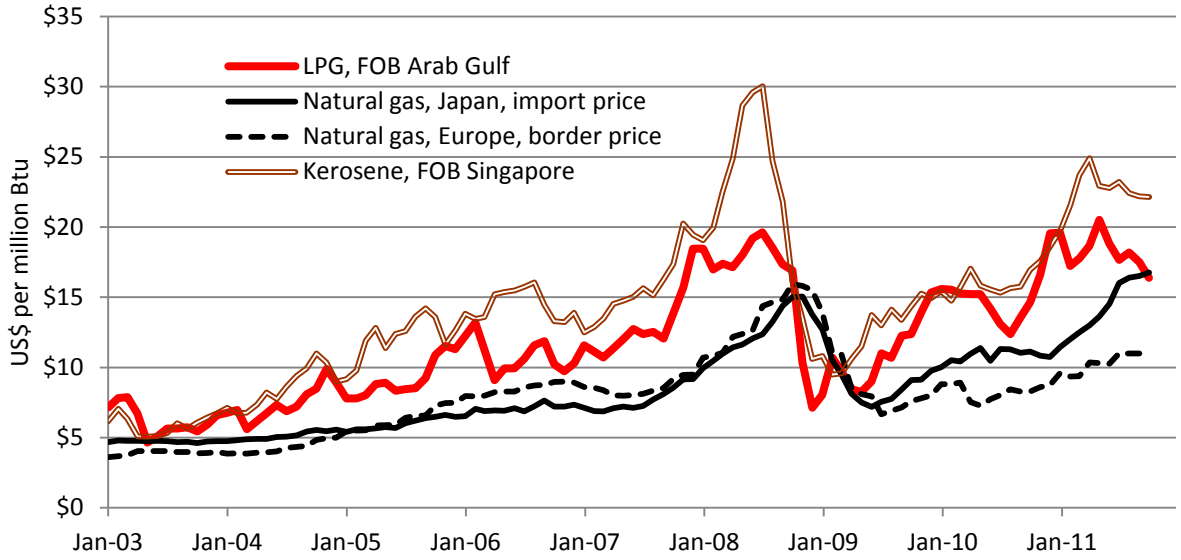
In developed countries, residential LPG consumers are predominantly in rural areas, which cannot be reached by natural gas pipelines and where LPG is often used for both heating and cooking. In developing countries, however, the presence of an extensive natural gas pipeline network connecting households is not common, and this, combined with the need to have a relatively high concentration of consumers who are able to pay for regular use of LPG, makes urban LPG consumers far more numerous than rural. Over the very long run, as income rises to the level where there is sufficient demand for natural gas in cities and households become capable of paying for natural gas connection and use, many urban households in developing countries, too, will shift largely to natural gas, electricity, or both for cooking and heating. As such, LPG is a transition fuel for many, if not most, urban households over the very long run.

Economics

For household energy in developing countries, LPG, natural gas, and kerosene are three modern commercial fuels that can potentially be used for cooking and heating. Kerosene can be burned in either wick or high-pressure stoves. If not properly maintained, wick stoves can be low in fuel efficiency and polluting. Pressure stoves vaporize kerosene first, allowing it to burn cleanly. It is, however, more costly and noisy than wick stoves. Natural gas is the cleanest of the three fuels.

One way of comparing the economics of the three fuels is to normalize prices based on the energy content of each fuel. Figure 1 shows (net-of-tax) monthly international average prices per million British thermal units (Btu), a unit of energy, since January 2003. Prices are for free on board (FOB) for LPG and kerosene and landed costs for natural gas. The LPG price chosen is the Saudi Aramco contract price, the benchmark price for LPG in Asia. To be consistent with the basis for LPG, other fuel prices are also taken from the Asian market: kerosene in the region's largest refining center, Singapore, and natural gas in the world's largest importer of liquefied natural gas, Japan. Because the price of natural gas in Asia in recent years has been higher than those in other major gas markets, European gas prices are also shown.

Figure 1: Evolution of monthly prices for LPG, natural gas, and kerosene since 2003



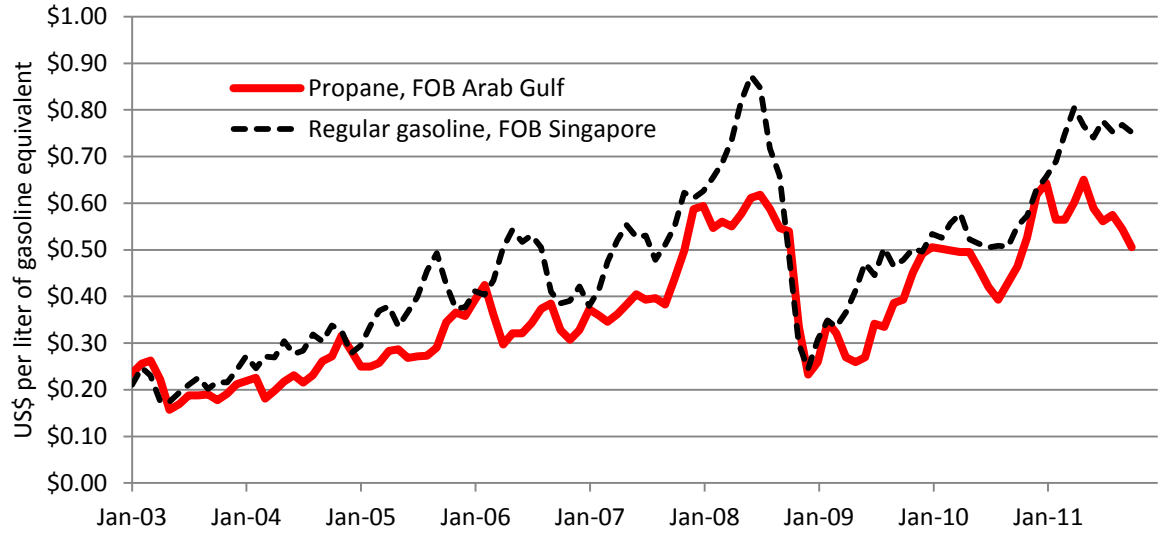
Sources: Reuters for propane, World Bank's Development Research Group for natural gas, various issues of the Platts Price Oilgram for kerosene, and World Bank staff calculations.
Note: The price of LPG is the average of Saudi Aramco contract prices for propane and butane.

The figure should be interpreted with caution because the prices do not include internal distribution costs or, in the case of kerosene and LPG, freight costs for importing the fuel. The costs of distributing kerosene are lower than for LPG because kerosene does not incur bottling and cylinder management costs. On the other hand, the efficiency of kerosene stoves tends to be lower than that of LPG stoves, requiring more kerosene per unit of cooking and hence pushing up the effective price of kerosene. The upfront cost of laying down a pipeline network for natural gas is very large, and that cost is not reflected in the figure. These limitations notwithstanding, the figure illustrates the trend observed globally. Where natural gas is available, it is the fuel of choice for households: excluding the connection cost, natural gas is cheaper than LPG, in addition to being potentially cleaner and safer. The Saudi Aramco contract price of LPG was higher than the landed cost of natural gas in Japan, which is the highest of three major oil markets (Asia, Europe, and North America), in 101 out of 106 months between January 2003 and October 2011. The difference between LPG and natural gas prices is markedly greater in the United States, where spot prices during the first 10 months of 2011 averaged only about US$4.20 per million Btu. In contrast, the Saudi Aramco contract price of LPG was lower than the FOB Singapore price of kerosene in 92 months during the same period. This price difference has been even greater in North America where propane prices have been lower than the Saudi Aramco contract prices in recent years. Where there are no price subsidies in favor of kerosene, households prefer LPG to kerosene because LPG is generally cheaper.

For autogas, the relevant comparison is that between the price of gasoline and the gasoline-equivalent price of propane (the dominant component of LPG present in autogas) quoted by

Saudi Aramco. These prices are shown in Figure 2. In the 106 months between January 2003 and October 2011, propane was cheaper than regular gasoline in 98 months. Although there is an initial upfront cost of converting a gasoline car to run on LPG, this additional expenditure can be quickly recovered if LPG is taxed much less, which is the case in most large autogas markets. For example, despite rising excise tax on LPG in recent years, the excise tax on regular gasoline in the Republic of Korea during the first quarter of 2011 was 78 percent of the next-of-tax fuel price, but the corresponding figure for autogas was 29 percent. The retail price of autogas was 22 percent lower per liter of gasoline equivalent. In earlier years, this difference in taxation was even larger; taking 2003 as an illustration, despite nearly comparable FOB prices of gasoline and LPG, the retail price of autogas was 40 percent lower per liter of gasoline equivalent (IEA 2011b).

Figure 2: Monthly prices for autogas and gasoline in Asia since 2003



Sources: Reuters for propane, Platts Price Oilgram for unleaded gasoline with a research octane number of 92, and World Bank staff calculations.

3. Factors Affecting Household Choice of LPG

This study examined LPG demand patterns in 10 developing countries using data from national household expenditure surveys conducted in recent years (Kojima, Bacon, and Zhou 2011). The survey data were collected between 2004 and 2009 depending on the country, and the sample size ranged from 3,420 to more than 120,000. Annual per capita expenditure, expressed in 2005 U.S. dollars at purchasing power parity (PPP), ranged from US$704 in India to US$4,566 in Brazil (Table 1). Expenditures that were added up to arrive at per capita expenditure included imputed values for non-purchased food, which provides a large part of the total household consumption in developing countries, and excluded infrequent large expenditures (such as those on weddings, jewelry, and large durable goods) to avoid possible distortions arising from such large purchases. Where available, deflation factors to account for spatial differences in prices were used to deflate all food expenditures, both cash and imputed. More than half of all households lived in urban areas in five out of ten countries. In each of the five countries, annual per capita expenditure exceeded US$3,000.

Table 1: Survey descriptions and country characteristics

Country	Survey year	Population (million)	Survey sample size	Per capita expenditure per year from survey (2005 US$ at PPP)	% of households in urban areas from survey
Guatemala	2006	13	13,656	3,777	54
India	2004–05	1,087	120,427	704	27
Indonesia	2005	219	9,928	812	44
Kenya	2005–06	36	12,754	1,251	25
Pakistan	2004–05	154	14,700	861	32
Sri Lanka	2006–07	20	18,473	1,673	14
Albania	2008	3	3,420	3,693	53
Brazil	2008–09	193	43,435	4,566	84
Mexico	2008	106	25,068	3,163	79
Peru	2009	29	20,414	3,149	66

Sources: Kojima, Bacon, and Zhou 2011; WDI 2011.
Note: Data are from surveys except total population in the survey year, which is from the World Development Indicators (WDI). All figures from the surveys are weighted using household weights provided in the survey data sets.

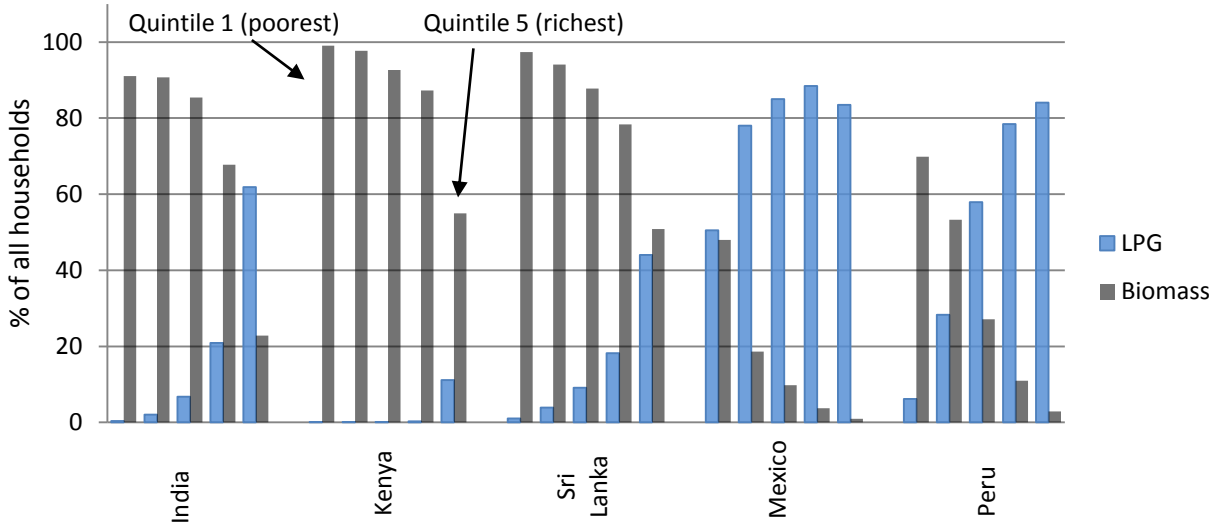
For descriptive statistics, each country's weighted population (using household size and household weights) was divided into quintiles, each containing the same number of *people*. Because household size generally decreased with income, the number of *households* increased with quintile. Each quintile was further divided into rural and urban. The rural population made up more than half of the total in the bottom quintile, except in Brazil, whereas the urban population made up more than half in the top quintile, except in Sri Lanka.

Two-stage Heckman-type models were set up to probe factors potentially influencing households' decision to use LPG (selection) and, for the households that have decided to use it, how much to use (consumption). The surveys in Guatemala, India, Indonesia, Kenya, Pakistan, and Sri Lanka had data to enable full modeling, including quantities of fuels purchased or consumed (from which prices faced by individual households were calculated). The surveys in the remaining countries—where LPG use was more widespread and data were more recent—lacked data on quantities, and national average prices were used to estimate quantities of LPG purchased. Although the impact of fuel prices on LPG demand could not be examined in the latter four countries, these countries were nevertheless investigated to see if their findings generally supported those from the first six countries. More details on the econometric analysis and its limitations can be found in Kojima, Bacon, and Zhou (2011).

Use of LPG in survey countries

Several surveys asked households to name the primary cooking fuel. The results for LPG and biomass are presented in Figure 3 by expenditure quintile. Biomass dominated the bottom four quintiles in India, Kenya, and Sri Lanka, and was more important than LPG even in the top quintile in Kenya and Sri Lanka. These patterns are in sharp contrast to the dominance of LPG for all quintiles in Mexico and for the top three quintiles in Peru.

Figure 3: LPG and biomass as the primary cooking fuel

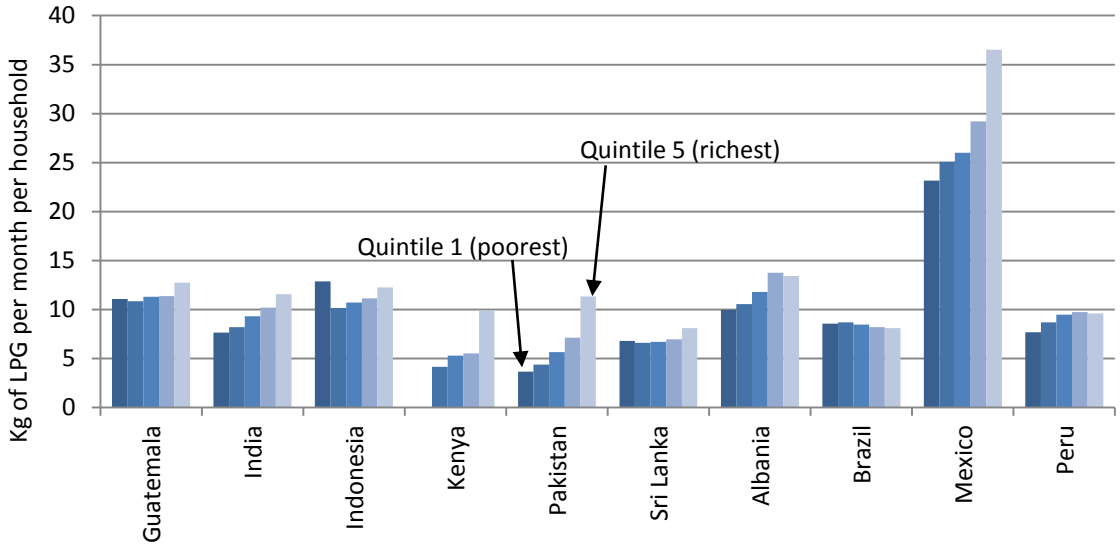


Source: Kojima, Bacon, and Zhou 2011.
Note: Pakistan also asked this question, but lumped natural gas and LPG into a single category.

Monthly consumption of LPG in kg averaged across all user households is shown by quintile in Figure 4. Mexican households stand out as consuming more than twice as much as those in other countries. Consumption followed the expected pattern of rising with quintile in most countries, and particularly in India, Kenya, Pakistan, Albania, and Mexico. The unusually high

monthly consumption of the bottom quintile in Indonesia is most likely to be due to the fact that there were only two user households in the sample, resulting in unrepresentative data.

Figure 4: Monthly household LPG consumption by user households by quintile



Source: World Bank staff calculations using data from national household expenditure surveys in Kojima, Bacon, and Zhou (2011).
Note: Consumption in Albania, Brazil, Mexico, and Peru is estimated from expenditures and national average LPG prices.

Measurement and recall errors with quantities consumed can be large, and uncertainties are even larger when quantities consumed have to be estimated by dividing expenditures by national average prices, as was the case with Albania, Brazil, Mexico, and Peru. Statistics provided by the Mexican energy ministry for annual residential consumption and the number of LPG-using households give an independent estimate of monthly consumption in that country and the results can be compared for an indication of the magnitude of uncertainties. The average of 29 kg per month for the four-month survey period from August to November, 2008, estimated in this study is about 10 percent higher than 26 kg calculated from government statistics for calendar 2008 (SENER 2010).

Table 2 provides summary statistics of LPG use by location. LPG-using households were identified as those reporting consumption or non-zero expenditure, depending on how the question was asked. In Mexico, however, the share of households reporting non-zero expenditure was smaller than that citing LPG as the primary cooking fuel, and the latter was used as the basis for identifying LPG users. The actual percentage of households using LPG would therefore be higher, because households using LPG as a secondary fuel were excluded from user households. A greater share of households use LPG in urban areas than in rural, except in Pakistan where 66 percent of urban households had access to natural gas; among LPG-users, however, urban households in Pakistan consumed 60 percent more than rural

households. More generally, urban user households consumed markedly more LPG than rural ones in India, Pakistan, Sri Lanka, Mexico, and Peru. In Albania, Pakistan, and Sri Lanka, urban user households devoted a greater share of their total expenditure to LPG than rural households. The share of total household expenditure spent on LPG varied from 1.8 percent in rural Sri Lanka to 5.6 percent in rural Mexico, and from 2.0 percent in urban Peru to 4.6 percent in urban Pakistan.

Table 2: Summary statistics on LPG use

Country	Share of households using LPG (%)		Quantity per user household (kg/month)		Expenditure share of user households (%)	
	Rural	Urban	Rural	Urban	Rural	Urban
Guatemala	24	74	11	12	2.7	2.5
India	12	59	9.1	12	4.8	4.3
Indonesia	2.2	13	11	12	3.4	2.3
Kenya	1.2	13	10	9.6	4.5	2.7
Pakistan	8.4	7.0	6.8	11	3.1	4.6
Sri Lanka	21	60	6.7	9.3	1.8	2.3
Albania[a]	71	72	11	12	2.8	3.3
Brazil[a]	81	89	8.0	8.4	3.5	2.5
Mexico[a]	54	87	25	30	5.6	4.4
Peru[a]	21	85	7.9	9.6	2.7	2.0

Source: Kojima, Bacon, and Zhou 2011.
a. Quantities are estimated using national average prices.

One measure of affordability of LPG is the percentage of total household expenditure needed to purchase 1 kg of LPG. The results are shown in Table 3. The table also shows FOB prices of LPG averaged during the survey period taken from a geographically relevant market for each country. Comparison of retail and FOB prices indicates that retail LPG prices were subsidized in India, Indonesia, and Mexico.

Table 3: Affordability of LPG

Country	Share of households using LPG (%)	Quantity per user household (kg/month)	Retail price of LPG (US$/kg)[a]	FOB price of LPG (US$/kg)	1 kg of LPG / total household expenditure (%)
Guatemala	51	12	1.11	0.54	0.2
India	24	11	0.47	0.39	0.6
Indonesia	7.1	12	0.41	0.39	0.4
Kenya	4.0	9.7	1.63	0.48	1.0
Pakistan	7.9	8.1	0.71	0.39	0.5
Sri Lanka	26	7.6	0.75	0.52	0.4
Albania[b]	71	12	1.51	0.88	0.2
Brazil[b]	88	8.4	1.39	0.59	0.2
Mexico[b,c]	80	29	0.86	0.80	0.1
Peru[b]	63	9.4	1.08	0.42	0.2

Source: Kojima, Bacon, and Zhou 2011.
Notes: FOB prices are taken from Mont Belvieu propane prices in Texas, United States for Guatemala, Brazil, Mexico and Peru; the average of propane and butane prices from the North Sea for Albania; and the average of propane and butane Saudi Aramco contract prices for India, Indonesia, Kenya, Pakistan, and Sri Lanka.
a. Local retail prices of LPG converted to U.S. dollars using the market exchange rate at the time of the survey.
b. Quantities are estimated using national average prices.
c. The shares of households using LPG are based on the statistics for those using LPG as the primary cooking fuel and exclude those using LPG but not as the primary fuel.

The combination of subsidies and relatively high income made LPG most "affordable" in Mexico. Whether Brazil or Mexico had the highest share of households using LPG could not be determined from the survey analysis because, as explained above, it was not possible to estimate the number of LPG users from expenditure data in the survey in Mexico. What the low ratio of price to income seemed to increase in Mexico was the average quantity purchased, which was nearly triple the average of the remaining nine countries. The affordability of LPG in Guatemala, Albania, Brazil, and Peru was comparable, but the selection rate ranged from 51 percent to 88 percent. These differences may be for a variety of reasons, including the share of unpurchased food in total household expenditure, which affects the amount of cash households had at a given total household expenditure; the importance of excluded expenditures (large infrequent expenditures), which affects the household's ability to pay; differences in household income, in contrast to measured expenditures; supply conditions of LPG and other fuels; upfront costs of LPG cylinder and stove acquisition; and cultural acceptance of different fuels. Nevertheless, the differences in the selection rate among countries with comparable affordability of LPG suggest that there is potential to increase its use further and help reduce reliance on solid fuels with their attendant problems.

Distributional impact of universal price subsidies

Quantities of LPG consumed enable examination of distributional effects of hypothetical universal price subsidies. This illustrative exercise asks what would have been the impact if, at the time of the survey, the government in each country was providing a universal price subsidy of US$0.20 per kg of LPG. For the purpose of this illustration, the poor are defined as those in the bottom two deciles in every country, making up exactly 40 percent of the total population (but a smaller percentage of the total number of households, because household size declines with increasing income). In practice, the poverty line in each individual country will differ and is typically much below 40 percent. The exercise focuses only on LPG consumed by households. The distributional impact assessment poses the following questions, the first three of which are subsidy performance indicators discussed by Komives and others (2005):

- How well does the subsidy target the poor (**benefit targeting**)? More specifically, what percentage of the total subsidy reaches the poor as opposed to the non-poor? If more than 40 percent reaches the poor, the subsidy is progressive. A benefit-targeting indicator of 100 percent would mean that the subsidized good is completely self-targeting, which LPG is not. The gap between 40 percent and the actual percentage (**equity gap**) indicates how far the subsidy scheme falls short of (or exceeds) an equal distribution across all income groups. As an example, if the benefit targeting indicator is 30 percent, then the equity gap is (40 – 30) ÷ 40 = 25%.
- How inclusive of the poor is the subsidy (**inclusion**)? That is, what percentage of poor people receives this subsidy?
- How material is this subsidy (**materiality**)? More specifically, what is the total subsidy received by the poor, expressed as a percentage of their total household expenditures?
- What is the total bill to the government of this hypothetical universal price subsidy if only LPG sold to households is considered?
- What is that total subsidy bill for households as a percentage of the gross domestic product (GDP)?

The results are shown in Table 4. It is striking that, even after including some lower-middle class households who are not poor, in no country is the subsidy neutral or progressive (zero or negative equity gap). The smallest equity gap is 20 percent in Brazil,[2] rising to virtually 100 percent in Kenya where almost all users of LPG were in the top three quintiles. The hypothetical subsidy hardly covers the poor in Guatemala, India, Indonesia, Kenya, Pakistan, and Sri Lanka, all with inclusion of 11 percent or lower. In terms of materiality, Mexico has the highest indicator at 0.7 percent of the total household expenditure, reflecting both the relatively high percentage of households in the bottom two quintiles purchasing LPG and high monthly

[2] The equity gap in Brazil is reduced to zero if defined in terms of the percentage of households instead of people, because poor households are larger.

consumption of LPG. The largest subsidy bill as a share of GDP occurs in India—despite poor performance on benefit targeting, inclusion, and materiality—followed by Guatemala. These unfavorable trends would worsen once non-residential users of LPG are included. These results suggest that a universal price subsidy for LPG, particularly in low-income and lower-middle-income countries, would not be equitable or cost-effective for social protection.

Table 4: Distributional performance of hypothetical universal price subsidies

Country	Benefit targeting, %	Equity gap, %	Inclusion, %	Materiality, %	Total hypothetical subsidy, US$ million	Total subsidy as % of GDP
Albania	24	40	66	0.03	16	0.12
Brazil	32	20	89	0.5	757	0.05
Guatemala	9.6	76	11	0.1	38	0.13
India	1.6	96	2	0.06	1,301	0.17
Indonesia	1.0	98	1	0.007	105	0.04
Kenya	0.07	100	0	0.0005	6	0.03
Mexico	23	43	68	0.7	955	0.09
Pakistan	8.5	79	5	0.04	30	0.03
Peru	13	68	28	0.2	96	0.08
Sri Lanka	4.9	88	6	0.05	21	0.07

Source: World Bank staff calculations.
Note: Inclusion and materiality in Mexico are clearly under-estimated. A recall period of a month for purchase was used in the survey, excluding those who did not buy LPG the month before, and the number of households who cited LPG as the primary cooking fuel was markedly larger than those who reported having purchased LPG during the previous month. Inclusion for Mexico is based on those who cited LPG as the main cooking fuel; materiality and benefit targeting are both based on purchases.

Heckman model

Descriptive statistics and comparison of affordability of LPG may be informative, but they cannot assess various factors affecting household use of LPG. To do so, this study set up a Heckman-type model with two equations to model LPG selection and consumption. The dependent variable was a 1/0 dummy for selection in the first probit (selection) equation and the logarithm of kg of LPG consumed or purchased per month per household in the second (consumption) equation. Heckman's approach allows for the existence of selection bias in the second stage, in which the decision to choose LPG depends in part on unmeasured variables.

The independent variables investigated in all ten countries—except household-level fuel prices, which were available only in the first six countries with quantity data, and a few other items in cases where the survey in one of the countries did not collect the data—were logarithms of total household expenditures, logarithms of household-level prices of LPG and other fuels (first six countries), the number of rooms or floor area, house and car ownership, household size and size squared, a dummy for engaging in agriculture, education variables, a dummy for male

household head, the age of the head of household, a dummy for urban residence, and a dummy for connection to electricity. With respect to the last variable, while the decision to collect firewood or use kerosene and other fuels for cooking is endogenous to decisions related to LPG consumption, the availability of electricity for connection is to a large degree exogenous to the household, reflecting public decisions taken by the government. Together with the fact that electricity was rarely used as the primary source of cooking—with the exception of Albania, where 40 percent of electricity users reported using electricity to meet some or all of their cooking needs—this study considered electricity connection exogenous as long as the coefficient was positive.

Two variables for education were tested in every country, motivated by the observation that the benefits of LPG are often not widely known and fears about potential fires and other dangers associated with LPG can be allayed if the consumer feels confident about being able to follow instructions for operating an LPG stove properly. Although none of the surveys collected information on these points, the level of education may serve as a proxy for having more information and a better understanding of the issues involved. Because women are usually more closely involved with household fuel use, their education level was viewed separately from that of the men. This study constructed a variable for the highest level of education attained by an adult female member of the household, and an equivalent variable for adult males. The hypothesis is that the higher these education levels, the more likely that LPG would be chosen. It is also possible that more LPG would be used with rising level of education. The measurement of the education level varied from survey to survey, so that coding was not always proportional to the number of years of education.

The results for the six countries with household-level fuel prices show that, in every country, LPG *selection* increased with household expenditure and the highest levels of education attained by female and male household members, and LPG *consumption* increased with household expenditure and decreasing price of LPG. Variables serving as proxies for the level of infrastructure development (electricity connection, urban rather than rural residence) increased selection (except urban residence in Pakistan where natural gas was widely available) and consumption, while engagement in agriculture (broadly associated with biomass availability) reduced them. Rising prices of kerosene and firewood, which compete with LPG, also increased LPG selection. More details are provided in annex A.

As expected, income and LPG prices had by far the two largest effects. Education also had significant effects on selection. Having a male household member with the highest level of education available in the country would have the same effect as increasing household expenditure by 30 to 80 percent relative to an average household (with average expenditure and education levels). Women's education had even larger effects; a female household

member with the highest level of education available would have the same effect as increasing household expenditure by at least 50 percent.

The gender of the head of household was significant only in Sri Lanka for selection and in India for consumption, and the coefficient was positive in both cases. This may suggest that male-headed households tend to have more assets and better access to credit and employment, providing them with more cash to pay for LPG. Where the age of the head of household was significant, the coefficient was positive. One interpretation is that households headed by older members tend to be more established and have more resources available for LPG purchase.

Because firewood is typically much cheaper than LPG, moving households away from firewood to LPG would be expected to require a very large increase in the prices of firewood. Indeed, for consumption, the magnitudes of the price elasticity for LPG were about an order of magnitude larger than those for firewood, suggesting that firewood prices would indeed have to rise steeply before households would start consuming more LPG. In contrast, the magnitudes of elasticity for kerosene were comparable to those for LPG.

It is possible to calculate unconditional marginal effects, which combine the marginal effect on demand among users and the increased probability of use (Table A.2). Income elasticities varied between 0.3 and 0.7. Own price elasticities were close to 1 in India, Pakistan, and Sri Lanka. The price elasticity for kerosene was high in India and Pakistan, and household size generally had a negative effect on LPG consumption.

The results of modeling of the data from the remaining four countries, which did not report quantities of fuels consumed, were broadly aligned with the foregoing results. The magnitudes of the coefficients for household expenditures (significant in every equation) and agricultural engagement were broadly comparable between the two groups of countries for both selection and consumption. Those for education, the age of the head of household, indigenous head of household, and electricity connection were comparable for selection. Lastly, those for car ownership and urban residence were comparable for consumption. The coefficient for the dummy for a male head of household was significant in three equations, and, as with Sri Lanka and India, the sign was again positive in each case.

It has been argued by some that the gender of the head of household—who often controls decisions about expenditures—may influence LPG selection and consumption. Other things being equal, female-headed households might be more willing to pay for LPG, and those using it would purchase more LPG, because LPG use would benefit women much more than men. This study found that, once education was taken into account, the dummy for a male head of household was statistically significant in only five out of 21 equations, and the sign was positive in every case. As mentioned earlier, these results do not necessarily suggest that women are less willing to switch to LPG, but may simply indicate that, at the same total household

spending as defined in this study, female-headed households suffer from economic disadvantages—such as having greater difficulties accessing credit, not having title to land, and having fewer employment opportunities—thereby constraining their ability to earn cash and hence being less able to purchase LPG.

4. LPG Markets in Developing Countries

The foregoing chapter points to the importance of relative fuel prices and their ratios to income as well as the level of awareness about the costs and benefits of LPG (with education levels serving as a proxy) in determining household use of LPG. The way LPG markets are structured and managed affect the availability and prices of LPG, the amount of information available to consumers, the quality of service including reliability of refills and safety, and the extent of commercial malpractice harming consumers and other LPG marketers, all factors that influence the willingness and ability of households to use LPG. To investigate the state of these factors with a view to identifying how to promote the development of a vibrant LPG market for residential consumers, this study undertook a survey of LPG markets in 20 developing countries, supplemented by field visits to Ghana and Turkey (Matthews and Zeissig 2011). Ghana was selected because its decentralized system of bulk distribution and mini-filling plants is unique and results in low costs, while Turkey's management of safety and other aspects of LPG and its regulatory framework are among the most comprehensive in the developing world.

Descriptive statistics for countries selected

The 20 countries selected cover all of the World Bank's six regions: Ghana, Kenya, Senegal, and South Africa in the Africa region; Fiji, Thailand, and Vietnam in East Asia and Pacific; Albania, Moldova, and Turkey in Europe and Central Asia; Brazil, Dominican Republic, Guatemala, Mexico, and Peru in Latin America and the Caribbean; Jordan and Morocco in the Middle East and North Africa; and Afghanistan, Pakistan, and Sri Lanka in South Asia. Together, they span a wide range of income, population, and urbanization (Table 5). According to 2010 data, population ranged from less than a million to nearly 200 million, urbanization from 15 percent to 87 percent, and per capita GDP from US$452 to US$10,710 valued at the market exchange rate and from US$798 to US$15,340 valued at PPP. Currency appreciation between 2003 and 2010 varied from –39 percent in Ghana to +75 percent in Brazil. Because LPG prices on the international market are quoted in U.S. dollars, currency fluctuations exacerbate or moderate the adverse effects of rising fuel prices. The selection includes a small island economy (Fiji), a post-conflict country (Afghanistan), three countries with urban household use of natural gas (Moldova, Pakistan, and Turkey), two landlocked countries (Afghanistan and Moldova), four countries entirely reliant on LPG imports (Afghanistan, Guatemala, Fiji, and Moldova), and three of the top 10 autogas markets in 2008—Turkey (ranked number 3), Mexico (ranked 8), and Thailand (ranked 9).

Table 5: Population, GDP, and currency statistics in 2010 for countries selected

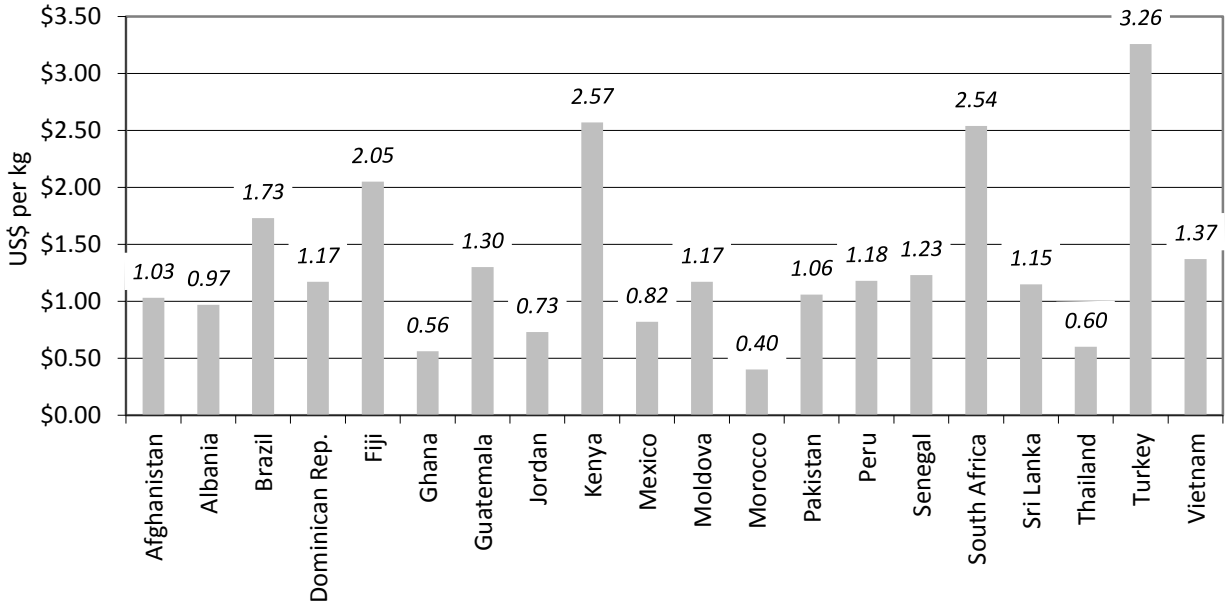
Country	Population	% Urban	GDP per capita (US$)		Currency appreciation 2003–10
			MER	PPP	
Afghanistan	34,385,068	24.8	452	798	5%
Albania	3,204,284	48.0	3,678	8,817	17%
Brazil	194,946,470	86.5	10,710	11,127	75%
Dominican Republic	9,927,320	70.5	5,195	9,280	-16%
Fiji	860,623	53.4	3,497	4,493	-1%
Ghana	24,391,823	51.5	1,283	1,625	-39%
Guatemala	14,388,929	49.5	2,863	4,740	-1%
Jordan	6,047,000	78.5	4,560	5,706	0%
Kenya	40,512,682	22.2	775	1,635	-4%
Mexico	113,423,047	77.8	9,166	14,566	-15%
Moldova	3,562,062	41.2	1,631	3,087	13%
Morocco	31,951,412	56.7	2,854	4,746	14%
Pakistan	173,593,383	37.0	1,007	2,674	-32%
Peru	29,076,512	71.6	5,291	9,470	23%
Senegal	12,433,728	42.9	1,042	1,917	17%
South Africa	49,991,300	61.7	7,275	10,486	3%
Sri Lanka	20,859,949	15.1	2,375	5,040	-15%
Thailand	69,122,234	34.0	4,613	8,490	31%
Turkey	72,752,325	69.6	10,106	15,340	0%
Vietnam	86,936,464	28.8	1,191	3,181	-17%

Source: WDI 2011 and IMF 2011a and 2011b.
Notes: The rate of urbanization is based on the percentage of people, not households as in Table 1. GDP is in 2010 U.S. dollars. Currency appreciation is based on annual average exchange rates. MER = market exchange rate.

Retail prices of LPG and household consumption of LPG in the selected countries vary by an order of magnitude or more. Retail prices of LPG sold in cylinders in December 2010 are compared in Figure 5. The highest price was recorded in Turkey, where taxes accounted for 40 percent of the total. In contrast, the tax component in the retail price in two other high-price countries is much lower: none in Kenya and only 12 percent in South Africa arising from a value-added tax of 14 percent. Prices in Kenya are high despite government removal of value-added tax in 2004 and of the East African Community common external tariff in 2005. Fiji, being a small island economy, suffers from lack of economies of scale and prices are understandably high. Brazilian prices are relatively high despite virtually constant producer prices and taxes since December 2002 in the local currency (although doubling in U.S. dollars because of currency appreciation); distribution and retail margins doubled in local currency in the intervening years (ANP 2011). At the opposite end of the spectrum are those where prices were kept artificially low: Morocco, Ghana, Thailand, Jordan, and Mexico. The price in Morocco had in fact remained constant in local currency between 1995 and 2010, while the currency

appreciated by only 1 percent. In Thailand, ex-refinery prices were set at about one third of Saudi Aramco's contract price in December 2010 (EPPO 2010).

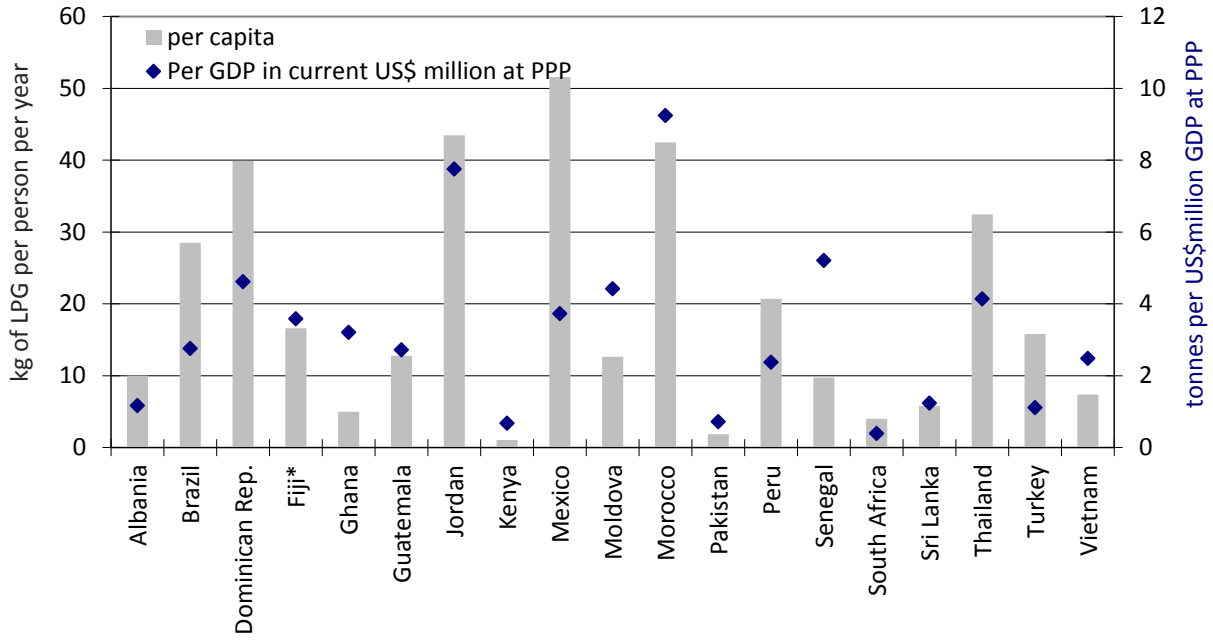
Figure 5: End-user prices of LPG in December 2010



Source: Matthews and Zeissig 2011.
Note: All prices are for LPG sold in cylinders except Moldova, where the price is the pump price for automotive LPG sold at filling stations. U.S. and Canadian prices are for Ontario and Texas, respectively. Most countries do not have pan-territorial prices and the prices shown are from one location, typically the capital city, or from one marketing company in the capital city, except in Brazil and Mexico where the government posts country-average prices.

It is not possible to obtain precise statistics on household consumption of LPG from national sales figures because end-use is not identified with each cylinder purchase. The amount of LPG sold in cylinders rather than in bulk is the starting point in estimating consumption by households, although commercial use—particularly in small-scale applications, such as for cooking by restaurants—is difficult to separate out. Estimates for the developing countries in the sample in 2009, the most recent year for which data are available in every country except Afghanistan and Fiji, are shown in Figure 6 in kg per person and per unit of GDP valued at PPP. Annual per capita consumption varied from 1.2 kg in Kenya to 57 kg in Mexico; given the small percentage of households consuming LPG in Kenya, the estimate is almost certain to include consumption by non-residential consumers. When consumption was scaled with respect to GDP, South Africa ranked at the bottom and Morocco, which registered the lowest price in the sample in December 2010, at the top.

Figure 6: Estimated household consumption of LPG in 2009

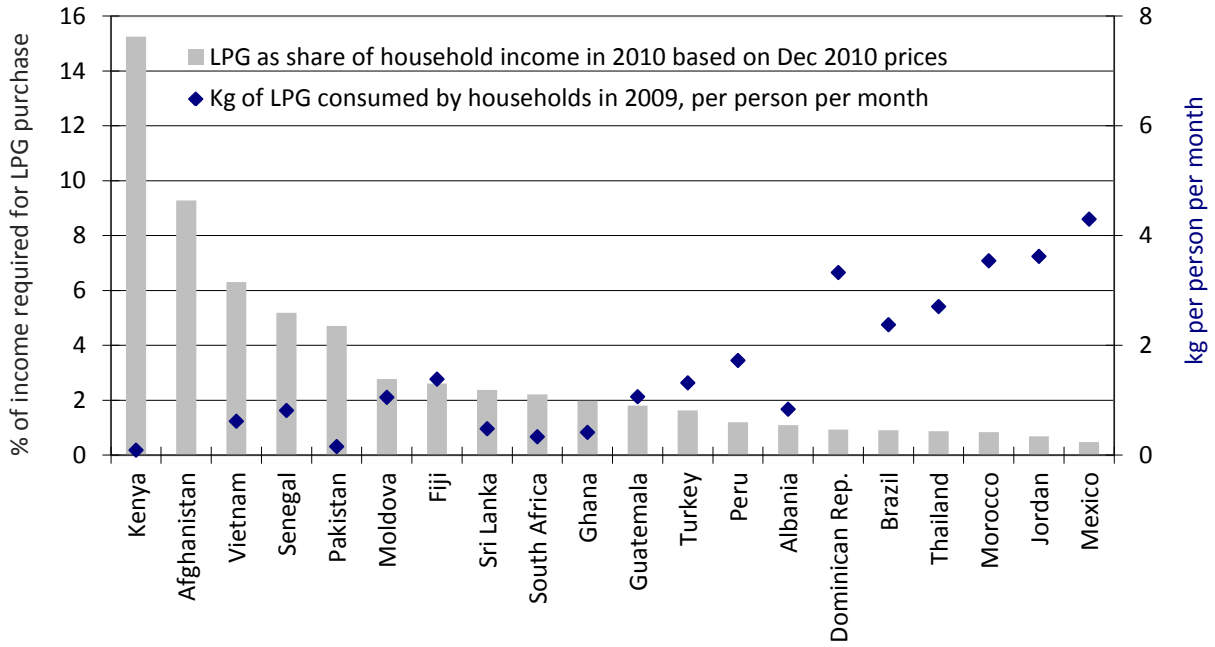


Sources: See appendix A.
Note: Consumption data are not available for Afghanistan.
* Data for Fiji are for 2008.

Based on the retail prices of LPG obtained for December 2010 and using several simplifying assumptions, the percentage of household income required to purchase LPG for use as the primary cooking fuel and water heating can be estimated. As in Table 3, the results can be considered one measure of affordability and are shown in Figure 7 in order of decreasing affordability. Household income was estimated from household total final expenditure as a share of GDP in 2010. Assumed monthly LPG consumption of 3 kg per person corresponds to 12–15 kg per household for a family of 4–5.[3] The correlation between the proxy for affordability and per capita consumption in Figure 7 is –0.54. Extensive use of other modern forms of energy for cooking and heating break this general pattern in Pakistan (where two-thirds of urban households use natural gas), South Africa (two-thirds of households use electricity), and Albania (electricity) (Kojima, Bacon, and Zhou 2011; WHO 2010). The top four countries where LPG is most affordable—Mexico, Jordan, Morocco, and Thailand—all subsidize LPG prices.

[3] Assumptions about per capita LPG consumption here and elsewhere are not intended to suggest that fuel consumption is directly proportional to household size; there are economies of scale in cooking. Rather, per capita consumption is one measure of consumption that can be compared across countries.

Figure 7: Share of household income required to be spent on LPG for regular use



Sources: Matthews and Zeissig 2011, those in appendix A, and World Bank staff calculations.
Notes: LPG consumption assumed to be 3 kg per month per person. Income is derived from household total final expenditure as the share of GDP in 2010. GDP data for all countries are from 2010. The household share of GDP in 2010 was not available in Afghanistan, Fiji, and Turkey, and the last year for which data were available—2008 in Afghanistan and Fiji and 2009 in Turkey—was taken. Consumption data are from 2009, except for Fiji for which only 2008 data are available. No consumption data are available for Afghanistan.

Infrastructure and market structure

The state of infrastructure for supplying LPG, where the country sources LPG from, and the degree of market concentration influence LPG prices. Among the 20 countries studied, only South Africa and Peru are self-sufficient in LPG supply, and Peru is the only net exporter. The remaining 18 countries in the sample import LPG to varying degrees, and hence opportunity costs are determined by import-parity prices.

There are economies of scale in the marine transport of LPG, raising shipping costs for small importing markets. Importers in Turkey contract parcels as large as 20,000 tonnes, enabled not only by the country's large LPG market but also in part by joint procurement activities and hospitality (swapping) arrangements for import-terminal storage facilities. This contrasts with parcel sizes of 1,200–5,000 tonnes in smaller markets in Sub-Saharan Africa and elsewhere (such as Ghana, Kenya, Senegal, and Sri Lanka). While these large parcels help reduce import shipping costs, Turkey suffers from high demurrage expenses on account of port congestion. Pakistan has private-sector terminal operators engaged in receiving, storing, and onward shipping LPG for third parties for set fees, potentially lowering the barrier to entry. Mexico has an extensive network of pipelines, spanning 1,835 kilometers in length, for importing LPG from

Texas and transporting it to other parts of the country; pipeline transport is cheaper than trucking.

Downstream in the supply chain, there are examples of opportunities that can exploit scale economy. Turkey's sole refining company, Tüpraş, serves as a bulk supplier to many small LPG marketing companies. By minimizing and even eliminating the need to build an import terminal, this arrangement lowers the barrier to entry for small marketers. Similarly, in Peru, Petroperu is a large bulk supplier not engaged as a competitor in the downstream business. The company supplies LPG to small operators, lowering the barrier to entry for these operators and helping to enhance competition by increasing the number of companies operating in the sector. Another means of avoiding duplication of facilities is to have mutual cylinder filling agreements. In Pakistan, the Oil and Gas Regulatory Authority (OGRA) encourages, and LPG distributors support, numerous hospitality arrangements whereby an operator would trade off storage capacity in one region in exchange for access to another company's storage in another region. These measures improve efficiency and enhance the potential for lowering costs.

Eight countries had no state ownership in both bulk supply and distribution. There was full or partial state ownership in 12 countries in bulk supply. There were only five countries with partial state ownership in distribution.

Table 6 shows the number of wholesale distributors and the Herfindahl-Hirschmann index (HHI), which is a measure of market concentration. The maximum value for HHI is 10,000, which represents a market with only one supplier. A market with an HHI above 1,800 is generally considered concentrated, while less than 1,000 is considered unconcentrated (U.S. Department of Justice and the Federal Trade Commission 1997). While there is no direct correlation between HHI and the level of actual competition, a market with high concentration is likely to be less competitive than an unconcentrated market.[4] Data to calculate HHI were available for only nine countries, and HHI ranged from a low of 473 for Ghana to a high of 10,000 for Jordan. The table also shows the size of the market in 2009, because the number of distributors, which influences HHI, is in part a function of market size. Ghana has a relatively small market but a large number of distributors and has a lower HHI than Turkey with more distributors. Thailand is at the opposite end of the spectrum, with the third largest market but only seven wholesale distributors.

[4] Where firms act in a collusive fashion, their ability to raise prices above the marginal cost is proportional to the ratio of the HHI to the price elasticity of demand. For more detail, see appendix B in Bacon and Kojima (2010).

Table 6: Number of wholesale LPG distributors and degree of market concentration

Country	Number of distributors	HHI	'000 tonnes consumed in 2009	
			Total	Residential
Afghanistan	12	—	—	—
Albania	5	—	42	32
Brazil	21	1,622	6,654	5,509
Dominican Republic	More than 65	809	842	391
Fiji	2	—	19[a]	14[a]
Ghana	58	473	161	118
Guatemala	3	4,498	233	179
Jordan	1	10,000	338	257
Kenya	9	—	75	42
Mexico	More than 300	—	8,837	5,780
Moldova	9	1,526	53	45
Morocco	16	—	1,895	1,344
Pakistan	90	—	553	316
Peru	53	—	1,001	595
Senegal	6	—	124	118
South Africa	5	—	322	197
Sri Lanka	2	5,800	167	119
Thailand	7	2,496	5,208	2,231
Turkey	64	968	3,620	1,134
Vietnam	20	—	1,148	636

Sources: Matthews and Zeissig 2011, government Web sites, and those in appendix A.
a. Consumption is for 2008.
Note:— = not available.

The number of distributors needs to be seen as the upper bound on the actual number of companies with distinct ownership, because distributors with different company names may ultimately be owned by a handful of large corporations. HHI may correspondingly represent a lower bound—that is, the actual level of competition may be lower than what the table at first glance may suggest. Aside from uncertainties about ownership, in countries with vast geography, such as Mexico and possibly Turkey, the presence of a large number of wholesalers in the country as a whole does not rule out local market concentration. A study published in 2004 on the Mexican LPG market found that, of the 30 political divisions (out of 32) analyzed, 21 had an HHI in excess of 1,800 and only one had an HHI lower than 1,000 (Yépez 2004).

The retail end of the supply chain is frequently handled by very small operators who deliver the cylinders to the homes and by consumers who pick them up at local filling stations or retail outlets. In most developing countries, rural retailers are small grocery shops. Regional sub-dealers use small trucks to deliver cylinders to larger villages, from which LPG may be carried by

animals and people to smaller villages. Regulating this end of the supply chain poses a considerable challenge.

Cylinder management

A factor that has significant effects on supply costs, the quality of service, and safety is cylinder management, which is unique to LPG. Because of its importance, this topic is treated separately and in some detail in this section.

Cylinder size

The need to keep LPG under pressure and distribute it in cylinders adds significantly to the cost of distributing LPG safely. There are large economies of scale in cylinder management, and scale economy has two distinct implications.

First, absent subsidies, buying LPG in large cylinders makes it more affordable for an individual household because the cost per kg decreases with increasing cylinder size. Not only is making one 15-kg cylinder cheaper than making five 3-kg cylinders, but the costs of cylinder inspection, maintenance, and refilling also rise with increasing number of cylinders. A large cylinder is also more convenient to the extent that it lasts longer, reducing the frequency of refills. But requiring a large sum of cash upfront for LPG purchase—for example, at US$1.35 per kg, it would cost US$20 to refill a 15-kg cylinder—would make LPG accessible only to the better-off in many developing countries. LPG is sold only in discrete quantities matching cylinder sizes available on the market. In contrast, kerosene can be sold in any quantity and the unit price of kerosene is typically the same whether a household buys only half a liter or 20 liters, because there is no equivalent of cylinder management with attendant scale economy for kerosene.

Second, to develop a commercially viable LPG market, a relatively high concentration of regular users of LPG—that is, a high population density with a good share of households willing and able to buy 10 kg or more a month—is ideally required. A high volume turnover may enable LPG bottling plants to be located close to consumption centers, lowering the cost of LPG distribution. Where consumers are spread out over a large area, they tend to be poor and consume little. The cost of transporting numerous cylinders over long distances and delivering only a few cylinders at a time to several villages is very high, and yet these are the very consumers who are least capable of paying high prices and for whom much cheaper alternatives exist.

Small cylinders are easy to carry around so that home delivery by the retailer is not essential, and the cost of LPG refill is relatively small. For this reason, small cylinders have been suggested as one way of making LPG affordable to the poor. Aside from lower costs per refill, cylinder deposit fees or purchase costs are also lower. LPG marketing companies frequently mount burners on top of small cylinders and market them as a package. But, absent cross-subsidy, the

price per kg would be much higher, and the number of cylinders in circulation would be correspondingly large, posing a challenge to enforcement of safety standards. And if LPG delivery is irregular or unreliable—as in many rural areas, because there is not enough demand to justify sending a delivery truck frequently—then the need to refill cylinders frequently can mean that a household must accept running out of LPG for days at a time. Fuel outage can be avoided by keeping two or more filled cylinders, but doing so adds to the initial start-up cost.

International experience with small LPG cylinders has been mixed. In some countries, small cylinders for household use have been tried by the industry in the past but eventually abandoned. For example, the LPG industry in Turkey experimented with 2, 3, 5, 6, and 12 kg, and eventually chose to retain only 2 and 12 kg, with 2 kg reserved primarily for camping.

In the sample countries, use of small cylinders is widespread only when LPG sold in small cylinders is cross-subsidized and where there is a long history of subsidizing LPG generally. In Senegal, 95 percent of LPG for residential consumers is sold in 2.7- and 6-kg cylinders, which have historically been heavily subsidized and, until recently, the lowest price per kg was offered for the smallest cylinder. As an illustration, the retail prices that went into effect on March 21, 2009 were CFAF 370 per kg for LPG sold in 2.7-kg cylinders, CFAF 417 per kg for 6-kg, CFAF 537 for 9-kg, and CFAF 601 per kg for 12.5-kg cylinders (*All Africa* 2009). Although the price differences have been narrowed since and the unit price of LPG is now the same between 2.7 kg and 6 kg, it remains slightly lower than that for LPG sold in 12-kg cylinders. In Morocco, there are more 3-kg cylinders (again heavily subsidized) than any other size: 20 million 3-kg cylinders in circulation in 2009, followed by 13 million of 12-kg cylinders; the unit price of LPG is the same regardless of the cylinder size. In the 20 developing countries surveyed, cylinders that are 6 kg or smaller are on the market in Afghanistan (1 kg and several other sizes), Brazil (2 kg and 5 kg), Fiji (4.5 kg), Ghana (5 kg), Kenya (3 kg and 6 kg), Morocco (3 kg and 6 kg), Peru (3 kg and 5 kg), Senegal (2.7 and 6 kg), South Africa (1.4, 3, 4.5, 5, and 6 kg), Sri Lanka (2.3 kg and 5 kg), Thailand (4 kg), and Turkey (2 kg). In some countries, small cylinders are used primarily or solely for camping and not for regular household use. In other countries, barring Senegal and Morocco, even where there are smaller-size cylinders, the most commonly used cylinders are in the range 10–15 kg. Still, especially with rising international prices of LPG, marketers in some countries are giving renewed consideration to small cylinders.

One notable exception to 10–15 kg (or smaller as in Senegal and Morocco) being the predominant size is Mexico, where only half of households using LPG purchase it in cylinders. According to the energy ministry, 91 percent of LPG cylinders in circulation in June 2009 were split evenly between 20 and 30 kg. The remaining LPG-user households were supplied by (very large) stationary tanks on their premises (filled by LPG delivery trucks) or by local pipeline networks fed from similar stationary tanks. The trend has been to shift away from cylinders to stationary tanks. Monthly household consumption averaged 23 kg in 2009, very high compared

to other developing countries (SENER 2010). The cylinder market in Brazil is also migrating to LPG tanks, as many new residential buildings are built with LPG tanks, similar to commercial clients (Petrobras 2011).

Cylinder ownership, refilling, and safety

Whether cylinder ownership can be clearly traced; who assumes the responsibility *in practice* for cylinder maintenance, repair, and replacement; who pays; and how customers obtain cylinder refills are all inter-related questions, and these in turn affect LPG prices as well as the safety of LPG cylinder use.

The cost of cylinder handling depends on the number of cylinders in circulation. In general, for a customer not to run out of LPG, there needs to be almost one cylinder in transit (transport, storage, bottling) for every cylinder being used by the household, although the number of extra cylinders in the system may fall to as low as 0.5 in an extremely efficient system. More specifically, a customer with two cylinders typically requires 2.8–3.0 cylinders in total in the supply chain on average, a customer with one cylinder a total of 1.8–2.0 cylinders, and so on. These extra cylinders add to the cost of supply. In practice, even with an extra cylinder in transit, a customer with only one cylinder at home is likely to run out of LPG for half an hour or longer when the cylinder runs empty while obtaining a refill.

Unlike natural gas, which rises when leaked, LPG is denser than air and hence sinks to the ground upon release. This means that any spark can trigger an explosion near ground level where people are located. Maintaining the physical integrity of LPG cylinders is therefore imperative for public safety. Cylinder ownership influences how an LPG marketer maintains cylinders and whom to hold accountable if there is an accident. If ownership is unclear, there could be far less incentive for individual marketing companies to spend time, money, and effort inspecting cylinders carefully and repairing or scrapping faulty ones. If empty cylinders are exchanged for filled ones, a given cylinder goes through the hands of numerous customers. Where customers go to different marketing companies to refill, no one company may want to assume full responsibility.

Globally, cylinder ownership can be broadly classified into company owned and customer owned:

1. When the company owns the cylinder, the company leases the cylinder to the customer. The customer exchanges an empty cylinder for a full one, paying only for LPG. The company is responsible for filling and maintaining cylinders. It is common to have the owner's investment secured through a system of refundable deposits or guarantees in cash, although the deposit may be set at a level that is much lower than the manufacturing cost of the cylinder to encourage LPG use.

2. When the customer owns the cylinder, there are two modalities.

    2a. The customer exchanges a legally owned cylinder for another. The initial cylinder is somewhere in the inventory float and the LPG marketing company is responsible for maintenance and replacement. The customer must accept whatever is available from the company—she may hand in a brand new cylinder just purchased and get a 10-year-old one, thereby immediately losing the value of the cylinder just purchased. For a customer who continues to use LPG for a long time, this is not an issue, but for someone who decides to stop using LPG after a few months, the financial loss is not negligible.

    2b. The customer has a personally identified cylinder, takes it to the local filling plant to be filled, and brings it home. The customer retains the same cylinder through its life and is responsible for any maintenance or replacement. The key safety element is the diligence of the operator filling the cylinder in rigorously inspecting and rejecting any cylinders not meeting safety requirements. The customer must be refused a filling and required to have the cylinder properly repaired or buy a new one. But the incentive to refuse a filling is weakened if other companies are willing to refill a substandard cylinder.

In the group of countries investigated, by far the most prevalent is the first system. In some markets, two or all three of the ownership patterns may co-exist. Globally, the case of customers owning and keeping the same cylinders (2b above), rather than exchanging cylinders for filled ones, is quite rare.

Where an empty cylinder is exchanged for a filled one (1 and 2a), an important question is whether there is interchangeability of cylinders across companies. Where there is complete interchangeability, incentives for any given company to repair and replace cylinders are considerably weakened unless there is a way of enforcing rigorous maintenance and replacement across all companies. Kenya's 2009 LPG regulations require that all wholesalers participate in the cylinder exchange pool, managed by a committee that regulates cylinder exchange among marketing companies. Cylinder sizes are also regulated—allowing 1, 3, 6, and 13 kg—and all cylinders are required to be fitted with unified valves. This system relies on all wholesalers to adhere to the same maintenance standards. (At the retail level, however, Kenya legally prohibits an operator from filling a cylinder without the permission of the cylinder or brand owner.)

Where there are different colors, markings, or both to identify cylinders belonging to different companies and repainting or filling cylinders belonging to others is legally prohibited (except where there are mutual arrangements), the incentives for maintenance and replacement are stronger because accidents can be immediately traced to the companies responsible. In many

countries, however, there is a significant failure in the enforcement of cross-filling prohibition. Lack of enforcement weakens incentives because there is no guarantee that repaired or replaced cylinders will not be diverted to other companies. The end result is poor maintenance and physical deterioration of the cylinder stock. The key is to set up a system where companies can be assured through effective enforcement that spending money on maintenance and replacement of their cylinder stock will not end up benefiting free-riders. This question is independent of whether cylinders are company-owned or customer-owned.

South Africa and Turkey have clear rules about ownership and cross-filling (prohibited except where mutual agreements exist), backed up by law and court action. In South Africa, each company's cylinders are color-coded and engraved with the company's name or logo, and cross-filling is prohibited unless explicit written permission is granted. The prohibition is backed up by the law and anyone caught cross-filling cylinders can be taken to court.

Turkey has a formalized system of cylinder distribution. By law, every cylinder must be insured, delivered to the residence (home delivery is legally required), and mounted by a certified installer. Installers are certified by the education ministry and the Chamber of Engineers. Cross-filling is minimized due to strong support from the legal system and courts to the LPG marketing companies. To ensure safety, all engaged personnel, from the chief executive officer down to delivery truck drivers and installers, are trained and certified with mandatory, regularly offered, refresher courses.

At the opposite end of the spectrum is Guatemala where, as of 2002 when the World Bank last conducted a field visit for a detailed study of the country's LPG market (Ahmed and others 2005), there were no rules for cylinder ownership or exchange. Distribution companies painted cylinders in different colors, but a cylinder could be filled at any filling plant regardless of its color or markings. Although there were quality and maintenance standards for LPG cylinders, it was difficult to assign responsibility because ownership had not been legally established.

Among the 20 countries examined, only Ghana falls entirely under 2b: consumers own and retain cylinders, which must be taken to filling plants to be refilled. There are many bulk-supplied mini-filling plants throughout the country. This means that there is no transport of filled LPG cylinders from and return of empty cylinders to bottling plants—that is, cylinder management is effectively bypassed—and no significant exchange of cylinders. This approach substantially reduces direct costs of supply, because the burden of transporting numerous cylinders to individual customers falls entirely on customers themselves, and conversely increases indirect costs of purchase. Customers take cylinders home by car, motorcycle, bicycle, or other means of non-motorized transport. In Ontario Canada, where systems 2a and 2b co-exist, LPG sold in 2b is much cheaper than in 2a.

The substantial cost reduction in 2b is a considerable advantage. However, this approach tends to compromise safety. Basic cylinder maintenance—checking for leaks, replacing valves, and repairing leaking cylinder heads—is carried out at some filling plants, but operators often do not check for recertification dates, carry out prescribed visual inspection of cylinder condition, or reject cylinders that are due for testing or that do not pass a visual inspection.

The start-up cost of LPG consists of paying for the cylinder, regulator, and the hose in the form of a deposit fee or purchase, and purchasing a stove. Recent prices charged for new cylinders include US$44 for 14.5-kg cylinder Ghana in July 2011; US$33 for a 12.5-kg cylinder and US$8 for a regulator in Sri Lanka in October 2011 (Laugfs Gas Limited 2011), and US$23 including a 14-percent value-added tax for 9, 12, and 14 kg in South Africa in October 2011. LPG stoves cost comparable amounts, although small camping stoves are cheaper. For example, a stove that fits on top of a 2-kg cylinder in Sri Lanka cost US$17 in October 2011 (Laugfs Gas Limited 2011).

Fiberglass composite cylinders, a relatively recent innovation, are much lighter, and hence transporting them is easier, which is an important consideration if customers assume the responsibility for home delivery as in Ghana. They are also transparent, so that it is easy to check how much is left. Being able to see the amount of LPG in the cylinder can help curb short-selling, and makes it easier to estimate when the cylinder will run out. However, these cylinders are much more expensive. For example, even in a country as wealthy as Saudi Arabia, they were introduced only in July 2010 at more than double the price of regular cylinders: 350 riyals (US$93), compared to 150 riyals (US$40) for the latter (Arab News 2010). As a result, the market penetration of composite cylinders in developing countries has been limited or non-existent. Although composite cylinders were introduced in Ghana in 2008, none of the LPG marketing companies and government officials met during the field visit in July 2011 had heard of them. Similarly, in Turkey, LPG marketing company representatives had not seen composite cylinders on the market.

Lowering the costs of cylinder and stove acquisition for residential consumers would lower the barrier to switching to LPG and could help a segment of middle-class households who are able to pay for LPG but find it challenging to save enough money to pay for the start-up cost. This segment, however, may be narrow because, unlike electricity, the difference between the start-up cost and monthly LPG fuel cost is not all that large. As a result, many households who cannot pay for a cylinder and a stove are also unable to pay for regular use of LPG (ESMAP 2003). For this reason, before asking the government to subsidize the acquisition of the first cylinder, stove, or both, the distributional impact of this subsidy would need to be carefully reviewed. One question is who pays for the difference: government, the rest of consumers, or the consumer benefiting from the lower payment for acquiring the cylinder by spreading the payment over time. In Turkey, the distribution companies cover 65 percent to as much as 80 percent of the actual cost of the cylinder, depending on their marketing policy, and consumers

pay for the balance in the form of a deposit fee. In South Africa, the current deposit fee of R150 (US$20) before value-added tax is about half of the cost of cylinder manufacture. The required amount for a refundable deposit fee is usually approximately 130 percent of the replacement cost of the cylinder. If marketing companies are offering a discount on cylinders, as opposed to giving the option of an installment plan for cylinder acquisition, then all consumers in effect subsidize new consumers—through slightly higher LPG prices to enable cost recovery or through higher safety risks if companies compromise cylinder maintenance and renewal to compensate for the loss in revenue.

Setting low cylinder deposit fees or purchase prices is not without risks. If dealer incentives or government subsidies lower deposit fees sufficiently, the cylinders may be resold on the black market or smuggled out of the country, and similarly with stoves. Customers obtaining cheap or free LPG cylinders in developing countries have also been known to use them for other purposes, such as metal beating or as flower pots. In all these cases, LPG marketers providing the cylinders make a loss because the business that these subsidies are intended to generate does not materialize. These losses will eventually have to be covered by higher prices elsewhere, and also weaken the incentive to implement full and proper maintenance procedures.

LPG stoves cost about the same as the unsubsidized prices of new cylinders. Quality control (durability, safety, performance) of LPG stoves and price competition would help promote household use of LPG.

Regulatory and institutional framework

Government policy affects virtually all aspects of the LPG market. Prices are affected directly by pricing policy and indirectly by competition policy, the extent to which economies of scale are exploited, regulations, and the level of enforcement, including the degree to which short-selling is tolerated. Safety is affected by regulations and their enforcement, as is the quality of service offered.

Sector legislation and regulation

The nature of legislation governing LPG depends on country circumstances. In every country, to the extent that environment, industrial health and safety, taxation, and legislation governing competition and commercial malpractice apply to all industries, general laws and regulations apply to LPG, even if LPG is not explicitly mentioned. In addition, there is typically sector legislation that has more details applicable to LPG, and this is indeed the case in 16 out of 20 countries. In countries with commercially recoverable reserves of hydrocarbons (oil and natural gas), there may be a petroleum law governing both upstream (exploration, development, and production of hydrocarbons) and downstream (refining, transport, wholesale, distribution, and retail of hydrocarbons), of which LPG legislation pertinent to this study falls under the latter.

Some countries with significant hydrocarbon reserves may have separate upstream and downstream laws. In other countries, downstream petroleum may be covered in an energy law covering both fuels and electricity, or even in a broader law covering multiple sectors (of which energy is one).

It would be rare to have a law devoted only to LPG. In the sample of developing countries, only Brazil has a law exclusively devoted to LPG, narrowly focused and mandating transparent weighing of LPG cylinders (Brazil 1995). Turkish law 5307 entitled "Liquefied Petroleum Gas (LPG) Market Law and the Law Amending the Law on Electricity Market" (Turkey 2005), although not dedicated only to LPG, is among the most comprehensive laws for LPG in developing countries. As a mark of a good law, this law establishes the framework and principles for sector operation but largely leaves implementation details to regulations. It addresses autogas, cylinder, and bulk LPG suppliers separately. It requires each licensed distributor to hold 20 days of supply in storage; submit annual sales projections and quarterly updates to the *Enerji Piyasası Düzenleme Kurumu* (EPDK, Energy Market Regulatory Authority); employ only those who have received training and obtained certificates in their main fields of activities; educate and inform consumers if the license holder is a dealer; and pay a fee to support the activities of the EPDK, which is set at 0.1 percent of the net sales up to US$2 million. The law requires those handling LPG cylinders to handle only cylinders that are marked with the distributor's brand name and logo (except where there are prior agreements with other distributors); inspect cylinders before, during, and after filling for any defects; and not fill cylinders that are rusty, unpainted, or bear marks of damage including those from fire. Enforcement is effective for the most part.

Setting aside quality and other standards, nine countries have regulations or rules devoted to LPG. The Dominican Republic, Kenya, Morocco, and Peru have comprehensive regulations devoted to LPG. Brazil has four resolutions covering various aspects of LPG (Petrobras 2008). Mexico and South Africa issue retail LPG prices as regulations and directives. The National Petroleum Authority (NPA) of Ghana has issued two public notices laying down requirements for LPG marketing and construction of LPG bottling plants, and Pakistan has "LPG (Production and Distribution) Rules" of 2001, last amended in August 2009.

Technical specifications for LPG and associated equipment are fairly standard and well established globally. Hundreds of technical standards and codes of practice for protection of occupational health, industrial safety, and the environment; design, construction, maintenance, and fire protection of buildings, electrical and other installations; construction materials, transport equipment, machinery and other equipment; appliances such as LPG stoves; and for quality testing methods have been developed worldwide over decades and are constantly being updated by numerous specialized national and international industry organizations and government entities. Examples include LPG standards and codes issued by the International

Organization for Standardization (ISO), the European Union, ASTM International (previously American Society for Testing and Materials), American Petroleum Institute (API), and the (U.S.) National Fire Protection Association (NFPA). Not much can be gained by re-creating product specifications and health, safety, and environment standards in each individual developing country. One effective way of taking advantage of the standards that already exist is to adopt them formally by reference, rather than transcribe all or part of the text of an international code in local regulations and standards. By formally adopting international codes, local regulations and standards will be automatically updated when changes are made to the original codes. Codes adopted from outside the country may need to be adapted to local circumstances. An example of a failure to do so is wholesale adoption of Canadian standards by a tropical country without excluding detailed protection against freezing temperatures. The approach adopted by the regulatory agency for LPG in the U.S. state of Texas illustrates good practice in this regard. The agency has formally adopted the most important industry standards together with all other standards referenced therein, but lists the exclusions, changes, and additional requirements and corrections as appropriate for each section of the code.

In the sample countries, Ghana, Albania, Moldova, Morocco, Pakistan, and Sri Lanka have formally adopted international standards without apparently developing any of their own. Mexican standards, in contrast, are largely based on voluntary standards issued by API, ASTM, NFPA, and others, but many do not formally adopt them so that these domestic standards, which are the ones that are enforced, are not automatically updated as the standards on which they are based are revised from time to time. The hydrocarbon law of the Dominican Republic stipulates that equipment and facilities comply with international technical standards accepted in the petroleum industry if domestic standards do not exist, which is an example of how *not* to set standards because such wording introduces ambiguities.

A well-developed regulatory framework includes requirements for consumer education as well as training and certification of management and personnel of the operators. Consumer education is particularly important for LPG because the cylinders, valves, and regulators remain under the sole control of the consumers for extended periods in their homes, where accidents can occur. It is critically important that the regulators and the suppliers educate the small distributors and consumers by appropriate means, because what governs safety to a large measure is the knowledge of small operators at the very end of the supply chain and of individual consumers, and realization on their part that they are handling a potentially dangerous product. A legal review of the 20 countries pointed to a near absence of such requirements. The legislation typically contains detailed provisions for enforcement and sanctions, but rarely does it require training of the operators and dissemination of information to the public as in, for example, the 1992 Consumer Protection Law of Mexico. A rare exception

is Turkey's law 5307, which requires licensed distributors to educate the vendors and consumers.

In nine countries, regulators that cover LPG have been set up by law as separate institutions outside of any ministry: the National Petroleum Authority (NPA) of Ghana, Energy Regulatory Commission (ERC) of Kenya, National Energy Regulator of South Africa (NERSA), National Energy Regulatory Agency (ANRE) of Moldova, Energy Market Regulatory Authority (EPDK) of Turkey, National Petroleum Agency (ANP) of Brazil, Supervisory Agency for Energy and Mining Investment (OSINERGMIN) of Peru, OGRA of Pakistan, and the Public Utilities Commission of Sri Lanka (PUCSL). In the remaining countries, a department, directorate, or an office in a ministry—of energy, petroleum, industry, commerce, or economy—oversees the LPG sector. In addition, other ministries may handle specific aspects, such as environmental, health, and transportation standards monitored and enforced by the respective ministries. Regulatory and institutional frameworks in the 20 developing countries under study are summarized in Table 7.

Table 7: Legislation and regulatory agency in sample countries

Country	Law covering downstream petroleum[a]	Dedicated LPG law, regulations, or rules[b]	Fuel quality and other standards		Regulatory agency in charge of LPG
			Issued	International standards formally adopted	
Afghanistan	—	—	UC	UC	Ministry
Albania	Downstream	—	√[c]	√	Ministry
Brazil	Energy, Fuel	√	√	√	ANP
Dominican Rep.	Fuel	√	√	√[d]	Ministry
Fiji	—	—	—	—	Ministry
Ghana	Downstream	√	√[c]	√	NPA
Guatemala	Petroleum	—	√	√[e]	Ministry
Jordan	—	—	√	√	Ministry
Kenya	Energy	√	√	√	ERC
Mexico	f	√	√	—[g]	Ministry
Moldova	Downstream	—	√[c]	√	ANRE
Morocco	Downstream	√	√[c]	√	Ministry
Pakistan	Downstream	√	√[c]	√	OGRA
Peru	Petroleum	√	√	√	OSINERGMN
Senegal	Energy	—	√	—	Ministry
South Africa	Downstream	√	√	—	NERSA
Sri Lanka	Downstream, public utilities	—	√[c]	√	PUCSL
Thailand	Energy	—	√	h	Ministry
Turkey	Downstream	—	√	√	EPDK
Vietnam	—	—	√	h	Ministry

Sources: government websites and Matthews and Zeissig 2011.

— = Not issued; UC = unconfirmed because the government Web site posting standards is currently under construction.
a. Downstream = there is a law devoted to the downstream petroleum sector; energy = downstream petroleum is covered in a general energy law, except in Senegal where the law covers energy, minerals, and water resources; petroleum = there is a law covering both upstream and downstream; fuel = there is a law covering various fuels, including biofuels or coal; public utilities = Public Utilities Commission of Sri Lanka Act of 2002.
b. Excluding fuel quality, cylinder, and other standards.
c. No national standards appear to have been developed; all standards identified in Matthews and Zeissig (2011) correspond to international standards that have been formally adopted.
d. Whether international standards have been formally adopted is unclear. See Matthews and Zeissig (2011) for more detail.
e. The method of formal adoption of international standards differs from that in other countries in that it is based on references to Guatemala's membership in the Central American Customs Union and the union's resolutions that adopt international standards by reference.
f. Laws defining activities of Mexico's national oil company, Pemex, cover the hydrocarbons sector including downstream petroleum.
g. International standards are referred to, but the wording of the text cannot be interpreted as formal adoption of these standards.
h. Whether international standards have been adopted could not be confirmed because of the language barrier faced by the study team.

Short-selling is always a problem in fuel sale and is particularly problematic with LPG. The tare weight of the cylinder may not be clearly marked and, even if it is, its accuracy is difficult to verify; the customer may not be able to weigh the cylinder before and after purchase; and the cylinder may be filled with substances other than LPG. It is no coincidence that the only law devoted to LPG in the 20 countries surveyed—Lei N^{o} 9.048 of Brazil—concerns transparency in weighing cylinders, starting with the requirement that the cylinder tare weight must be clearly visible to the customer. The 2009 LPG regulations in Kenya require every retailer to have a properly calibrated weighing instrument.

As expected, enforcement varies from country to country. An example of a country where information on enforcement is transparent is Pakistan. OGRA is self-financed through charges and fees including license fees, fines and other penalties collected, and proceeds from sales of data and other publications (Pakistan 2002). It regularly issues a request for expressions of interest for third-party inspection of the works of licensees, and posts the results of inspection (for safety, cross-filling, and over-charging), including the fines imposed, on its Web site. More recently, OGRA has announced that it is setting up its own enforcement office.

Just as the existence of regulations does not imply widespread compliance with the regulations, absence of regulations does not mean that unsafe practices abound. In countries where the regulatory framework is incomplete, regulators and the industry often apply international standards. The subsidiaries of major international oil companies and well-organized local operators also tend to apply well-established international standards whether they are mandatory or not. In Afghanistan, some LPG suppliers have contracted international companies providing inspection, testing, and certification services to certify the design and construction of new facilities and check the quality of imported fuels at the border.

Pricing policy

The government plays a role in setting prices—ranging from intervening only when prices rise too steeply to subsidizing and freezing prices for years at a time—in more than half of the sample countries (Table 8). The government does not intervene in price setting in six countries.

Table 8: Pricing policy for LPG in sample countries

Country	Pricing policy
Afghanistan	Deregulated.
Albania	Deregulated.
Brazil	Deregulated. Assistance to enable the poor to use LPG takes the form of vouchers for LPG in *Bolsa Familia*, the government's social welfare program.
Dominican Rep.	Ministry of Industry and Commerce issues an official price notification every week based on import-parity pricing. In Sep 2008, the price subsidy for LPG was eliminated and replaced with a social protection scheme whereby 800,000 *bonogas* cards were issued to poor families, entitling them to a monthly reduction of RD$228 (about US$6) for LPG purchase. As of mid-2011, about 750,000 families were benefitting from this scheme.
Fiji	Deregulated.
Ghana	NPA sets price ceilings and uses the government budget and a cross-subsidy from gasoline to subsidize LPG and other petroleum products. The subsidy from the budget has been much larger than the cross-subsidy in recent years, and is used to pay importers and the refinery the difference between the import-parity price and the regulated ex-refinery price, amounting to hundreds of U.S. dollars per tonne. There were no LPG price adjustments in 2010. The price was increased by 25% in Jan 2011, but the price ceiling remains below US$0.70/kg.
Guatemala	Deregulated.
Jordan	Regulated and subsidized. In 2008, the government deregulated the prices of all petroleum products except LPG. Subsidies for fuels other than LPG were re-introduced but virtually eliminated in 2011.
Kenya	Deregulated.
Mexico	Ministry of Energy regulates transport and distribution tariffs. Ministry of Economy gazettes maximum consumer prices in 145 distribution zones every month. When the benchmark prices in Belvieu, Texas, United States, are high, prices in Mexico have been kept below import-parity levels, despite Mexico's being a large net importer of LPG.
Moldova	Prices must comply with "Methodology of Oil Products Price Calculation and Application," an administrative board decision of Oct 2007. It limits profitability to 10%. ANRE monitors every price adjustment based on comparative analysis of prices in neighboring countries.
Morocco	Regulated and subsidized. Prices remain unchanged for years at a time.
Pakistan	LPG from gas fields and refineries are subject to maximum producer prices set by OGRA every month. Prices of imported LPG are deregulated. Companies are required to report retail prices every month to OGRA.
Peru	Prices were deregulated (market-based) by a 2004 law but the Petroleum Product Stabilization Fund is used to keep domestic prices low in times of high international prices, using savings in the fund from times of low international prices by keeping domestic prices relatively high. In effect, this fund has not been self-sustaining, requiring budgetary transfers in excess of US$1.5 billion since 2005.
Senegal	The National Committee for Hydrocarbons regulates prices based on an import-parity formula, but prices have been frozen at times, especially when international prices are rising.

Country	Pricing policy
South Africa	Minister of Energy issues maximum retail prices for residential customers in 54 zonal areas every month as LPG regulations.
Sri Lanka	LPG is a specified item, requiring approval of the Consumer Affairs Authority prior to a price increase.
Thailand	The Oil Stabilization Fund has historically been used to subsidize LPG. Ex-refinery prices have been kept at a fraction of world prices. LPG price has been frozen at 18.13 baht per kg since March 2008, and the new administration that came into power in July 2011 has pledged to maintain the price of LPG for households at that level until the end of 2012 while raising autogas prices by 0.75 baht per kg every month for a total increase of 9 baht per kg in 2012.
Turkey	Largely deregulated but the EPDK, where it deems that market conditions warrant government intervention, is authorized to establish price ceilings regionally or nationally for a maximum of two months.
Vietnam	Deregulated, but the finance ministry issued a circular in Oct 2010, requiring price registration for LPG and 16 other goods and services and stating that the government can apply price stabilization measures for these 17 items.

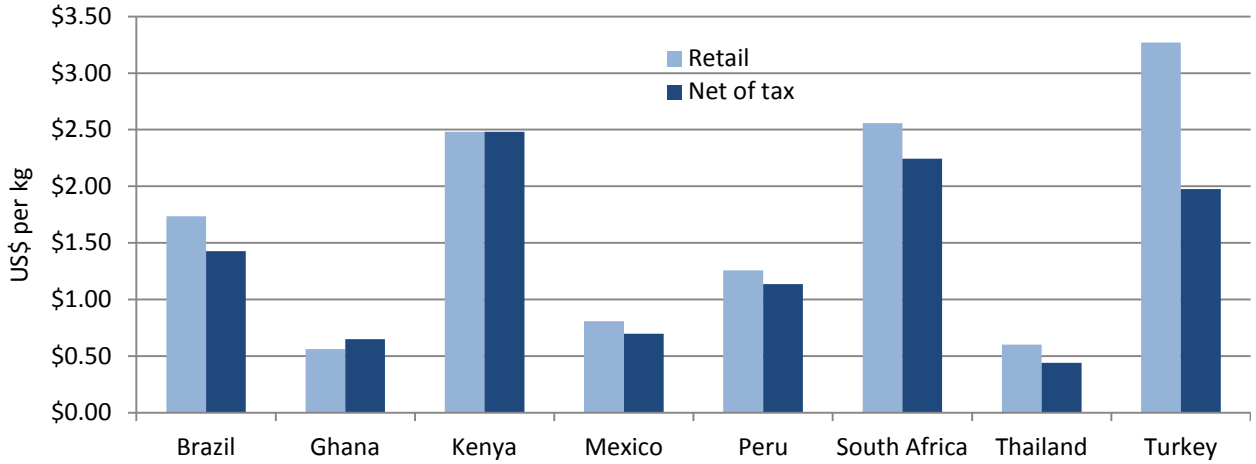
Sources: Matthews and Zeissig 2011, Petrobras 2011, DominicanStar809 2011, Peru 2011, Reuters 2011, Economist Intelligence Unit 2011, and government Web sites.

An oil price stabilization fund has been historically used to subsidize LPG in Thailand and Peru. The budgetary transfers for the price stabilization fund in Peru in 2010 alone amounted to S/. 1,195 million (US$420 million), although a breakdown by fuel type is not available (Peru 2011). LPG prices in Thailand have been subsidized for decades, reportedly amounting to more than US$500 million of subsidies in the first seven months of 2011 (*Platts Oilgram News 2011*). The new government that came into power in July 2011 plans to start reducing subsidies for autogas in 2012 but hold the price of residential LPG constant until the end of 2012. In Ghana, the ex-refinery price was subsidized by an estimated US$0.42/kg in July 2011, and the cross-subsidy from gasoline provided an additional subsidy of US$0.12/kg, totaling US$0.54/kg. A government official reported in August 2011 that the government was spending US$10 million a month on LPG subsidies (*All Africa* 2011a). Pemex posts a graph of estimated annual subsidies since 2003 on its Web site. The subsidies, for which Pemex is not necessarily reimbursed by the government in full, in recent years amounted to US$2.4 billion in 2008, US$0.5 billion in 2009, US$1.9 billion in 2010, and US$1.5 billion during the first seven months of 2011 (PGPB 2011). The most subsidized LPG on a unit basis is found in Morocco, where the government compensation fund is used to subsidize prices of such basic commodities as LPG, sugar, and flour.

Information on the price structure available on government Web sites and information collected during the field visit to Turkey enable calculation of net-of-tax prices of LPG in December 2010 in several countries (Figure 8). The net-of-tax prices calculated in this way point to the degree to which subsidies are not made explicit. Both Ghana and Thailand post subsidized ex-refinery prices in the price structure without indicating the level of subsidy; subsidies are made explicit only for the cross-subsidy from other fuels. As such, the net-of-tax

prices in the figure are not directly comparable. In Ghana, the subsidy component of the ex-refinery price in December 2010 is estimated to be about US$0.51/kg, making the net-of-tax price inclusive of the ex-refinery subsidy US$1.16/kg, about the same as in Peru.

Figure 8: End-user prices of LPG with and without taxes and other government charges in December 2010



Sources: Appendix A and World Bank staff calculations.
Note: The net-of-tax prices are computed from the price structure available in Brazil, Ghana, Peru, South Africa, and Thailand, and do not fully capture all subsidies in Ghana and Thailand.

Subtracting ex-refinery prices from net-of-tax prices gives the sum of bottling, transport, and retailing costs. This nets out implicit subsidies in ex-refinery prices. The results for December 2010 vary by an order of magnitude across the countries for which information was available to carry out the calculations: US$1.43/kg in South Africa, US$0.99/kg in Turkey, US$0.91/kg in Brazil, US$0.52/kg in Peru, and US$0.11 kg in Ghana and Thailand. The low cost in Thailand needs to be interpreted with caution, however, because there could be cross-subsidization vertically across the supply chain depending on how the ex-refinery subsidy is calculated and reimbursed.

In countries with natural gas for household use in urban areas—Moldova, Pakistan, and Turkey, and increasingly in Brazil and Mexico—the primary market for LPG is or will be rural households. High LPG prices pose a special challenge to rural households, whose cash income tends to be lower than that of their urban counterparts and who have access to much cheaper biomass fuels. Under these circumstances, LPG taxation needs careful consideration, which is complicated if LPG is also used as an automotive fuel. The latter point is discussed in the next section.

Competition from autogas

Household use of LPG competes with autogas in several markets. Both autogas and gasoline are used in vehicles with spark-ignition engines, making fuel switching from gasoline to autogas relatively easy. Unless the use of autogas is legally required, it must be cheaper than gasoline

before anyone would consider using it, because the conversion cost or the higher vehicle purchase cost needs to be recovered through lower fuel costs. In addition, a widespread network of filling stations typically does not exist for autogas; absent a much lower fuel price, it would not be worth the inconvenience of switching to autogas and being constrained in when and where to refuel. Where the price difference is sufficiently large, taxis are often the first to switch—the large kilometers per year taxis are driven reduce the payback period, and refueling is not as significant a challenge as for other vehicle types because taxis usually operate within a confined area and a handful of filling stations can serve them. Once the autogas market surpasses a critical size, it is possible for the number of filling stations to start rising rapidly, making autogas increasingly convenient and attractive.

As Figure 2 shows, FOB autogas prices have been generally lower than gasoline prices in recent years. This price difference in favor of autogas is amplified when, as is typically the case, gasoline is taxed more than LPG. Particularly in developing countries, gasoline is often the most heavily taxed petroleum product, because much of its consumption is by private car owners and taxis. Private car owners are among the better-off, as are also users of taxis. This makes gasoline taxation generally progressive.

Taxing autogas and gasoline the same to maintain progressive taxation of automotive fuels would reduce the attractiveness of autogas and make LPG for household use very expensive. Introducing different tax rates for autogas and LPG for household use to make the latter more affordable would lead to illegal diversion of household LPG to the automotive sector, often accompanied by illegal and unsafe installation of cylinders for household use in vehicles as fuel tanks. In terms of the willingness and ability to pay for LPG, taxi and private car drivers are more willing and capable on average than households, especially when drivers are comparing autogas with a more expensive fuel while households are often comparing LPG with cheaper alternatives.

These differences in fuel prices and the ability to pay have led to a rapid rise in fuel switching from gasoline to autogas in some developing countries. On the one hand, market expansion should enable greater scale economy and more competition, both of which can lower prices. On the other hand, the generally lower tax rates for autogas reduce government revenue, this when petroleum product taxation is an important revenue source, especially in low-income countries, because collecting fuel taxes is relatively straightforward and the consumption of fuels as a group is highly income elastic, ensuring buoyant revenue as income rises (Bacon 2001). The loss of revenue would be particularly damaging if LPG is subsidized.

The price difference between auto gas and gasoline in Ghana and Turkey has resulted in increasing fuel switching from gasoline to LPG. The expansion of the autogas market as well as large price subsidies have both been blamed in recent months for acute LPG shortages in Ghana, prompting commercial LPG vehicle drivers to ask the government for subsidy removal

so as to ensure reliable supply (*All Africa* 2011b). Because autogas and LPG for other uses are equally subsidized, the end result is that a sizable fraction of LPG is benefitting private and commercial autogas users, making the subsidy highly regressive. In Turkey, autogas consumption surpassed gasoline consumption in 2009, and there are more than 8,500 filling stations today, the largest number of autogas stations in the world (Polat 2010). Although auto gas is taxed less than gasoline, the tax component of LPG in Turkey is still very high. According to information provided by Tüpraş, taxes and fees amounted to US$1.12 per kg in October 2011, corresponding to 37.5 percent of the retail price. Against the backdrop of rising retail prices of gasoline and static LPG prices, the number of autogas filling stations in Thailand is said to have increased from 140 recorded in December 2010 to 1,030 by mid-2011 (*Platts Oilgram News 2011*). Where there is suppressed demand for lack of adequate LPG supplies, effectively rationed subsidies, or both, residential users tend to lose to autogas users.

Fuel shortages

A disruption at any point in the supply chain can cause a LPG shortage: gas field, refinery, delay in arrival of an LPG shipment, transport strike. Several survey countries—Ghana, Kenya, Senegal, and South Africa among them—have faced serious LPG shortages in the last two years. In Pakistan, natural gas shortages have pushed up demand for LPG, widening the gap between supply and demand. Lack of sufficient import or storage capacity and unplanned refinery closure, exacerbated by fuel price subsidies in Ghana and Senegal, are typical causes of the shortages. Shortages tend to increase prices, providing opportunities for profiteering. Allegations about the "LPG mafia" and "artificial LPG shortages" created to push up prices have been made for quite some time in Pakistan (Pakistan Press International Information Services 2011). At its worst, an acute LPG shortage leaves even families who are prepared to pay more with no fuel for days or weeks on end. Poor supply reliability and erratic sharp price hikes in turn deter households from considering LPG.

Countries with serious LPG shortages in 2011 include Ghana and South Africa. The acute LPG shortage in Ghana prompted the government to set up a special task force to investigate causes of the shortage. The only refinery in the country has had to shut down repeatedly for lack of crude oil, in part because of the inability of the refinery to obtain letters of credit from banks to buy crude oil. Rising demand for autogas and for industrial use of LPG has also been blamed for the shortages. Inadequate storage capacity exacerbates the problem: Ghana's total storage capacity is 6,500 tonnes, against weekly consumption in mid-2011 of 4,000–5,000 tonnes, leaving a buffer of only 1,500–2,000 tonnes, or about three days of consumption. The NPA has announced an in-depth nationwide study on LPG to advise the energy ministry on "long-term solutions to the perennial shortages of LPG." In South Africa, the Department of Energy issued a press statement on October 19, 2011, expressing concerns over growing shortages of LPG following shutdowns of four of the country's six refineries. The Restaurants Association of

South Africa reported that more than half of its members, exceeding 1,000 restaurants, had to close by the end of October for lack of LPG. The lack of LPG gas storage and import terminals also constrains sector development and exacerbates fuel shortages (*All Africa* 2011, IHS 2011a and 2011b, *Mail & Guardian* 2011, NPA 2011a, *Platts Commodity News* 2011).

Kenya has suffered from LPG shortages, caused in part by the poor state of its only refinery which operates significantly below its nameplate capacity and the operations of which have been disrupted by power outages and unplanned repairs. The energy ministry in December 2010 also blamed piracy in the Indian Ocean for disrupting LPG imports (*All Africa* 2010, BMI 2011). By law 15 days of operational stock and 90 days of strategic stock are required for LPG, but the existing infrastructure is far from adequate for compliance. Other examples of stock requirements include those in Turkey and Morocco. Turkey requires licensed LPG distributors to hold 20 days of LPG consumption in storage. Morocco requires a minimum operating stock of 2.5 months based on previous monthly sales.

Senegal experienced a prolonged LPG shortage in early 2009, caused by the inability to pay for imports due to mounting subsidies; the subsidies to the refinery and for LPG in 2009 are estimated to have amounted to US$70 million. The shortage doubled the price of LPG and also pushed up the price of charcoal, which competes with LPG in that market. In October 2010, the energy minister was replaced, in part in response to the public anger over electricity and LPG shortages (Reuters 2010, IHS 2010, *Global Post 20*11). Earlier examples of publicized LPG shortages include one from Jordan where, in January 2007, the government began an investigation into causes of the shortage. The only refinery in the country reported at the time that its limited LPG production capacity and steeply rising demand because of the widening price difference between LPG (selling for US$0.48/kg at retail, against the Arab Gulf FOB price of US$0.55/kg in that month) and other fuels were among the factors (IPR Strategic Information Database 2007).

Promotion of LPG

Subsidies have historically been used widely to promote LPG. Subsidies are effective in helping households start using LPG. LPG subsidies, however, are seldom, if ever, progressive in developing countries (World Bank 2010 and Table 4). In Senegal, after two decades of LPG price subsidies, the International Monetary Fund estimated in 2008 that the bottom two quintiles were capturing only 19 percent of the LPG subsidy while 61 percent went to the top two quintiles (IMF 2008). LPG price subsidies have also been found to be fiscally unsustainable, especially against the backdrop of rising fuel prices since 2004. In addition, subsidies have often deterred investment in a number of markets and even led to crippling fuel shortages, as discussed above.

Unlike subsidies, dissemination of information through various means does not require a large budgetary outlay and is helpful under all circumstances. The econometric analysis of household surveys in chapter 3 highlights the importance of informing consumers, while regular publication of industry statistics can help LPG marketers make informed decision about investments and marketing strategies. In addition, promotion programs undertaken by companies, civil society organizations, government, and donors have contributed to growing awareness of, and interest in, LPG as a household fuel.

Web-based dissemination of information

One of the most important and useful roles a government can play is to make information available to the public. Consumers may be interested in learning about trends in international and domestic prices, investors about industry statistics and government policy and regulations, and energy analysts in both. Consumers would also benefit from information about safety features of LPG, which would help them understand what needs to be done for safe handling of LPG and allay fears about explosion and other accidents, as well as what the government is doing to curb commercial malpractice (such as short-selling) and what steps consumers themselves can take to minimize it.

Given increasing use of the Internet, Web posting is one of the fastest and cheapest ways of disseminating information widely. The ease of navigating the Web site and finding information is important, as is the ease of downloading information, particularly for time-series data—if data have to be downloaded one by one for each time period, temporal comparison can become time-consuming. Where LPG prices are deregulated, how prices vary over time, from location to location, and among marketers may influence household purchase decisions, although such information can be resource-intensive to collect and compile. The Web sites of the regulatory agencies in Peru, Pakistan, and Turkey post prices by company and location, enabling consumers to compare prices. The Web site of EPDK in Turkey is the most extensive for price information, enabling a search for prices by location, company, and cylinder size going back to the beginning of 2007. Examples of the type of information available on government Web sites are given in Table 9.

Table 9: Examples of information available on government Web sites

Country	Web site address and type of information available
Brazil	www.anp.gov.br/?id=2368 posts current and historical price structures starting in Nov 2001. www.anp.gov.br/?id=548 has monthly supply and demand statistics beginning in Jan 2000.
Dominican Rep.	www.seic.gov.do/hidrocarburos/Perodo%2020002011/Forms/AllItems.aspx posts current and historical prices beginning in Jan 2003 except 2009. www.seic.gov.do/hidrocarburos/default.aspx posts historical and current notices notifying official prices by cylinder size and industry statistics such as consumption and import volumes
Ghana	http://www.npa.gov.gh/npa_new/Downloads.php lists current and historical price components and national consumption starting in Jan 1989.

Country	Web site address and type of information available
	www.npa.gov.gh/npa_new/index.php has links to pages with a wide range of information, including LPG safety tips.
Guatemala	www.mem.gob.gt/Portal/Home.aspx?tabid=57 posts prices by cylinder size for three marketing companies in the current year going back to Jan. www.mem.gob.gt/Portal/Home.aspx?sub=Dirección%20General%20de%20Hidrocarburos posts legislation, supply and demand statistics beginning in 2002, and other information.
Kenya	www.erc.go.ke/erc/regulatory_instruments/?ContentID=17 lists regulations governing LPG. http://www.erc.go.ke/erc/licencing/LPG%20Licence%20Register.pdf lists licensees. http://www.erc.go.ke/erc/consumer_affairs/?ContentID=1 sets out procedures for lodging complaints against suppliers of energy. http://www.erc.go.ke/erc/news_and_publications/?ContentID=3 posts notices, one of which is to inform LPG consumers about their right to insist on having cylinders weighed and who can fill cylinders. http://www.erc.go.ke/Announcements.htm posts invitations for public comments before finalizing government documents, including LPG regulations of 2008.
Mexico	www.energia.gob.mx/res/91/Precio.xls posts monthly average retail prices by region (188 locations), starting in Mar 2001. www.energia.gob.mx/portal/dg_de_gas_lp.html is dedicated to LPG with a wide range of information, including calculation of LPG consumption using different appliances.
Moldova	www.anre.md/press/index.php?vers=1 posts reports containing import and stock statistics.
Pakistan	www.ogra.org.pk/cats_disp.php?cat=22 lists regulations and policies; information on authorized distributors, licensed LPG marketing companies, and authorized LPG equipment manufacturers; hospitality agreements; and provisional licenses for constructing gas plants and autogas refueling stations. www.ogra.org.pk/cats_disp.php?cat=153 lists enforcement news, such as imposition of penalties on LPG marketing companies. www.ogra.org.pk/cats_disp.php?cat=160 lists LPG prices notified by marketing companies by city every month starting in Jan 2010
Peru	http://facilito.osinerg.gob.pe/facilito/pages/facilito/menuPrecios.jsp lists current prices by company, location, and cylinder size www.osinerg.gob.pe/newweb/pages/GFH/155.htm is dedicated to LPG with a wide range of information. http://www2.osinerg.gob.pe/preciosreferencia/TarPreciosBanda.html has price structures for various fuels for certain months.
South Africa	www.energy.gov.za/files/petroleum_frame.html has information on price structure and LPG regulations stating maximum retail prices. www.energy.gov.za/files/policies_frame.html lists all petroleum legislation.
Sri Lanka	www.caa.gov.lk/web/index.php?option=com_caproductprices&task=subcat&Itemid=114&id=82&lang=en lists maximum prices for 2 companies for 2.3-kg and 12.5-kg cylinders
Thailand	www.eppo.go.th/petro/price/index.html posts price structure in Bangkok on a daily basis. www.eppo.go.th/info/8prices_stat.htm posts monthly prices and stabilization fund flows. www.eppo.go.th/retail_LPG_prices.html lists current retail prices in Bangkok by cylinder size. www.eppo.go.th/info/2petroleum_stat.htm posts supply and demand statistics beginning in 1986.

Country	Web site address and type of information available
Turkey	http://lpg.epdk.org.tr/fiyatlar.aspx lists prices by date, company, location, and cylinder size, starting in Jan 2007. www.epdk.org.tr/lpg_piyasasi posts detailed sector reports with various statistics collected every quarter.

LPG marketing companies and industry association also post information on their Web sites. LPG industry associations, by virtue of their focus, can help disseminate useful information to all parties, from industry actors to residential consumers. Table 10 provides examples of the type of information available. Some have information that can be readily understood by consumers, including use of pictures to illustrate the points made. Examples include brochures on safety in three languages posted on the Web site of the LPG Safety Association of Southern Africa (LGASASA), and the frequently asked questions as well as safety information on the Web site of Liquigás in Brazil. The Web site of Pemex has graphs comparing international and domestic prices and estimated annual and cumulative subsidies since 2003; the graph for subsidies visually informs the Web viewers of the scale of subsidies and their increases in recent years. Large corporations that are involved more in the upstream segments of the supply chain than the retail end, such as Pemex, focus primarily on industry statistics and information of general interest to wholesalers and large consumers.

Table 10: Examples of information available on non-government Web sites

Country	Entity	Web site address and type of information available
Afghanistan	SunGas	www.sungas.net/lpg.html has information on safe handling of LPG in English. As of Dec 2011, the Afghan version did not seem to be operational.
Brazil	Liquigás (Petrobras)	www.liquigas.com/br has extensive information on LPG, including a comprehensive list of frequently asked questions, the number of years before each item of equipment needs to be replaced or recertified, and a long page dedicated to safety with illustrations.
Fiji[a]	Origin Energy	www.originenergy.com.au/1699/LPG-safety has a check list on what to do in case of a leak and how cylinders should be handled. www.originenergy.com.au/1693/Bushfire-safety-procedure explains what to do with LPG cylinders in a bushfire.
Mexico	Pemex	www.gas.pemex.com provides extensive industry statistics. There is a considerable amount of information on international and domestic prices, including estimated annual subsidy figures.
South Africa	LPG Safety Association of Southern Africa (LPGSASA)	www.lpgas.co.za/ has a check list on LPG safety, lists verified appliances and color markings on cylinders by company, and posts several brochures on LPG safety by application with easy-to-understand pictorial guides, including two in local languages.
	Easigas	www.easigas.co.za/safety.html has detailed information on various aspects of safety, including cylinder safety, cooking safety, and safety checks.
Sri Lanka	Laugfs Gas	www.laugfs.lk/llg/laugfs_gas_product.htm lists prices for LPG by cylinder size, cylinders, regulators, a camping stove, and other accessories. www.laugfs.lk/llg/laugfs_gas_energy.htm compares prices of different fuels per unit of energy

Country	Entity	Web site address and type of information available
Thailand	PTT	http://www.pttplc.com/th/lpg.aspx has basic information on LPG and appliances provided by PPT and an Excel file containing detailed information on LPG dealers, but does not provide other information of interest to residential customers.
Turkey	Turkish LPG Association	www.tlpgder.org.tr has industry statistics as well as safety information for consumers, including how frequently to replace tubes, how to check for a leak using soap bubble, and what to do when one detects a leak.
Vietnam	Petro Vietnam Gas	www.pvgas.com.vn/vi/ProductDetail.aspx?id=16 has information suitable primarily for industry participants.

a. Origin Energy, headquartered in Australia, operates in Fiji.

In general, however, only a few of the major LPG distributors have web sites with safety tips and consumer information. Shell Gas (LPG), which is probably the world's largest LPG dealer and which claims to serve 40 million customers around the world in more than 65 countries and territories, posts some tips for cylinder safety on its general Web site in English but no pictures for illustration, and does not appear to have anything customized to individual countries for household users.

National programs and campaigns

Governments, industry, and international organizations have engaged in national programs and campaigns to promote household use of LPG at various times. LPG price subsidies are clearly intended for that purpose, as are discounts offered by the industry on cylinders and stoves, discussed in the section on cylinder management. Three examples, two implemented by government and one by industry association, are briefly described below.

With the discovery of natural gas in the Gulf of Thailand in 1981, the government of Thailand began to promote household use of LPG to displace fuelwood. The Oil Stabilization Fund cross-subsidized LPG heavily and enabled implementation of the uniform wholesale pricing policy enacted in 1986. The government also directly engaged with the Petroleum Authority of Thailand (PTT), a state-owned energy company, to build six large LPG storage and terminal facilities nationwide by 1985. Between 1986 and 1996, the government also provided subsidies to LPG producers and suppliers to maintain and operate storage facilities in provinces, paid for by the oil fund. By the early 2000s, the government had identified several safety problems, regulatory loopholes, and commercial malpractice. Safety problems included cross-filling by independent LPG traders and illegal manufacture of cylinders. In response, the government tightened the regulatory framework, and also took immediate action to repair, remove, and replace unsafe cylinders. In 2002, the government initiated a cylinder exchange program, financed jointly (50–50) by the oil fund and by LPG suppliers and producers. Interestingly, the program was aimed at all households and did not target the poor. It was focused on making the fuel affordable and its supply reliable, particularly beyond the Bangkok Metropolitan Area and not at helping the poor pay for the initial start-up cost (Ekouevi and Tuntivate 2011). The

overall success of the government program can be seen from the statistics collected in a 2006 national household survey: half of rural households and four fifths of urban households cited LPG as the primary cooking fuel (Bacon, Bhattacharya, and Kojima 2010).

The government of Ghana launched a national promotion program for LPG in 1990 to encourage fuel switching away from firewood and charcoal, targeting households, public institutions requiring mass catering facilities, and commercial operators including food sellers. The government supported upgrading the country's refinery and carried out education campaigns; has been paying for the long-distance transport of LPG and other fuels to locations more than 200 km away from the refinery through the Uniform Petroleum Price Fund (UPPF), which is intended to assist rural households; and has been subsidizing LPG prices most of the time. Between 1990 and 1994, household use of LPG doubled every two years (IEA 2011c). An assessment of the program last updated in 2009 noted that modernization of the refinery had not been successful and refinery outages had caused LPG supply shortages throughout the country, forcing households to continue to use woodfuels (charcoal and firewood). Household use of LPG remained low and was confined mostly to urban areas. Low UPPF-capped margins were said to have prompted large, established international corporations to exit the market, leaving numerous small- and medium-sized companies that struggled to obtain loans from banks. For rural households, even with all the subsidies, the cost of LPG was prohibitively high relative to their cash income. One market that saw rapid expansion was autogas, which diverted an increasing portion of subsidies intended to help displace woodfuels to car owners (EnergyAccess 2009).

The Turkish LPG Association has been active in the Clean Energy for Development project under the auspices of the United Nations Development Programme. Its nationwide activities have been designed to improve safety; foster public awareness; help set up an appropriate legal, regulatory, and institutional framework; and promote LPG use in rural areas.

Other measures

Industry associations can play an important role in reducing safety risks. For example, the LPG Safety Association of Southern Africa (LPGSASA) offers various training courses, including driver training and training for filling cylinders, inspection, and installation. LPGSASA is also one of four member associations of the South African Qualification and Certification Committee for Gas, which has been officially appointed and mandated by the labor department to register gas practitioners. All registered installers are issued an identity card bearing their photograph, name, and categories for which they are registered (domestic, commercial, industrial, or autogas). Installers are required to issue a certificate of conformity after completion of the installation and to instruct the end-user on the safe operation of the installed appliance(s) before handing over the installation (LPGSASA 2011). In 2009, following increases in illegal

cross-filling, LPGSASA ran a series of television and print advertisements aimed at educating consumers on safety measures when refilling or exchanging gas cylinders. The campaign included information about the illegal practice of cross-filling and the correct procedures for gas appliance installations. LPGSASA also established a system whereby consumers could get information on the location of the closest authorized LPG dealers on their cell phones (*Engineering News* 2009).

In 2007, after a gas explosion in Ghana's second largest city, Kumasi, that injured about 135 people, the Ghana Standards Board and the NPA sponsored newspaper advertisements to alert consumers about the risks of using LPG cylinders. The NPA also regularly publishes simplified guidelines for safety and consumer protection, and organizes training courses for LPG operators in cooperation with other authorities and the industry.

Also in Ghana, LPG user associations have reportedly been formed in six districts with more than 500 members. These associations have become an integral part of the supply chain for LPG to members and non-members, and provided a cost-effective forum for disseminating product information. The associations actively organize their members to obtain LPG products and services from suppliers, thereby improving their bargaining power and lowering the costs, and offer end-user training sessions to households, commercial food vendors, and institutional kitchen staff to increase overall confidence in handling LPG (UNDP 2011).

Providing a mechanism to lodge complaints about unsatisfactory service or commercial malpractice can reduce their occurrence and improve the perception of LPG by consumers. The consumer affairs page of the Web site of Kenya's Energy Regulatory Commission promises consumers that written complaints will be acknowledged in writing within three working days and will be responded to within 10 working days, with 15 working days being the goal for addressing complaints even in more complicated cases (ERC 2011).

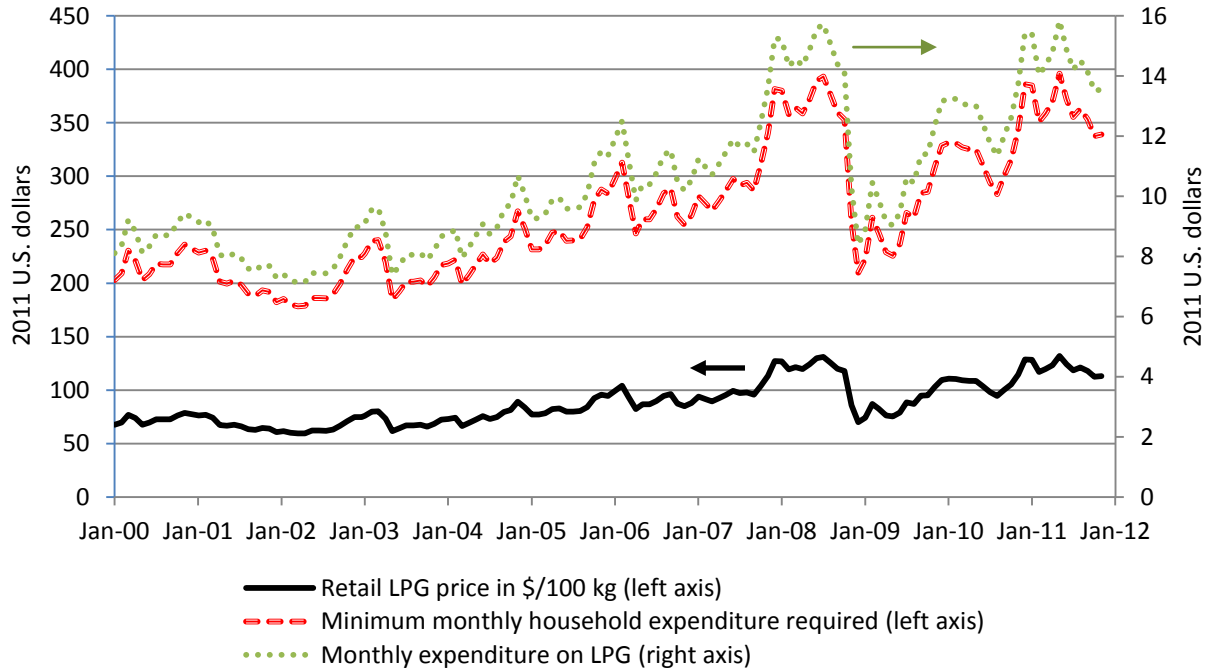
5. Concluding observations

It is widely acknowledged that substituting traditional solid biomass or coal with cleaner fuels is one effective way of reducing household energy poverty, which is estimated to kill four people every minute. LPG is a merit good in this context: proper use of LPG can virtually eliminate indoor and outdoor air pollution from fuel combustion, benefiting not only the user but also others in the vicinity, and yet many are not aware of the extent of the harm caused by traditional solid fuels and hence do not recognize the full benefits of switching to LPG or other gaseous fuels. Fuel substitution has been given a new momentum following the designation by the United Nations of 2012 as the International Year of Sustainable Energy for All.

Near doubling of international LPG prices since 2000 in real terms, however, poses a significant challenge to fuel switching to LPG as one pathway toward the UN goal of universal access to modern energy by 2030. The average price of an even more important expenditure item, food, has also doubled since 2000 in real terms (FAO 2011), placing considerable pressure on household income. And yet, worldwide, per capita GDP increased by 85 percent or more in real terms between 2000 and 2010 in only 11 countries, half of them major oil exporters.

An estimate of the level of income required to start using LPG as the primary cooking fuel can be calculated by making several simplifying assumptions. For the purpose of this illustration, the combined cost of transport, bottling, distribution, retailing, and taxes are assumed to add US$350 per tonne to the world price to arrive at the end-user price. This assumption puts the retail price in December 2010 at US$1.29/kg, the price level observed in Guatemala. Second, based on the findings in chapter 3, monthly consumption of LPG is assumed to be 12 kg, sufficient for cooking and water heating in many parts of the developing world. Third, again based on the findings in chapter 3, the share of total household expenditure spent on LPG is assumed to be 4 percent. The results are plotted in Figure 9 in 2011 U.S. dollars.

Figure 9: Hypothetical retail LPG price, monthly household expenditure on LPG, and minimum total monthly household expenditure needed for regular use of LPG



Sources: Reuters for Saudi Aramco contract prices for propane and butane and World Bank staff calculations.
Notes: LPG is assumed to be an equal mixture of propane and butane. Calculations assume transportation, bottling, distribution, and retailing costs and taxes totaling $350 a tonne of LPG in 2011 U.S. dollars; monthly consumption of 12 kg per household; and 4 percent of total monthly household expenditure spent on LPG.

The minimum monthly household expenditure required to start using LPG regularly remained largely below US$250 until mid-2005, but has risen to as high as US$400 in recent months. The actual minimum expenditure is likely to be even higher because the analysis in chapter 3, on which this estimate is based, excludes large infrequent expenditures. Households would need to spend about US$15 a month on fuel purchase at the current world price of LPG. In three survey countries in chapter 4, the retail prices are double (or even more than double) those in Figure 9. Currency appreciation against the U.S. dollar offsets the rise in global LPG prices, but there are only four developing countries where the local currency appreciated by more than 50 percent between 2000 and 2010, and none where the appreciation was greater than 60 percent. At the opposite end of the spectrum, there are 28 developing countries in which the local currency *depreciated* against the U.S. dollar by more than 40 percent, exacerbating the challenge of high and volatile LPG prices on the world market.

These observations suggest that LPG is unlikely to be the fuel of the poor, because the magnitude of financial assistance required to enable the poor to use LPG as the primary source of household energy would not be fiscally sustainable in many developing countries. If the financial assistance takes the form of universal price subsidies, they are captured more by better-off households than the poor. If there is an autogas sector, the subsidies are also

captured by vehicle owners, who typically have far greater resources to pay for LPG than households. This in turn means that either subsidies need to increase even more rapidly, or fuel shortages ensue as the government limits the total subsidy outlay for LPG and households compete with the automotive sector for subsidized LPG which is effectively rationed. Although a price subsidy could be restricted to a particular use of LPG, such as LPG use by low-income households only, it would be difficult to control illegal diversion of subsidized LPG to automotive use. Allowing market forces to govern LPG prices and assisting low-income households through cash transfer or some other means would be preferable.

Even when there are no subsidies for LPG, a growing autogas market poses a policy challenge. Autogas competes with gasoline, on which most countries impose an excise tax to raise revenue and to account for such externalities as damage to road, congestion, and pollution from exhaust emissions. If the excise tax on autogas is very small, the loss of government revenue can be significant as vehicle owners increasingly switch from gasoline to autogas. But if an excise tax comparable to that on gasoline is imposed on LPG to minimize the revenue loss, the price of LPG can become so high as to be out of reach of many more households. If there is differential taxation between autogas and LPG for all other users, there is a risk of illegal diversion of the latter to the automotive sector. Most countries have opted for light taxation on LPG, including autogas. This is a policy choice and government needs to weigh the benefits of automotive fuel diversification and promotion of LPG as a household fuel on the one hand and the loss of tax revenue on the other.

But even without subsidies, there is still considerable scope for LPG to play an important role in reducing *energy poverty*. First, there are approximately three billion people globally who are not using modern household energy, and a significant portion of the three billion is not *income-poor*. Lack of satisfactory LPG supply services, price levels that are higher than what the market could achieve under fair competition, inefficiency in the supply chain, poor regulation leading to unsafe handling of LPG cylinders and commercial malpractice, and unfamiliarity with LPG are among the reasons why more households, who can otherwise afford it, are not using LPG today. Second, relative fuel prices also matter. As prices of competing fuels, such as charcoal, rise—and they are rising sharply in some urban settings—LPG becomes increasingly attractive.

This study found that net-of-tax prices of LPG varied substantially across countries. The wide range of variation highlights the potential for reducing costs in countries with high net-of-tax prices. Comparison between high- and low-cost countries is complicated by implicit subsidies in the low-cost countries (Ghana, Thailand), which make estimation of prices net of taxes and subsidies difficult. In the case of Ghana, one reason for the very low cost of delivering LPG to end-users is that LPG is supplied by bulk transport down to the retail level and consumers transport LPG cylinders to and from mini-filling plants. Among the countries studied, no other country relies largely on a decentralized, bulk-supplied system. It is worth noting that this

system delivers LPG at much lower prices than the practice of exchanging empty cylinders for filled ones in Ontario, Canada, where both the centralized and decentralized systems of cylinder filling co-exist, although the indirect cost of purchase in the latter may be high for some consumers. While decentralized filling substantially slashes direct costs of supply, it can pose serious safety risks unless there is rigorous enforcement of internationally accepted safety standards. This enforcement applies to both LPG suppliers and consumers. On the supply side, the key safety element is the diligence of the mini-plant operators in rigorously inspecting and rejecting, as necessary, any substandard cylinders, and refusing to refill them. The customers need to follow safety rules for transporting filled LPG cylinders in cars, motorcycles, or bicycles, and for installing cylinders properly at home; this in turn requires that LPG cylinder users can understand and follow safety instructions. Rigorous enforcement is difficult under all circumstances, and particularly in low-income countries where the incentives for short cuts are strong, regulatory capacity is weak, and the culture of compliance tends to be less well established.

Turkey sets high standards for safety and the quality of service generally—for example, home delivery and cylinder installation by technical professionals in customers' homes are both legally required—and effective enforcement is paid for by a small levy charged to LPG marketing companies. However, net-of-tax prices in Turkey are not low, essentially doubling the price of LPG compared to the world price before taxes and levies are added on. This is despite enjoying very large scale economy across the supply chain and having a relatively low HHI. In Thailand, in spite of a relatively high HHI and having the centralized system of filling, costs seem as low as in Ghana. That said, the government of Thailand has historically subsidized the LPG industry heavily, helping consumers and producers alike and supporting the establishment of supply infrastructure outside the Bangkok Metropolitan Area. The present study, being global in nature, was not in a position to carry out an in-depth investigation into the cost elements (including any enduring benefits of past subsidies) in the LPG industry in these countries. A more detailed study on these markets would help gain a better understanding of the factors contributing to supply costs.

Chapter 4 covered several means of reducing costs in the study countries. Hospitality arrangements for storage facilities and granting third-party access to terminals lowers the barrier to entry and reduces costs. Having a large bulk supplier not engaged as a competitor in the downstream business so that a new LPG bottler/distributor does not need to invest in a marine terminal and can instead source LPG from the bulk supplier, as in Peru, also lowers the barrier to entry. Having large companies capable of exploiting economies of scale in importing LPG as much as possible reduces costs. Scale economy may require expanding import terminals to be able to receive larger parcels. Port demurrage charges can add considerably to LPG prices; port congestion and customs clearance are outside the control of LPG operators and need to be

tackled by the government. Having enough companies to enable price competition is important, although the sheer number of marketing companies and retailers alone does not provide an accurate picture of the nature of competition. For example, market conditions that prompt large, creditworthy companies to exist, leaving many small operators who are not capable of raising funds or exploiting scale economy, could result in diminishing investment in the supply infrastructure and may even increase costs.

At the retail end of the supply chain, in addition to fuel price subsidies, two other ways of reducing the financial burden on consumers have frequently been suggested:

1. *Subsidy for the start-up cost*. Although this subsidy is more targeted than price subsidies, in most countries it generally does not benefit the poor because the poor do not have the financial means to pay for regular use of LPG (unless the prices of alternative fuels are even higher, as in Haiti and in some urban settings). It is hence not clear if subsidizing the start-up cost of LPG would or should be a government priority and each circumstance would need to be assessed individually in the light of the need to finance essential services that are also merit goods—education, health, safe water and sanitation, to name a few. LPG marketing companies may consider introducing an installment plan or building a portion of the cost of the cylinder in the fuel price. Although households are much less likely to borrow money for consumption than for production, where there is interest, micro-credit schemes may also help pay for the start-up cost.
2. *Small LPG cylinders*. Cylinders that are 6–7 kg or smaller have several benefits—low cylinder deposit fee, low refill cost, and ease of transportation. Small cylinders, however, make LPG more expensive on a unit basis and also pose a greater challenge to cylinder maintenance, repair, and replacement. Although smaller cylinders are available in all markets, cylinders that are twice as large dominate most markets examined in this study. The larger cylinder sizes appear to represent a compromise once unit versus refill costs, the ease of handling cylinders by households versus the cost of inspecting and maintaining them, refill frequency, and consumer preferences are taken into account. Even without large cross-subsidies, as in Morocco, however, there may nevertheless be a niche market for small cylinders, particularly among lower-income urban households. Where there is no government intervention, the marketing decision to cross-subsidize LPG sold in small cylinders should be left to LPG suppliers.

Two common consumer complaints are short-selling and slow response to a request for a refill. Short-selling is largely a regulatory matter, although industry associations could help reduce the prevalence of this commercial malpractice. For example, a system could be set up whereby companies that calibrate their scales regularly and that have been shown not to short-sell are certified and given a seal of quality to display at their retail outlets, while periodic unannounced checks continue and those failing are stripped of their certification status. How quickly to

respond to a request for a refill is a commercial decision by retail outlets, but branded wholesalers may set up and enforce rules for the retail outlets that buy LPG from them depending on the location, the time of day, and the distance to the customer. Industry associations can mount publicized programs in which their members pledge to turn cylinders around within a certain time period.

Aside from serious accidents, nothing destroys consumer confidence like crippling LPG shortages. Unfortunately, such shortages are not rare. Aside from the inconvenience of running out of the cooking and heating fuel, acute shortages can lead to sharp price hikes, doubling or even tripling end-user prices. For business users of LPG, shortages could even mean shutting down business altogether, as happened to restaurants in South Africa in October 2011. The immediate cause is typically supply disruption coupled with inadequate storage capacity. Increasing storage capacity and requiring and enforcing minimum operational and/or strategic stock would help, especially in countries where the total national storage capacity is of the order of a week. But countries with frequent shortages seem to have one thing in common: an uneconomic refinery in a state of disrepair suffering from years of neglect, often exacerbated by fuel price subsidies. While this report does not cover the economics of refining, the recent trends in global refining point to the importance of large economies of scale and the ability to withstand years of low margins (World Bank 2008a and 2008b). Small-scale simple refineries in Sub-Saharan Africa in particular are unable to compete with fuel imports, and when their inherent uncompetitiveness is combined with financial difficulties compounded by fuel subsidies, the end result is repeated fuel shortages. It is significant that in both Ghana and Senegal the inability to pay for crude oil, LPG, or both has led to major episodes of prolonged fuel shortages. Even in Thailand, where refineries are large and competitive but LPG prices are kept artificially low, the private sector is said to be reluctant to invest in the LPG market because of low returns (Thai News Service 2011).

High world oil prices in recent years have increased politicization of fuel pricing in a number of countries. Governments can help foster informed debate by posting detailed information on prices. As long as price information is being collected, it would make sense to retain and post historical prices (that is, price information that has already been collected) in addition to current ones. Where LPG prices are kept artificially low, it is informative to list international prices in U.S. dollars and in local currency and show the price build-up starting with ex-refinery or landed cost, so that consumers can see which segments of the supply chain are subsidized. Without such information, it would be extremely difficult, if not impossible, to have a sensible discussion on whether and how to reduce and eventually eliminate universal price subsidies. LPG suppliers can similarly post subsidy amounts, as Pemex has done, although they may not enjoy the same degree of perception of independence as government agencies.

While many factors that influence the LPG market are outside government control—global prices, size of the economy (which affect the size of the potential market and the level of competition), the geographical spread of the country and its terrain, whether the country has domestic oil and natural gas resources—regulatory and institutional frameworks are entirely under government control and can help drive down costs by making the sector competitive and efficient, minimize conditions that lead to supply shortages, strengthen safety, and minimize commercial malpractice. This study found that the laws and regulations in some countries were incomplete, outdated, or both. Nearly all regulatory systems were deficient when it came to requiring training and certification of management and staff of the operators and consumer education. All but one have issued technical specifications and some type of health, safety, and environment standards for LPG. These standards are well established globally and there is no compelling reason why developing countries would need to write their own, other than adapting them for their climatic and other conditions. Some governments have indeed formally adopted international standards, which is the preferred approach because it ensures that the standards are automatically updated as changes are made to the original codes.

Monitoring and enforcement is weak in a number of countries. There is lack of both funds and technical capacity. Without effective regulation, a competitive market with a large number of marketers is likely to lead to partial or total degradation of product quality. A low-quality product (unsafe cylinders, LPG cylinders filled in part with substances other than LPG) drives out a high-quality product because of consumers' difficulty in distinguishing between the two at the point of purchase. In a well-regulated market, suppliers that run efficient operations while complying with safety and other standards might expand their market shares and drive out unscrupulous firms; in a poorly regulated market, unscrupulous firms might drive out companies that comply with regulations.

Strengthening monitoring and enforcement is a long-term process. While government agencies engage in that process, industry associations, consumer groups, and others can help with monitoring by raising public awareness about malpractice and even conducting and publicizing the results of spot-checks. Given weak enforcement capacity in many developing countries, one way to strengthen safety is to establish a system of registered installers, as in South Africa, and accredited inspectors who operate under the supervision of the regulatory agency, as in Chile and South Africa. The law for the regulator covering electricity and fuels in Chile enables the regulator to authorize laboratories, other entities, and installers to carry out inspection and establish the procedure for accrediting, licensing, and supervising the inspectors (Chile 1999).

Analysis of household surveys found that the higher the education level attained by female and male members of a household, the more likely the household was to select LPG. This effect was larger for women than for men. Education is likely to be a proxy for the level of awareness about the benefits and costs of LPG. In persuading households to start using LPG, raising

awareness about the benefits of LPG use and providing basic training on safety features of LPG, especially among women, might be effective.

At a minimum, Web-based information—one of the cheapest means of information dissemination—should be widely used. The Web will not reach the poorest of the poor, but the very poor are unlikely to be regular users of LPG as long as the current price trend continues. Making the Web sites user-friendly for average household LPG users is imperative if the information is to benefit them. This would mean, for example, using simply-worded text and pictures (as necessary) to illustrate safety features. LPG marketing companies can do much more in this regard; not many Web sites of LPG distributors, including major oil companies, seem to have household-friendly safety tips and consumer information. Government Web sites can post basic rights of consumers, such as the right to be shown the tare weight of the cylinder, the date of the last calibration of the scale, and the date of last recertification of the cylinder; the right to ask to have the filled cylinder weighed; and so on.

Radio and television advertisements are likely to reach even more households, as are cylinder labels, marketing letters, and point-of-sale notices. Particularly in areas where LPG is not yet widely used, neighborhood demonstrations, targeting women, of how to cook with LPG and how to use it safely may help allay fears about fires and give comfort that LPG is a perfectly acceptable fuel for cooking the local cuisine. LPG marketing companies, industry associations, and consumer associations can all take part in these campaigns.

Taken together, the foregoing findings suggest that campaigns and programs to promote household use of LPG to substitute biomass are likely to be more effective if they first focus on areas where biomass is diminishing, the costs of biomass cooking are high, and there is infrastructure for reliable LPG delivery that does not impose an undue burden on households. The last aspect would include the existence of a tarred road connecting the nearest bottling plant to a shop selling LPG and inexpensive means of getting to the shop by consumers or home delivery at a nominal fee, if any.

In promoting household use of LPG, it would make sense to first target households whose income is sufficiently high to start using LPG without subsidies and who already live in areas with LPG marketers, because these households are best placed to switch entirely to LPG and sustain its use. Such a shift will also help ease growing pressure on biomass resources, which will continue to be used by the rural poor for the foreseeable future and the mitigation policy for which must include cleaner-burning, efficient stoves for solid fuels. There are others who will start using LPG but will retain solid fuel use. Starting to use LPG is not the same as abandoning solid fuels altogether but is the first step nevertheless, and, with experience, a household will feel increasingly comfortable handling LPG. Increasing use of LPG in the community could in turn lead others to consider LPG through demonstration effects.

The government can contribute in a variety of ways to facilitate household use of LPG within and outside the LPG sector. Outside the sector, provision of roads on which heavy trucks can travel is the first requirement for being able to deliver LPG in sufficient quantities. Addressing port congestion and facilitating the expansion of port capacity as needed may be important for importing countries. Within the sector, the government should make it easy for LPG suppliers to see what laws, regulations, standards, and policy are currently in effect by posting them in one place in reverse chronological order. In some countries it is difficult to figure out what has superseded which regulation or standard. The regulatory framework should be complete, internally consistent, and broadly aligned with widely accepted international practice. Consideration should be given to minimum stock requirements, taking into account what can be realistically enforced. Having established such a framework, the government needs to work on monitoring and enforcement and on creating fair competition that will improve the efficiency of the sector and, equally important, that will ensure that efficiency gains are passed on to consumers in the form of lower prices.

In countries that do not yet have such associations, a helpful development would be the formation of national LPG associations that include marketing companies, cylinder manufacturing and maintenance companies, government representatives, and consumer organizations. Such associations can contribute to regulation and policy formulation, promotion of fair competition, adoption of international safety standards, collection and dissemination of information, and education and training. Governments, LPG marketing companies, and civil society organizations can all contribute especially to consumer education and awareness-raising, as well as watching out for commercial malpractice and helping to create market conditions whereby efficient, law-abiding firms increase their market share to the benefit of all consumers.

Practical steps to take based on the findings of this study are outlined in Table 11, which provides a summary of options for improving market conditions to promote greater use of LPG by households. Not all options are applicable to a given market. Country-specific recommendations can draw upon the options listed in the table, tailored to specific country circumstances.

Table 11: Examples of options for facilitating household use of LPG

Goal	Option	
Lower costs to consumers	Exploit economies of scale	Hospitality arrangements, third-party access
		Bulk purchase, joint purchase, large import parcels
		Large refineries
	Lower barrier to entry	Hospitality arrangements, third-party access
	Minimize demurrage charges	Rapid customs clearance
		Reduced port congestion
		Round-the-clock staffing by port authorities

Goal	Option	
		Adequate port receiving capacity
	Minimize short-selling	Clear marking of cylinder tare weight
		Enforcement of scale calibration and date of last scale calibration visible to customers
		Customer's right to check cylinder weight
		Industry association's (voluntary) seal of quality/certification
		Publication of names of companies found short-selling
	Increase price competition	Posting of prices by company, location, and cylinder size on government Web site
		Competition policy
	Improve auxiliary infrastructure	Improved road conditions
		Improved port infrastructure in importing countries
Enhance safety	Establish clear regulations	Formal adoption of international standards by reference
		All regulations posted in one place on the Web in reverse chronological order
		Training of supply personnel legally required
		Education of consumers about safe handling of LPG legally required
	Enforce safety regulations	Where there is a ban on cross-filling, ban effectively enforced
		Small fee levied to finance monitoring and enforcement
		Registry of certified installers
		Clearly marked date of last cylinder recertification
		Registry of certified private inspectors operating under government supervision
		Training workshops organized by LPG industry association
		Publication of names of companies violating safety rules
	Educate consumers	Pictorial guides in local languages, newspaper/radio/TV advertisements, Web posting of safety information
		Neighborhood demonstrations by retailers, industry association, and consumer groups
		In-house demonstration of proper cylinder and stove handling by installers
Target financial assistance	Move away from universal price subsidies	Expansion of social safety net program to help pay for LPG, such as cash transfer or vouchers
	Spread or reduce upfront adoption cost	Dealer incentives for cylinder deposit fee and stove
		Dealer-financed installment plan
		Micro-finance scheme
		Small cylinders in niche market
Minimize shortages	Require minimum commercial and/or strategic stockholding in regulations	
	Ensure reasonable returns (through, for example, removal of universal price subsidies) to efficient operators to build capital for construction of storage facility	
	Encourage hospitality and third-party access	
Raise awareness and involve	Government: Publish price information, industry statistics, frequently asked questions, safety tips, and names of companies violating rules that directly affect consumers on the Web and in reports; establish a simple mechanism for registering complaints	

Goal	Option
consumers in improving market conditions	Industry association: Publish information, frequently asked questions, and safety tips on the Web; publish brochures; take out newspaper/radio/TV advertisements; publicize information on retailer location and contact details; establish quality control and issue seals of quality for companies in compliance; establish a simple mechanism for registering complaints against members
	Companies: disseminate information on proper handling of LPG cylinders, frequently asked questions, and safety tips; have installers show new customers in their homes how to handle an LPG cylinder and stove properly; establish a simple mechanism for registering complaints

Appendix A: Heckman Model Results

Table A.1 shows the results for the six countries with household-level fuel prices. Rho is the correlation between the errors in the selection and consumption equations. As expected, income and LPG prices had by far the two largest effects. Kerosene prices also had relatively large effects: at average observed prices, the magnitude was 2.0 for India, 4.7 for Indonesia, and 1.0 for Sri Lanka in the selection equation—that is, the product of the coefficient for kerosene prices and the average of the logarithm of kerosene prices, which appears on the right-hand side of the selection equation, was -2.0 in India—and 1.1 for India and 3.0 for Pakistan in the consumption equation. For selection, there were other important variables: household size in India, Indonesia, and Sri Lanka; electricity connection except in Pakistan where availability of electricity tended to be linked to the availability of natural gas; and, the highest levels of education attained by male and female household members. Having a male household member with the highest level of education available in the country would have the same effect as increasing household expenditure by 30 to 80 percent relative to an average household (with average expenditure and education levels). Women's education had even larger effects; a female household member with the highest level of education available would have the same effect as increasing household expenditure by at least 50 percent, and as much as several-fold in Guatemala. The effects of education on consumption were significant in two countries each for men and women, but the sizes of the effects expressed in terms of percent increase in expenditure were comparable between men and women.

Table A.1: Heckman model for LPG in countries with household-level prices

Independent variable	Guatemala	India	Indonesia	Kenya	Pakistan	Sri Lanka
Selection equation (probit)						
Log of household expenditure	0.54 (0.044)	1.5 (0.016)	1.3 (0.068)	0.78 (0.051)	0.31 (0.042)	1.2 (0.033)
Log of LPG price	—	—	–1.5 (0.27)	–0.76 (0.23)	–2.3 (0.65)	—
Log of firewood price	0.16 (0.030)	0.18 (0.013)	NA	—	—	0.079 (0.031)
Log price of charcoal	NA	—	—	0.27 (0.13)	—	NA
Log of price of kerosene[a]	—	0.88 (0.073)	0.65 (0.15)	—	—	0.25 (0.11)
Number of rooms[b]	—	NA	0.0017 (0.0003)	0.073 (0.021)	0.10 (0.014)	0.098 (0.014)
Dummy for car ownership	—	0.16 (0.037)	0.47 (0.057)	—	—	0.44 (0.061)
Household size	–0.13 (0.012)	–0.31 (0.006)	–0.22 (0.027)	–0.11 (0.016)	—	–0.26 (0.029)
Household size squared	—	0.0066 (0.0003)	0.004 (0.001)	—	—	0.010 (0.003)
Dummy for engaging in	–0.72	–0.20	–0.18	–0.27	—	–0.59

Independent variable	Guatemala	India	Indonesia	Kenya	Pakistan	Sri Lanka
agriculture[c]	(0.045)	(0.016)	(0.068)	(0.091)		(0.033)
Highest level of education for men	0.016 (0.008)	0.083 (0.003)	0.026 (0.006)	0.042 (0.011)	0.020 (0.005)	0.065 (0.006)
Highest level of education for women	0.054 (0.007)	0.11 (0.003)	0.041 (0.006)	0.058 (0.012)	0.023 (0.006)	0.078 (0.006)
Age of household head	—	0.002 (0.0005)	—	—	–0.005 (0.001)	
Dummy for male household head	—	—	—	—	—	0.071 (0.036)
Dummy for indigenous household head	–0.57 (0.047)	NA	NA	NA	NA	NA
Dummy for urban residence	0.61 (0.044)	0.48 (0.013)	—	0.22 (0.099)	–0.34 (0.049)	0.64 (0.030)
Dummy for electricity connection	0.87 (0.070)	0.82 (0.020)	0.82 (0.21)	0.59 (0.076)	—	0.85 (0.12)
Constant	–4.68 (0.34)	–16 (0.21)	–12 (2.7)	–7.2 (1.3)	**4.4** **(2.4)**	–16 (0.57)
Consumption equation (regression)						
Log of household expenditure	0.083 (0.016)	0.19 (0.008)	0.23 (0.056)	0.16 (0.078)	0.77 (0.072)	0.26 (0.028)
Log of LPG price	–0.41 (0.12)	–0.96 (0.033)	–0.67 (0.089)	–0.63 (0.11)	–1.3 (0.37)	–0.91 (0.12)
Log of firewood price	0.053 (0.015)	0.12 (0.009)	NA	—	—	0.074 (0.023)
Log of kerosene price[a]	—	0.46 (0.043)	—	—	0.91 (0.28)	—
Log of kerosene price, other[d]	NA	0.073 (0.025)	NA	NA	NA	NA
Dummy for house ownership	0.11 (0.022)	—	—	—	0.19 (0.084)	—
Dummy for car ownership	—	0.035 (0.010)	—	—	0.23 (0.085)	0.064 (0.025)
Household size	—	0.070 (0.003)	0.048 (0.013)	—	–0.036 (0.007)	0.040 (0.006)
Square of household size	—	–0.002 (0.0002)	–0.0008 (0.0002)	—		—
Dummy for engaging in agriculture	–0.067 (0.030)	–0.21 (0.009)	—	—	–0.14 (0.052)	–0.22 (0.025)
Highest level of education for men	—	0.017 (0.002)	—	—	—	0.014 (0.004)
Highest level of education for women	0.011 (0.002)	0.003 (0.001)	—	—	0.051 (0.008)	—
Age of household head	—	0.0004 (0.0002)	—	—	—	0.002 (0.001)
Dummy for male household head	—	0.046 (0.009)	—	—	—	—
Dummy for urban residence	0.073 (0.027)	0.14 (0.007)	—	—	0.26 (0.071)	0.23 (0.020)
Dummy for electricity connection	—	—	—	—	0.18 (0.070)	0.38 (0.14)

Independent variable	Guatemala	India	Indonesia	Kenya	Pakistan	Sri Lanka
Constant	2.4	1.7	4.5	3.6	–4.4	2.2
	(0.27)	(0.17)	(0.88)	(0.89)	(1.4)	(0.64)
Inter-equation correlation						
Rho	0.29	–0.17	**–0.12**	**–0.25**	0.37	**0.005**
	(0.068)	(0.017)	**(0.11)**	**(0.16)**	(0.16)	**(0.057)**

Source: Kojima, Bacon, and Zhou 2011.

Notes: — = statistically insignificant at 5 percent or of the wrong sign; NA = variable not available in the survey. Coefficients are followed by standard errors in parentheses. Numbers in bold indicate that the variables are not significantly different from zero using a 5-percent test.

a. For India, the price of subsidized and rationed kerosene distributed through the Public Distribution System.

b. Number of bedrooms for Sri Lanka, floor area for Indonesia.

c. This variable is not available in Pakistan and is replaced by an alternative dummy that is 1 if the household owned, leased, or rented agricultural land.

d. Price of unsubsidized kerosene in India.

Table A.2 summarizes the unconditional marginal effects. The second-stage (consumption) equation provides both direct and indirect effects of a change in an independent variable. The first comes from the coefficient of the variable estimated by the Heckman approach, while the indirect effect comes from the effect of a change in that variable on the correlation (rho) by the coefficient of rho in the second equation. The sum of the two effects is the conditional effect of a change in the independent variable at a given probability of using LPG. The increase in the independent variable also increases the probability that the household will use LPG, and hence will increase its purchase through this route. The sum of this effect and the conditional effect is termed the unconditional effect, which shows the combined effect on the quantity of LPG purchased.

Table A.2: Unconditional marginal effects

Independent variable	Guatemala	India	Indonesia	Kenya	Pakistan	Sri Lanka
Log of household expenditure	0.26	0.74	0.32	0.28	0.73	0.59
Log of LPG price	–0.41	–0.96	–0.79	–0.75	–1.0	–0.91
Log of firewood price	0.11	0.18	—	—	—	0.095
Log of charcoal price	—	—	—	0.042	—	—
Log of kerosene price[a]	—	0.77	0.053	—	0.91	0.065
Log of kerosene price, other[b]	—	0.073	—	—	—	—
Number of rooms[c]	—	—	0.0001	0.001	–0.010	0.026
Dummy for house ownership	0.11	—	—	—	0.19	—
Dummy for car ownership	—	0.094	0.042	—	0.23	0.20
Household size	–0.042	–0.038	0.031	–0.017	–0.036	–0.029
Household size squared	—	0.000	–0.001	—	—	0.003
Dummy for engaging in agriculture[d]	–0.29	–0.28	–0.016	–0.042	–0.14	–0.36
Highest level of education for men	0.005	0.046	0.002	0.006	–0.002	0.031
Highest level of education for women	0.028	0.042	0.003	0.009	0.048	0.021
Age of household head	—	0.001	0.0004	—	0.001	0.002
Dummy for male household head	—	0.046	—	—	—	0.018
Dummy for indigenous household head	–0.18	—	—	—	—	—
Dummy for urban residence	0.27	0.32	—	0.035	0.30	0.42
Dummy for electricity connection	0.25	0.25	0.055	0.096	0.18	0.54

Source: Kojima, Bacon, and Zhou 2011.

Note: — = coefficient not significant in either equation.

a. For India, the price of subsidized and rationed kerosene distributed through the Public Distribution System.

b. Price of unsubsidized kerosene in India.

c. Number of bedrooms for Sri Lanka, floor area for Indonesia.

d. This variable is not available in Pakistan and is replaced by an alternative dummy that is 1 if the household owned, released, or rented agricultural land.

Appendix B: Sources of Data

Table B.1: Sources of data for figures 6 and 7 and table 7

Country	LPG consumption	Population and GDP
Afghanistan	Not available	WDI 2011 for population, IMF 2011a for GDP
Albania	IEA 2011	WDI 2011
Brazil	IEA 2011	WDI 2011
Dominican Rep.	IEA 2011	WDI 2011
Fiji	United Nations Statistics Division 2011 for 2008 data	WDI 2011
Ghana	NPA 2011b for total consumption and IEA 2011 for residential share	WDI 2011
Guatemala	IEA 2011	WDI 2011
Jordan	IEA 2011	WDI 2011
Kenya	IEA 2011	WDI 2011
Mexico	SENER 2010	WDI 2011
Moldova	IEA 2011	WDI 2011
Morocco	IEA 2011	WDI 2011
Pakistan	IEA 2011	WDI 2011
Peru	IEA 2011	WDI 2011
Senegal	IEA 2011	WDI 2011
South Africa	IEA 2011	WDI 2011
Sri Lanka	IEA 2011	WDI 2011
Thailand	EPPO 2011	WDI 2011
Turkey	EDKS 2011	WDI 2011
Vietnam	IEA 2011	WDI 2011

Table B.2: Sources of data for figure 8

Country	Sources
Brazil	ANP 2011
Ghana	NPA 2011c
Kenya	Local newspaper reports on retail prices; no taxation
Mexico	Price and tax for Mexico City available at http://dof.gob.mx/nota_detalle.php?codigo=5168848&fecha=30/11/2010
Peru	17% value-added tax imposed on the ex-refinery price of S./ 1.74 in Dec 2010 subtracted from the retail price in Lima to arrive at the net-of-tax price. Weekly ex-refinery prices in Dec are available at www2.osinerg.gob.pe/preciosreferencia/TarPreciosReferencia_2010.html
South Africa	Department of Energy 2010a and 2010b
Thailand	EPPO 2010
Turkey	Information collected during the field visit to Istanbul in July 2011

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