HOW DO HOUSEHOLDS CONSUME ENERGY?

Evidence from Latin America and the Caribbean

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Foreword

From an economic, environmental, policy, and political perceptive, households are central to energy markets, particularly in Latin America and the Caribbean. The region has increased its energy consumption fourfold since 1971. This growth is associated with a sustained rise in incomes, as well as with increasing urbanization and broader access to modern energy sources. As income growth and urbanization are expected to continue, the countries in the region face the challenge of meeting rising energy demands in a sustainable and affordable manner.

Households play a key role in shaping energy consumption and are of fundamental importance for practitioners in the design of energy policies. Understanding households' energy consumption behavior is fundamental for long-term energy supply planning and for setting energy pricing policies and subsidies. At the same time, in the face of more stringent climate targets, improving energy performance is a core priority for the region.

In this context, and with the aim of helping to improve the effectiveness of energy policies, this book sets out to investigate a fundamental question: How do households consume energy? Based on a novel collection of information at country and household levels, the book provides a comprehensive distributive analysis of energy consumption and expenditure, and distinguishes between fuels used at home and those used for private transportation.

The analysis reveals the growing relevance of energy services in household consumption and budget allocation decisions. The book documents the transition of households towards greater use of modern fuels such as electricity and gas. As income increases over the coming decades, these fuels will become ever more important, and they will be the main component of growing energy demand. The expected increase in demand for transport fuels is even more pronounced due to generalized motorization. These facts underscore the coming challenges across the region stemming from household energy needs.

Correspondingly, energy emerges as one of the main components in household budgets, second only to food. The analysis by income groups, and by type of fuel, also reveals distinct expenditure patterns relevant for policymakers. For instance, higher-income segments concentrate most of the aggregate energy expenditure in the region. In households at the top of the income distribution, transport fuels represent the main energy expenditure; while for lower-income groups with access to modern fuels most energy expenditure is on electricity and gas. Along with these features of energy consumption, the book by extension also documents a pronounced misallocation of energy subsidies towards higher-income groups.

This book outlines and analyzes energy challenges in the residential sector, and reveals significant opportunities for actions and improvements going forward. Our goal is to document the energy reality of the region so that policy interventions are informed by empirical facts such as those presented here.

Introduction

Providing universal access to energy sources is necessary to enhance socioeconomic well-being, but it comes at the cost of larger greenhouse gas emissions. This points to a trade-off between household needs and reducing the environmental impact of human activities. Therefore, understanding energy consumption and expenditure in the household sector is fundamental in the design of energy policies around the world.

In Latin America and the Caribbean (LAC), households are directly responsible for over 16 percent of total energy consumption and for about 25 percent of total electricity use.[1] Thus, the residential sector plays a key role in shaping energy consumption. These figures reflect only domestic consumption and do not include the use of liquid fuels for private transportation – one of the main components of household energy consumption.[2] As countries in the region develop and access to modern fuels continues to expand, LAC faces the challenge of ensuring a reliable energy supply that is environmentally sound, sustainable, and affordable in the years to come.

Alongside the doubling of per capita income in the region, household consumption of electricity and gas combined has more than trebled since 1971. Such growth is faster than that of either the transportation or industrial sectors, and thus has important implications for pricing policies, investment planning, and the design and evaluation of subsidy schemes – all of which are part of a multi-dimensional energy policy.

1. Authors' calculations based on data from the International Energy Agency as of 2013.

Even though in recent years there has been an increasing amount of research directed toward informing public policy discussions on these topics, there is a need for more disaggregated and context-specific analysis. Furthermore, few studies concentrate on LAC, and even fewer include distributional perspectives on energy consumption at the household level. This study seeks to close this gap and answer specific questions about household behavior in the region in order to inform the discussion on energy and environmental policy and provide a platform for understanding the likely effects of alternative interventions on households.

With this aim in mind, this book examines household energy consumption and expenditures in LAC with a focus on time and income distribution. The book also addresses several questions regarding the region's residential sector. What are the drivers of household energy consumption? How has residential energy consumption (and its composition) evolved over time? How has energy use responded to changes in income levels? What share of household income is spent on energy? Which fuels account for household energy expenditures? What have been the trends in household energy composition and the cost of energy as a share of total income? How have energy expenditures responded to income changes? The answers to these questions provide an extensive empirical characterization of the household sector that should be of interest to policymakers.

2. See Cashin and McGranahan (2006) and Advani et al. (2013) for the cases of the United States and the United Kingdom, respectively.

In this context, the book addresses energy consumption in both real (quantity) and nominal (expenditure) terms, based on a novel collection of publicly available data sets that include country data at the national and household levels. The country aggregate data come from the International Energy Agency and include 22 LAC countries over the period 1971–2013. The household expenditure data come from the most recent nationally representative household surveys, covering over 200,000 households in 20 LAC countries. The detailed data sets allow for distinguishing the types of fuels used within dwellings from those used for private transportation. Throughout this book, references to fuels used within dwellings include electricity, natural gas, and additional non-modern sources such as firewood, kerosene, and coal. Fuels used for private transportation of household members include gasoline, diesel, alcohol, liquefied petroleum gas (LPG), and compressed natural gas (CNG).

This book outlines some general policy guidelines based on a thoughtful characterization of consumption and energy expenditures in the region's households under a structure consistent with the literature and with the evidence on what is being done, what has worked, and what has not. In this way, the aim is to contribute to a joint effort to improve the functioning of electricity markets in the residential sector and to facilitate households' access to affordable, reliable, and clean energy sources.

The book is divided into four major parts. The first part presents an overview of the key findings from all chapters and provides a review of the literature on topics the book touches upon. The second part offers a country-level perspective of residential energy use in the region, including trends, the role of economic development, and income-group profiles with countries as the unit of analysis. The third part presents a microeconomic perspective on residential energy use based on country surveys, where households as such are the unit of study. The key topics in this part of the book are household energy use and expenditures. The final part centers on energy policy in the region: prices, subsidies, conservation, and energy efficiency. Some of the overarching topics touched on in the book include an overview of the composition of residential energy consumption for the period between 1971 and 2013; the relationship between per capita income growth and energy consumption (residential and other economic sectors); patterns in household energy expenditures by income group and in urban and rural locations (with implications for energy subsidies); and microeconometric analyses of the relationship between household income, energy use, and energy expenditure shares.

Part I

Household Energy Consumption

Chapter 1

Energy for Households: Summary and Recommendations

In Latin America and the Caribbean (LAC), household demand plays a key role in shaping aggregate energy consumption. For example, household consumption of electricity and gas has more than tripled since 1971, outpacing high energy consumption sectors such as transportation and industry. However, the interest in LAC households in terms of energy lies beyond this growing demand. Formulation of energy policies by governments has the residential sector as a key priority, mainly due to affordability concerns. Indeed, this is particularly true in LAC, where setting the right energy prices remains a political and technical challenge. At the same time, energy markets, mainly the electricity sector, are faced with significant technological developments that will magnify the urgency to address these challenges and, perhaps more importantly, put households at the center of discussions in the near future, both in the regulatory and business spheres.

With this in mind, understanding household energy consumption and expenditure is a key input for effective energy policy design and implementation, with implications for fiscal and environmental policy. An intricacy about household energy demand is the interplay among the determinants of energy consumption. At the forefront is income, but income in turn determines and is also determined by population growth, urbanization, expansion of the middle class, energy prices, energy efficiency, and even temperature and conservation policies.

This book examines household energy consumption and expenditures in LAC, with a particular focus on variations over time and among the different levels of income distribution. The analysis is based on a unique collection of nationally representative data sets that distinguish between "at home" and "transportation" fuel use. The former fuels are also referred to as residential energy or domestic fuels, of which there are three categories: modern (electricity and gas), transitional (kerosene, diesel, and coal), and traditional (biomass).

The sections that follow outline the main lessons from the book.

Residential Energy Consumption

In LAC, the household sector has been experiencing a marked transition towards modern energy sources. As income grows and access to such energy sources improves, households are correspondingly increasing their consumption of electricity, natural gas, and transport fuels. As this happens, the region finds itself at a stage of development where it is highly dependent on these fuels for a sustained path of economic progress. In the decades to come, as countries in the region continue to ascend the development ladder, the household sector is bound to become a central player in the growth of energy demand. Critical points regarding residential energy consumption include the following:

- ***The growth of residential energy has been underpinned by the use of modern energy sources (electricity and domestic gas), shifting the composition of energy consumption.*** Between 1971 and 2013, the residential sector increased its aggregate energy consumption by 70 percent, mainly driven by growth in modern energy sources. Electricity and gas consumption grew by more than 300 percent in that period. The composition of residential energy consumption shifted from 80 percent traditional and transitional fuels in 1971 to 40 percent in 2013, while the share of gas and electricity increased from 20 to 60 percent of the total.

- ***Most of the growth in modern energy consumption has occurred in higher-income countries, while households in lower-income countries remain dependent on traditional and transitional fuels.*** In high- and middle-income countries in LAC, electricity and natural gas consumption has increased alongside sustained reductions in the use of traditional and transitional fuels. Although the proportional use of these latter "dirty" fuels is also decreasing in low-income countries, they still account for as much as 80 percent of total residential energy consumption. In contrast, modern fuel use in high-income countries makes up around 80 percent of total residential energy consumption.

- ***Domestic gas and firewood are the two main cooking fuels used in LAC households.*** Domestic gas is used by 80 percent of LAC households, while the remaining 20 percent rely on less efficient and dirtier fuels. However, the consumption of dirty fuels for cooking is mainly concentrated in rural areas, where more than 50 percent of households rely on biomass and, to a lesser extent, kerosene. Geographic location and income combine to paint a more dramatic picture: the share of rural households using traditional or transitional fuels ranges from more than 70 percent in the lowest income quintile in rural areas to around 1 percent in the highest urban income quintile. It follows that as modern fuels become more readily available and incomes increase, households replace traditional fuels with more efficient and cleaner energy sources. As the LAC region has moved up the energy ladder, the shift towards electricity and gas, which are cleaner and more efficient for cooking, lighting, and heating, has meant that per capita energy consumption levels have remained stable over the last four decades, with efficiency gains offsetting greater consumption.

- ***It follows from the above that facilitating access to a diversified energy portfolio increases both energy efficiency.*** Firewood is an inefficient and highly polluting fuel that mainly harms lower-income households. Further, firewood represents not only an inefficient stage of energy use, but also a fuel used mainly because of lack of options to diversify. Having access to diversified array of modern fuel sources promotes efficiency in energy use but having access, for example, only to electricity and not to gas, may lead to overconsumption of one fuel due relatively low efficiency of heating equipment based on electricity.

- ***Transport fuels are one of the main components of household energy consumption.*** The transport sector represents approximately one-third of total energy consumption in LAC. While disaggregated household

figures are not available, fuel consumption increases significantly with household income due to greater private vehicle ownership and demand for public transportation to commute in urban settings. For instance, in Mexico and Peru, ownership of private motor vehicles has increased significantly across all income groups since the mid-1990s. Vehicle ownership in the lowest income quintile rose from 4 to 13 percent in Mexico and from 2 to 8 percent in Peru between the mid-1990s and 2014.

- ***A doubling of per capita income would translate into a 50 percent increase in per capita consumption of modern fuels in the residential sector.*** Despite variations in energy income elasticities across countries and within countries among income groups and economic sectors, LAC is at a stage of development driven by modern fuels, and where household economic conditions have spillover effects on transport, industry, and commerce. In the case of domestic fuels, the income elasticity of electricity and natural gas tends to decrease as income increases. Due to structural shifts that stem from the development process (e.g., rural to urban migration), the income elasticity of transport fuels increases with per capita income.

- ***The observed patterns in residential energy consumption in LAC follow other regions' development path.*** As the LAC economies grow, so does their modern energy needs, which raises questions of reliability, affordability, and sustainability. Planning for energy infrastructure has to be informed by forecasts on the composition of energy demands, with a focus on electricity and natural gas along the climb of the energy ladder.

Household Energy Expenditures

While documenting energy consumption patterns across income groups, this book also emphasizes the distributive effects of energy policies. The analysis shows the crucial role of income in shaping household energy consumption. Energy commodities emerge as essential components of the household budget, representing the second most important expenditure category after food, although with important distinctions across income groups. While the share of energy expenditure in the annual household budget ranges between 7 and 9 percent across income groups, its composition significantly changes as households grow wealthier. Families in the lowest income quintile allocate 85 percent of their energy spending to domestic fuels. As income rises, expenditure on transport fuels increases to the point where it becomes the largest energy expenditure, representing 65 percent of energy spending in the highest income quantile.

This change in composition has a sizable impact at the aggregate level, as transport fuels make up 50 percent of regional energy expenditure, followed by electricity (34 percent) and gas (15 percent). Energy expenditure is also significantly concentrated in the richest households, particularly in the case of transport fuels – the fourth and fifth quintiles (the wealthier 40 percent households) account for around 80 percent of aggregate spending on those fuels. Overall, this indicates that fuels for private transportation behave as a luxury good, for which expenditure increases more proportionally than household income.

With regard to domestic modern fuels – electricity and gas – they exhibit characteristics of an economic necessity. Their consumption is mainly determined by access to the energy source, but actual take-up ultimately depends on the household's capacity to pay for the services. Affordability problems concentrate in lower income groups and in countries highly dependent on energy imports. In the poorest income quintile, domestic fuels represent around 8 percent of the household budget, a share that decreases as one moves to the wealthier side of the income distribution, although consumption rises significantly with income. As net importers of energy, most Caribbean countries and Uruguay largely exceed this average, indicating their greater vulnerability to shocks in domestic energy prices. There is also notorious variation among poorer households between rural and urban areas, which creates difficulties in properly targeting the most vulnerable households. For these reasons, the balance between affordability and ensuring cost recovery is one of the main concerns for policymaking directed towards facilitating equitable consumption of cleaner and more efficient energy. Critical points regarding household energy expenditures include the following:

- ***Energy expenditures constitute the second most important budgetary item after food for all income groups in LAC countries.*** On average across countries, households allocate around 8 percent of their annual expenditures to energy, including fuels used within the dwelling and fuels used for private transport. This share remains roughly stable across the income distribution, from the poorest consumers (8.9 percent) to the highest income groups (7.4 percent). However, the average energy share varies by country, ranging from 3.4 percent in Ecuador to 17 percent in The Bahamas. In countries where electricity prices are relatively higher (Barbados, Chile, Jamaica, The Bahamas, and Uruguay), expenditure on electricity and its share in household budgets are significant, reflecting the vulnerability of household budgets to energy prices. These figures do not include household expenditures on public transport, a relevant source of indirect demand for liquid fuels, averaging 3.6 percent of total household budgets.

- ***The composition of energy expenditures, however, is markedly different across income groups.*** Domestic fuels make up most of the energy expenditures of the poorest groups. The energy share of expenditure decreases with household income, and holds across electricity, gas, and other fuels used within the place of residence. For dwelling consumption, the energy share of expenditure ranges from approximately 7.8 percent for the bottom income quintile to around 3 percent for the top quintile. On the other hand, the share of transportation fuels increases from 1.3 percent in the first (poorest) quintile to 4.9 percent in the fifth (wealthiest) quintile, for which it accounts for most energy expenditures. These figures show the dual role of energy sources as inferior and normal goods: solid and liquid fuels are replaced by modern fuels as long as income allows for doing so; and transport fuels eventually behave as luxury goods among higher income groups. The counterpart to this demand behavior is analogous to food as a subsistence good and to leisure as a luxury good.

- ***The distributional effect of changes in energy prices depends on the type of fuel and on the income group.*** A 10 percent increase in the price of modern domestic energy sources (electricity and natural gas) would translate into a 0.74 percent increase in living costs for the poorest households; in contrast to a 0.3 percent increase in living costs for the highest income group. On the other hand, a 10 percent increase in gasoline prices would translate into expenditure increases equivalent to 0.1 percent in the lowest income group and 0.44 percent in the highest. Increases in gasoline prices disproportionately affect richer households, while increases in electricity and domestic gas prices disproportionately affect poorer ones.

- ***In absolute terms, average household energy expenditures in LAC are around US$1,000 per year in 2014 prices.*** However, there is significant variation in annual average energy expenditures across LAC countries, ranging from around US$330 in Bolivia to

For citizens of Latin American countries, **one of ten dollars spent goes toward paying energy bills**

However, the amount of energy the citizens get to consume **is different for every country.**

US$4,800 in The Bahamas. The two main components of energy expenditures are transport fuels (50 percent) and electricity (34 percent), while the share of gas (15 percent) varies considerably across countries. Energy expenditures also vary significantly based on income levels, ranging from around US$400 per year in the poorest quintile to US$1,900 per year in the richest quintile at the regional level. In addition to the differences across countries, there is also considerable variation across income quintiles. There is larger skewness and dispersion of the energy expenditure shares at the bottom than at the top of the distribution of income. In the first quintile, 1 in 10 households spends more than 24 percent of its budget on energy, indicating an extreme affordability problem. In the top quintile, by contrast, 75 percent of all households have energy budget shares in the narrow range of 1 to 3.6 percent of household income.

- ***In aggregate terms, the richest 20 percent of households account for more than 40 percent of total energy expenditures in the household sector.*** At the other end of the income distribution, the bottom 20 percent of the population account for around 8 percent of total energy expenditures. In terms of composition, 64 percent of regional energy expenditures by the richest group go toward transport fuels, while expenditures on domestic energy sources make up the largest share of the poorest income group, at 76 percent.

- ***Gasoline accounts for over 80 percent of expenditures on transport fuels and represents households' largest expenditures on private transportation.*** By income group, around 79 percent of regional gasoline spending is concentrated in the two top quintiles, while the bottom quintile accounts for less than 2 percent of gasoline expenditures.

- ***The distributional characteristics of consumption and expenditures indicate that conditions are not suitable for progressive subsidy programs for transport fuels.*** In addition to the patterns shown in this study, recent evidence has pointed at significant misallocations of transport fuel subsidies such that they mostly benefit higher income groups. Furthermore, given the size of transport expenditures, poorly targeted subsidy programs may translate into significant and unjustified fiscal burdens on the state, generate price distortions, and cause severe financial harm to the energy industry. In the medium and long run these conditions reduce investment and lead to inefficient and underdeveloped energy systems that lack the capacity to supply quality energy services.

- ***As incomes have grown, both expenditures on and consumption of modern fuels have increased across all income groups.*** In the analysis of Mexico and Peru, increments in household energy consumption and expenditure have occurred among all income groups. In both countries, the upward trend in energy expenditures has been accompanied by greater use of transport fuels among all income groups, suggesting increasing fossil fuel demand from the household sector.

- ***There is substantial room for improved energy efficiency in the household sector.*** Energy-efficient policies and programs need long-term institutional and financial backing. Overcoming barriers to the diffusion of energy efficiency in the residential sector may need unwavering policy support to empower such initiatives.

- ***The design of energy efficiency interventions needs to incorporate the behavioral response of the consumer to the policy.*** For example, interrelated dimensions to be considered include (1) participation in energy efficiency programs, (2) optimal subsidies, and (3) the need for estimated energy savings to account for the behavioral response of households to a new setting. Currently, household participation is mainly encouraged through subsidies, but there may be less expensive ways to incentivize participation, including "nudges" (i.e., to reduce inattention problems or as a moral suasion tool) or dedicated financing lines or guarantees directed towards target beneficiaries. Even if subsidies are necessary, the adequate amount of the subsidy needed to achieve cost-effective levels of participation needs to be evaluated. For Mexico, Davis et al. (2014) show that most households would have participated even with much lower subsidy amounts. Finally, energy savings from subsidies are usually less than expected because the estimates are based in most cases on a rigid ex ante approach. In order to design better programs, lessons need to be learned from the ex post results of pilots and previous experiences. Thus, it is key to investigate the main drivers behind the energy saving deviations to correct energy efficiency policies.

Policy Recommendations

The empirical regularities uncovered in this book have important implications for addressing the energy needs of the people of LAC. Four broad interrelated dimensions in which the region will need to place particular attention are described below. However, the guiding principle should be to account for the specific circumstances of each country, region, or government in terms of organization and culture, and to tailor policies on the basis of those idiosyncrasies. Policy design has to take the following dimensions into account in order to be effective:

1. ***Managing the energy transition: Urbanization trends and the rise of the middle class are expected to significantly boost household demand for electricity, domestic gas (i.***e., natural gas and LPG), and transport fuels. Meeting this incremental demand will require long-term planning of investments in energy supply. In a business-as-usual scenario, reaching the level of economic development of the member countries of the Organization for Economic Cooperation and Development (OECD), would require an expansion in yearly modern energy production in the region equivalent to Brazil's total energy consumption (as of 2013) solely to meet the additional aggregate energy

demand of the residential sector. The composition of modern energy use is also expected to shift towards greater demand for natural gas and transport fuels. These figures point to today's underinvested energy sector, highlighting the need for long-term integrated energy planning that should include all energy subsectors and account for demands from all economic sectors. Improving the productivity of energy infrastructure, deepening regional energy integration, and diversifying the energy matrix are important strategies to reduce the environmental impact and the financial costs of the required investments.

2. ***Enhancing pricing policies: Together with affordability and cost recovery, minimizing price distortions constitutes a key element to avoid overconsumption of energy and provides incentives to increase energy efficiency and conservation practices in households.*** Finding an adequate balance between those areas will be more difficult in countries where energy markets are subject to political interference and inefficient management of natural endowments. Therefore, greater attention needs to be directed towards enhancing institutional capacity and the independence of the energy sector in order to facilitate technically sound formulation of energy prices.

   Establishing the right prices also requires a better understanding of household energy consumption behavior. This is an area where further research is required, and better data is a necessary input. In effect, information on quantities of energy consumed by households is scarce, which severely restricts the understanding of how households respond to different environments or policies. Related measures towards improving data availability include strengthening the expansion of metering of electricity and gas and implementing systems for acquisition and control of consumption records. In addition to providing essential information for energy pricing policies, these measures contribute to reducing energy losses and improving decision-making within utilities.

3. ***Improving subsidies schemes: There is room for significant improvement in most LAC countries, given the presence of subsidies in most energy subsectors, whether implicitly or explicitly.*** An increasing amount of evidence suggests that subsidies are poorly targeted with considerable filtrations toward richer income groups, representing a heavy fiscal burden. This is particularly the case for transport fuels, where the richest quintile captures over 40 percent of the subsidy benefits (accounting for both direct and indirect benefits), based on the observed distribution of energy expenditure. Under the distributive characteristics presented in this book, no current subsidy scheme for transport fuels has desirable progressive properties for the household sector.

   Furthermore, the weight of transport fuels on household budgets is increasing across all income groups over time. This trend, which is strongly associated with greater ownership of private motor vehicles indicates a heavy motorization of LAC cities. The current scenario of low oil prices represents an opportunity to reduce or remove subsidies on fuels for private transportation. As a step forward, carbon taxation may be evaluated as an energy policy instrument with potential cross-sectoral impacts on city planning, fiscal revenues, and reducing greenhouse emissions.

   However, a key underlying factor of any subsidy consideration is a sharp differentiation between the policy and the political aspects of energy subsidies. For energy subsidies to work, countries must disassociate political from legitimate policy objectives and allow subsidy programs be designed and managed based on technical grounds.

4. ***Energy efficiency and conservation policies: Appropriate energy efficiency and conservation measures can contribute significantly to shaping consumption patterns, attenuating the pressure of energy demand growth in developing countries, reducing future investment requirements, and in turn, placing the region on a more sustainable energy consumption path.*** This calls for policies that accelerate technological improvements to close the energy efficiency gap in relation to developed countries. Areas where efficiency policies have demonstrated a positive net effect on reducing energy use are building construction codes that set efficiency standards for water heating, heat pumps, air conditioning, permanent lighting, and dwelling insulation. These measures tend to translate into savings in domestic energy and a consequent reduction in energy expenditures, which has a larger relative impact on poorer households than on richer ones.

One of the main remaining challenges is facilitating affordable access to cleaner and more efficient domestic energy sources, mainly cooking fuels. While the consumption of traditional fuels has consistently decreased in LAC and is being replaced by modern fuels, the pace of substitution has been significantly slower in low-income countries, particularly in Caribbean and Andean areas. These countries still rely extensively on biomass, which constitutes around 80 percent of total residential energy consumption, mostly for cooking in rural areas where modern fuels are not available. In terms of the take-up rate of cooking fuels, firewood represents the main energy source for over 60 percent of rural households. Therefore, facilitating access to electricity, providing affordable access to domestic gas, and efficient cooking stoves, would constitute a proactive energy policy with considerable potential to benefit the lowest income groups.

The findings of this book cannot be generalized to other sectors (i.e., industry, transportation, agriculture). Energy costs may have effects on the competitiveness and productivity of firms, setting greater policy challenges for reconfiguring subsidies and carbon taxation. Thus, supplementary research on the patterns of energy consumption and expenditure in other economic sectors is required to provide a holistic assessment aimed at informing current and future energy policies.

The exposure of poor households to the rising electricity prices is such **that a**

10%

increase in electricity cost would make their living almost

1%

more expensive.

Chapter 2
A Conceptual Framework for Household Energy Consumption

In today's world, most activities require the use of modern fuels. Lighting, heating, refrigeration, cooking, and transportation exemplify some of the essential household energy needs, and meeting them requires a reliable and affordable supply of modern energy sources. The factors determining energy consumption are varied and highly interrelated, and thus require a thorough examination to understand and inform the design of effective energy policies. This chapter reviews some of the existing literature on household energy consumption and expenditures to provide a vantage point for the rest of the book.

As a starting point, the determinants of energy consumption may be grouped into demand-driven factors (income, prices, habits, population growth, etc.); supply-driven factors (improvements in energy efficiency, weather, discovery of new energy sources, etc.); and public policies (such as taxes, subsidies, and environmental regulations). The literature points to household income, energy prices, energy efficiency, temperature, and conservation policies as key determinants of energy consumption and expenditures. Among these, income features prominently in determining energy demand and energy composition. At the same time, income also determines the demand response to other drivers, such as changes in energy prices or the adoption of more efficient technologies.

The focus of the literature review concentrates on empirical studies of household energy consumption and in the areas of energy efficiency, conservation, and climate change. The larger body of research that stems from these different fields emphasizes the opportunities and challenges related to these dimensions. The assessment presented here, however, is confined to a selection of empirical literature that relates to the purpose of the book and fits the available data for the LAC region.

Which Type of Energy Do Households Consume?

The scope of the present study covers all energy sources used by the household, including residential energy use and fuels for private transportation of family members. Residential energy use refers to all energy currencies (e.g., electricity, gas) and energy sources (e.g., coal, firewood) used for delivering essential energy services within the dwelling, such as space heating, domestic water heating, lighting, cooking, etc. Fuels for private transportation include all fuels used (e.g., gasolines, diesel, liquefied petroleum gas) for movement of family members in motorized vehicles. The approach used throughout the chapters is based on final energy use, accounting for the energy that can readily be used by consumers to serve their energy needs.[1] This approach is preferred because it closely reflects households' effective energy demand.

Energy Poverty and Energy Affordability

Energy poverty has proved to be a persistent challenge, even in developed countries. Focusing on final energy use in the household sector is key for long-term planning and at the same time useful for informing policies oriented to ensure that basic energy needs are satisfied both in terms of quantity and quality. However, defining energy poverty is challenging because it requires identifying a threshold of energy consumption. Such minimum levels of basic consumption are hard to pinpoint, as they depend on a variety of economic and noneconomic factors that not only tend to be widely heterogeneous among the population, but also tend to change over time due to technological advances and socioeconomic progress.

It is, therefore, not surprising that previous studies have obtained a wide range of estimates for energy poverty lines for different fuels. Those studies tend to concentrate on modern energy, mainly referring to electricity and gas. However, considering the technical difficulty of obtaining fully accurate data, other approaches evolved from preexisting measurements of poverty. For instance, Foster, Tre, and Wodon (2000) define a nominal fuel poverty line as the average energy consumption of all households whose overall per capita consumption expenditure level falls within a plus or minus 10 percent range of the official expenditure poverty line.

In the case of electricity, Table 2.1 shows some estimates of minimum energy needs ranging between around 25kWh/month to 105 kWh/month per capita. In the case of the minimum consumption of liquefied petroleum gas (LPG), calculations are scarce, although some estimates indicate between 40 and 100 kilograms of oil equivalent (KGOE) per year. Such estimates are mostly calculated in terms of energy or energy services such as space heating, cooking, or lighting. While energy needs change along with a variety of factors (e.g., temperature, household preferences), the range estimates in the literature provide a reference for determining energy poverty.

A related concept is that of energy affordability, which refers to the capacity of a household to pay for energy services. This concept is also known as monetary energy poverty, and given the relative ease of computation, it has been used extensively to approximate levels of energy poverty and vulnerability.

Drivers of Residential Energy Consumption: What Do We Know?

Despite the relevance of home energy use and the large number of studies, there is a general consensus that there remains much to understand about the household energy transition process. This represents a weakness in formulating meaningful policies and intervention strategies (Kowsari and Zerriffi 2011; Farsi et al. 2007; Pachauri 2007). The following briefly summarizes finding regarding some of the main drivers explored in energy economics literature, serving as building blocks over which next chapters and sections will examine the Latin American experience.

From Income to Energy

Income strongly determines the pattern of energy consumption. Income works as a constraint (or enabler) on households' choices for fuel type and quantity consumed. At the same time, income tends to determine access to modern energy sources, conditioning household fuel selection. From a policy perspective, this association has important implications with regard to energy poverty – defined as energy consumption that falls below a certain threshold – and energy

1. See http://energyeducation.ca, following the definitions of the International Energy Agency.

Table 2.1: Electricity Poverty Line

Authors	Year	Country	Threshold kWh/ month	Household Size
Pereira et al. (2010)	2000–2004	Brazil	209	4
Pachauri et al. (2004)	1999	India	108	5
Foster, Tre, and Wodon (2000)	1998	Guatemala	178	-
Goldemberg and Johansson (1985)	1980	Developing countries	720	1
Goldemberg and Johansson (1985)	1980	Developing countries	61	1
Douglas, Khandker, and Samad (2011)	2004	Bangladesh	30	1
Reddy (1999)	1992	Tropical developing countries	72	-
Modi et al. (2006)	2006	World	49	1
Sanchez (2010)	2010	World	52	1

Source: Prepared by the authors.

Note: It is important to highlight that the studies differ in periodicity and assumption of minimum energy needs. This table expresses their estimation in monthly levels.

affordability – defined as a household's capacity to afford its energy needs. Therefore, distinguishing between income groups is important when assessing the net benefits of energy reforms.

In theory, energy consumption can be seen as an input to a household production process, where demand for energy is derived from the number of appliances held by the household, which in turn is determined by its wealth (Baker, Blundell, and Micklewright 1989). The empirical literature also suggests a nonlinear relationship between energy consumption and income. Studies have found that consumption of modern and cleaner energy sources tends to increase with household income, and it is accompanied by a considerable reduction in the use of cheaper and dirtier fuels, mainly biomass (Wolfram, Shelef, and Gertler 2012; Heltberg 2004; Fouquet 2014; Pachauri and Jiang 2008; Medlock and Soligo 2001; Hanna and Oliva 2015). These studies also suggest that the pace at which energy consumption responds to income changes may differ by fuel type.

Two theories have provided a framework for this transition: the energy ladder and energy portfolio hypotheses. Under both frameworks, households transition through three stages of energy consumption along their income path. In the first phase, which corresponds to the lowest income level, households rely completely on traditional fuels (biomass). In the second stage, in response to incremental income changes, households move to transitional fuels, such as kerosene, coal, and charcoal. Finally, at the highest income level, households switch to LPG, natural gas, and electricity –the so-called modern fuels. The ladder hypothesis suggests the gradual but complete displacement of basic and transition fuels by modern energy sources as incomes increase. In contrast, the energy portfolio approach argues that multiple fuels are used in an optimal mix, conditional on a set of factors including income and cultural influences (Leach 1992; Bacon, Bhattacharya, and Kojima 2010; Kowsari and Zerriffi 2011; Arseneau 2011).

The transition is explained by several factors. Compared to traditional fuels, modern energy sources are cleaner, more convenient, and provide greater efficiency for cooking, lighting, and heating (IEA 2007; Nordhaus 1996; Pachauri and Jiang 2008). Traditional and transitional fuels, in contrast, have been shown to generate high levels of intra-house pollution, with negative effects on health, especially for women and children. Also, traditional fuels are less convenient given that biomass requires a significant amount of time to collect, often implying major physical effort. However, as explained by Hanna and Oliva (2015), at the microeconomic level, the relationship between higher income and the use of dirty fuels is not obvious, as it depends on the weight that households attach to the benefits and convenience of using those fuels and on price and income considerations.

In these terms, the portfolio hypothesis provides greater flexibility for explaining how households form their energy portfolio over time. For example, a study of Mexican households by Masera and Navia (1997) confirms this model by showing that, as households get wealthier, the change in energy use can be characterized as an "accumulation of energy options" rather than as a linear switching between fuels. They term this process "fuel stacking." Fuel stacking is commonly practiced in rural

regions of the developing world and, to a lesser extent, in urban centers (Heltberg 2004), and it essentially is a manifestation of the portfolio hypothesis. In some countries, such as Ghana and Nepal, it is practiced by a majority of the population (ESMAP 2003a; Heltberg 2004). Moreover, at the country level, the portfolio hypothesis is compatible with the continued consumption of traditional and/or transitional fuels at higher income levels. For example, as shown in Section 2, Chapter 1, relatively high-income countries in LAC (e.g., Uruguay and Chile) have a substantial share of biomass consumption. In general, this may be explained by underlying cultural practices, or by income inequality within a country, meaning that most of the lower-quality fuels are consumed by the poorer households. A key insight from Chapter 6, however, is that access to distribution infrastructure is the key to the use of modern fuels for cooking. Figure 2.1 provides a representation of the energy transition under the stacking or portfolio hypothesis.

The association between income and energy consumption is often measured by the income elasticity of fuel demand. Tables 2.2 and 2.3 present a compilation of such elasticity estimates for electricity and gasoline demand, respectively, in the residential sector. In both cases, most estimates are in the interval [0,1], suggesting that electricity and gasoline are necessity goods, which means that incremental changes in income lead to less than proportional increases in fuel demand. There is substantial variation across studies, which may be explained by the different time periods, case studies, types of data, and methodologies used by the authors. For example, for electricity consumption, a 1 percent increase in income translates into a response ranging from 0 percent (Reiss and White 2005, for the United States) to

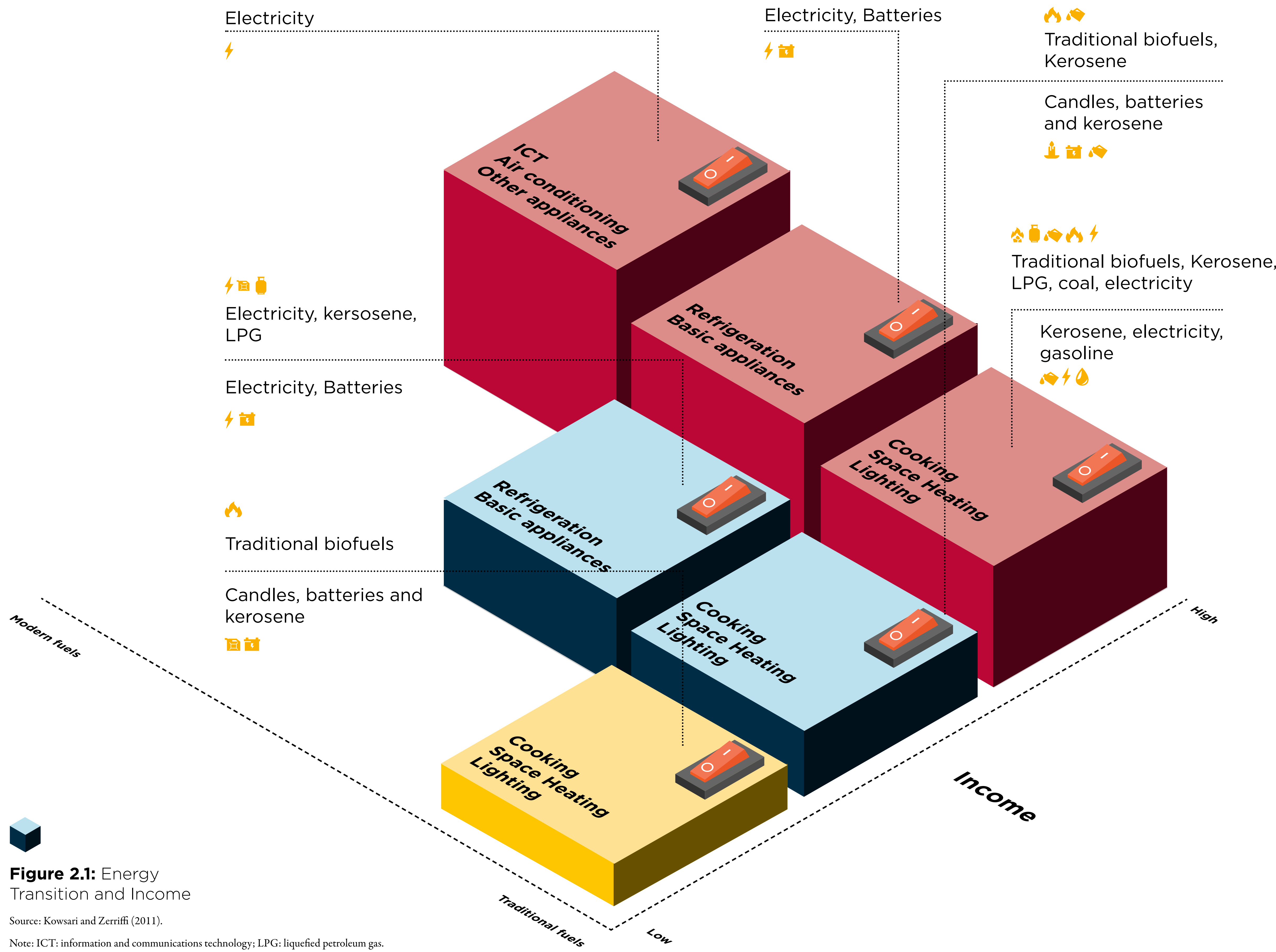


Figure 2.1: Energy Transition and Income

Source: Kowsari and Zerriffi (2011).

Note: ICT: information and communications technology; LPG: liquefied petroleum gas.

1.95 percent (Chang and Martinez-Chombo 2003, for Mexico). For gasoline consumption, the response ranges from 0.19 percent (Lin and Prince 2013, for the United States) to 0.76 percent (Crôtte, Noland, and Graham 2010, for Mexico).

Despite such variation, there are common patterns across different studies. Overall, those patterns suggest that the intensity and composition of energy consumption varies in the same direction along the income distribution and adapts similarly over time in response to price changes. For example, the share of domestic energy use (fuels used within a dwelling, such as electricity, domestic gas, firewood, kerosene, etc.) tends to decrease as income increases, implying that the interaction of energy prices and energy consumption increases at a slower pace than income. In contrast, expenditures on transport fuels as a share of total expenditures tend to increase with income. Pooling estimates of the share of energy expenditures found in the literature, the average share is around 2.1 percent, but goes up to 17.5 percent for the poorest quintile, indicating potentially severe affordability problems (Jamasb and Meier 2010; Meier, Jamasb, and Orea 2013; Bacon, Bhattacharya, and Kojima 2010).

Regarding responses to income or prices changes, the evidence indicates that short-run price and income elasticities are roughly one-half of long-run equivalents (see Balza et al., 2013 for total primary energy supply in different regions; Jimenez and Yépez-García, 2016, for residential energy consumption; and Havranek and Kokes, 2015, and Galindo, Samaniego, and Alatorre, 2015, for gasoline demand).

There are few studies that have examined the links between energy consumption and household income in LAC. They include the case study of Peru by Meier et al. (2010); the study by Navajas (2009) that focuses on natural gas and LPG; the case studies of Guatemala by ESMAP (2003b) and Foster, Tre, and Wodon (2000); and a multi-country study on the use of non-transport fuels in Brazil, Guatemala, and Nicaragua by Heltberg (2004). In the case of transport residential spending, Rivas, Serebrisky, and Suárez-Alemán (2018) show that, consistent with previous findings, those expenditures increase (as a share of income) as households get richer. Although these studies are not directly comparable, they show the relevance of income in determining energy consumption, and underscore the differences in the patterns of energy consumption across income groups.

Energy Consumption beyond Income: Energy Prices

The economic challenge regarding public policy pricing is efficiency. This involves minimizing price distortions and at the same time aiming to achieve equitable use of energy. Price signals also play a key role in consumption decisions in terms of incentivizing long-run energy efficiency improvements and encouraging energy conservation practices. As for the latter, it has been shown that persistent high energy prices make development and adoption of more energy-efficient technologies and conservation practices economically viable (Popp, Newell, and Jaffe 2010; Gillingham et al. 2009; Anderson and Newell 2004). On the other hand, energy prices directly relate to affordability concerns in both developed and developing countries, where the main objective is to ensure access to modern energy sources (Winkler et al. 2011).

The literature finds a strong negative relationship between energy prices and consumption for all types of fuels. However, there are important differences by income level and type of fuel consumed. The studies find that the price elasticity of demand for different fuels may differ considerably. There is also large variation in the estimates reported in the literature. In the case of electricity, long-run price elasticity estimates for the United States range from -0.1 (Allcott 2011) to -1.89 (Houthakker and Taylor 1970) (Table 2.2). Large variations in price elasticity are also observed in the case of gasoline: estimates range from -0.04 (Dahl 2012) to -1.06 (Bhattacharyya and Blake 2009) (Table 2.3). In addition, energy price elasticities do not seem to be constant along the income distribution – that is, in wealthier households, price sensitivity decreases (for the United States, see Dahl, 2012, for liquid fuels, and Reiss and White, 2005, for electricity).

A takeaway from the review of the empirical literature is that fuel demand (for electricity and gasoline) seems to be relatively price inelastic. In the case of gasoline, this could be due to the fact that the use of transport fuels is concentrated among higher income groups, which tend to be less sensitive to price variations (EIA 2014a). In the case of electricity, the low price elasticity can be interpreted as a result of the low substitutability of the power for which it is used – such as lighting and appliances – that drive electricity demand (Halvorsen and Larsen 2001). Implicit in pricing questions lies the role energy scarcity or abundance of a country or region. Liquid fuels are internationally traded commodities subject to international reference prices, but the pass-through from international to local prices may not be smooth in resource-abundant countries, or in net importers of fuels, for that matter. On the other hand, the price of electricity depends primarily on a country's energy endowment. Therefore, cross-country differences in natural resource endowments may translate into different levels of energy prices and patterns of energy consumption.

Weather

An extensive and growing literature has documented that greenhouse gas emissions affect the global climate and its interconnected subsystems, while the local impact of those emissions on temperatures in specific geographic areas is uncertain (Tol 2009; Wilbanks and Bilello 2014). While temperatures could become more extreme or milder, it is the former that is of greater concern, as steep temperature increases would lead to higher energy demand, and more expensive energy. Also, more frequent or extreme weather events will require additional plants and equipment that can withstand harsher conditions, thereby implying incremental generation costs (Mideksa and Kallbekken 2010; Rübbelke and Vögele 2012). In a study of the United States, Houser et al. (2015) find that the net effect

In the Bahamas, annual energy expenditures average **US$ 4,800**

While in Bolivia, the annual average would be **US$ 330.** This is, **a 6% of that of a Bahamian.**

Energy expenditures vary depending on where you live.

Table 2.2: Income and Price Elasticities of Residential Electricity Demand

Author(s)	Country	Short-Run Price	Long-run Price	Short-run Income	Long-run Income
Fisher and Kaysen (1962)	USA	-0,15	-	0,1	-
Houthakker and Taylor (1970)	USA	-0,13	-1,89	0,13	1,94
Mount, Chapman, and Tyrrell (1973)	USA	-0,1385	-1,21	0,0343	0,3
Anderson (1973)	USA	-0,91	-	1,13	-
Houthakker, Verleger, and Sheehan (1974)	USA	-0,9	-1,02	0,14	1,64
Halvorsen (1975)	USA	-	(-1,-1.21)	-	(0.47,0.54)
Wilder and Willenborg (1975)	USA	-1	-1,31	0,16	0,34
Acton et al. (1976)	USA	-0,7	-	0,4	-
Murray et al. (1978)	USA	-1,01	-	0,69	-
Houthakker (1980)	USA	-0,111	-1,42	0,139	1,78
Barnes, Gillingham, and Hagemann (1981)	USA	-0,55	-	0,203	-
Shin (1985)	USA	-0,143	-0,464	0,172	0,558
Branch (1993)	USA	-0,2	-	0,23	-
Bentzen and Engsted (1993)	Denmark	-0,13	-0,46	0,67	1,21
Silk and Joutz (1997)	USA	-0,63	-0,48	0,38	0,52
Beenstock, Goldin, and Nabot (1999)	Israel	-	-	0,58	1,09
Filippini and Pachauri (2002)	India	(-0.292,-0.507)	-	(0.60,0.64)	
Holtedahl and Joutz (2004)	Taiwan	-0,15	-0,16	0,23	1,04
Reiss and White (2005)	USA	-	-0,39	-	0
Narayan and Smyth (2005)	Australia	-0,26	-0,54	0,01	0,32
Boonekamp (2007)	Netherlands	-	-0,13	-	-
Brännlund, Ghalwash, and Nordström (2007)	Sweden	-0,24	-	0,49	-
Zachariadis and Pashourtidou (2007)	Cyprus	-0,103	-0,43	0,21	1,175
Dergiades and Tsoulfidis (2008)	USA	-0,386	-1,0652	0,101	0,2728
Allcott (2011)	USA	-	-0,1	-	-
Modiano (1984)	Brazil	-	-0,118	-	0,332
Berndt and Samaniego (1984)	Mexico	-	-0,47	-	0,73
Westley (1989)	Costa Rica	-	-0,5	-	0,2
Maddock, Castaño, and Vela (1992)	Colombia	-0,466	-	0,301	-
Benavente, et al. (2005)	Chile	-0,0548	-0,39	0,079	0,2
Chang and Martinez-Chombo (2003)	Mexico	-	-0,44	-	1,95
Schmidt and Lima (2004)	Brazil	-	-0,085	-	0,539
Irffi et al. (2006)	Brazil	-0,2349	-0,8393	0,0127	0,684
Casarin and Delfino (2011)	Argentina	-0,1	-0,2	-	-

Source: Prepared by the authors.

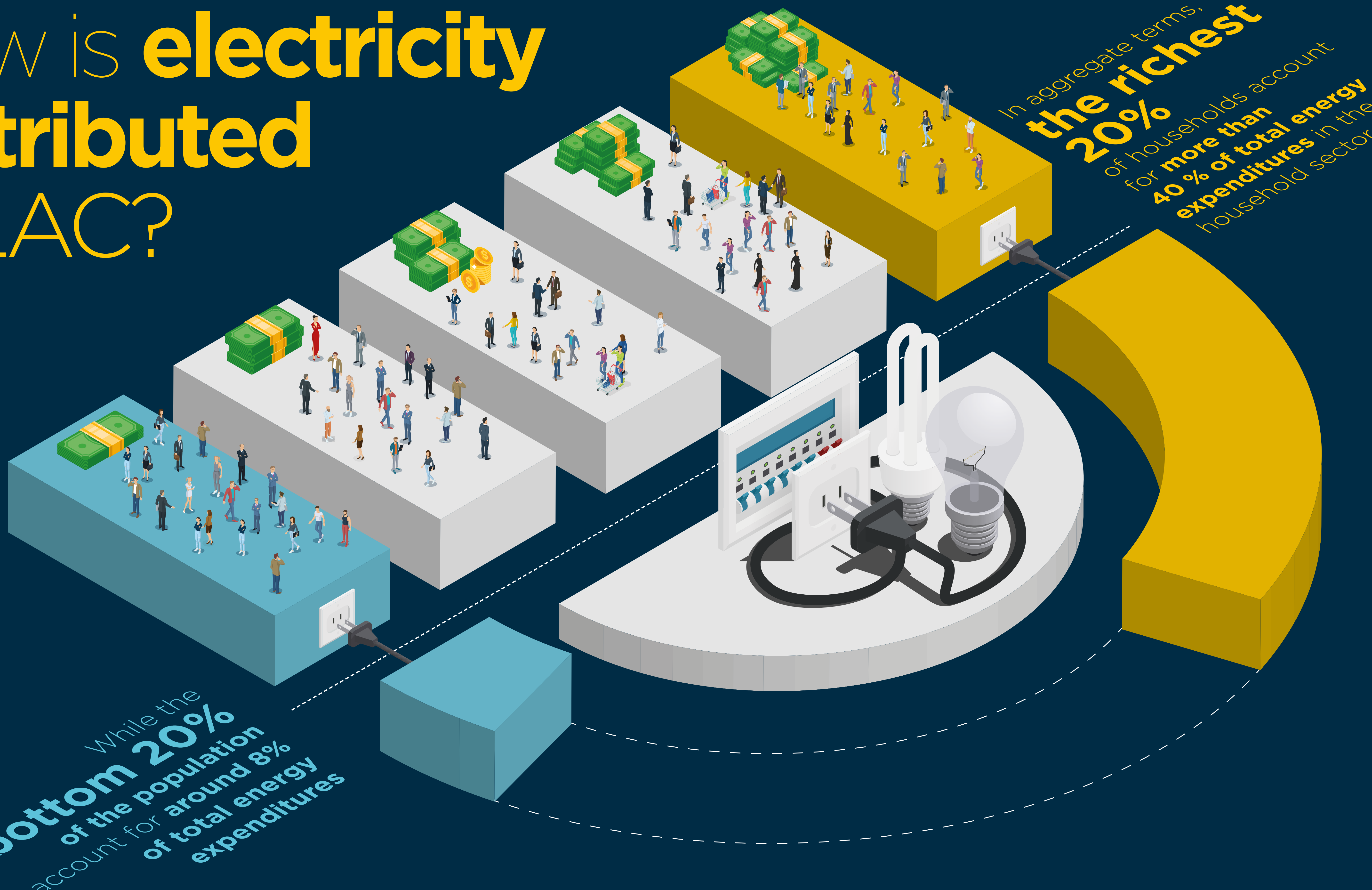
Table 2.3: Income and Price Elasticities of Residential Gasoline Demand

Author(s)	Country	Short-Run Price	Long-run Price	Short-run Income	Long-run Income
Yatchew and Joungyeo (2001)	Canada	-0,9	-	0,29	-
Nicol (2003)	USA	-0.162	-	0.285	-
	Canada	-0.466		0.523	
Hueges, Knittel, and Sperling (2008)	USA	(-0.034, -0.077)	-	(0.21, 0.75)	-
Akinboade,. Ziramba, and Kumo (2008)	South Africa	-	-0,47	-	0,36
Rao and Rao (2009)	Fiji	-	-0,244	-	0,429
Wadud, Graham and Noland (2009)	USA - Canada	(-0.065, -0.091)	(-0.102, -0.118)	-	-
Neto (2012)	Switzerland	-	-0,167	-	0,692
Sene (2012)	Senegal	-0,1212	-	0,4581	-
Baranzini and Weber (2013)	Switzerland	-0,09	-0,34	0,025	0,673
Lin and Zeng (2013)	China	(-0.497, -0.196)	-	(1.01, 1.05)	-
Lin and Prince (2013)	USA	-0,027	-0,089	0,036	0,193
Bhattacharyya and Blake (2009)	Middle East and North African countries	(-0.18, 0.08)	(-0.49, -1.06)	(0.21, 0.65)	(0.28, 2.58)
Pock (2010)	14 European countries	(-0.04, -0.19)	-	(0.04, 0.23)	-
Dahl (2012)	124 countries	-	(-0.04, -0.69)	-	(0.23, 2.06)
Burke and Nishitateno (2013)	132 countries	-	(-0.23, -0.53)	-	-
Arzaghi and Squalli (2015)	32 countries	-0,05	-0,25	0,16	0,81
Galindo (2005)	Mexico	-0,09	-	0,84	-
Alves and Bueno (2003)	Brazil	-0,0919	-0,4646	0,1216	0,1217
Crôtte, Noland, and Graham (2010)	Mexico	-0,056	-0,062	0,782	0,757

Source: Prepared by the authors.

Note: This compilation is based on a literature review of the 15 years from 2001 to 2015.

How is **electricity distributed** in LAC?



of climate change would increase annual residential and commercial energy costs between 0.1 and 2.9 percent by 2020–2039 and by up to 22 percent by 2080–2099.

The effects of climate change on the LAC energy sector require further study. At first glance, the region may be severely affected by changes in water flows, as more than half of its electricity use comes from hydropower. At the same time, the extent to which LAC will be able to cope with higher energy costs and difficult environmental conditions will depend on its development stage. Better economic conditions of the population and technological progress would be key for generating cleaner energy, as well as for its more efficient use.

Energy Efficiency

Efficiency gains result in the use of less energy, lower costs, and fewer carbon emissions in order to provide the same service. This has been clearer to observe over the last few decades in developed economies, where reductions in per capita energy consumption have been attributed to gains in efficiency, mainly derived from the diffusion of more efficient buildings, space heating technologies, and electrical appliances. However, there is some discussion with regard to the size of this change and its net benefits (Fowlie, Greenstone, and Wolfram 2015). There is also the argument that technical estimations of efficiency gains may not be fully realized because of potential rebound effects.[2] And finally, energy efficiency and economic efficiency do not always go together, since the cost of implementing energy-efficient technologies may not necessarily be offset by the returns to their use (Fowlie, Greenstone, and Wolfram 2015).

The extent of the trade-off between economic efficiency and energy efficiency generally depends on market conditions such as energy prices, information availability, household income, and end-user behavior, and it remains an area where further research is required (Gillingham et al. 2009; Gram-Hanssen 2012). However, there are indications of net gains from energy efficiency in the category of durable goods, such as homes and cars. In a case study from California, Costa and Kahn (2011) find that recently built homes consume less energy than homes that were constructed in the 1960s and 1970s, partly as result of the establishment of building codes[3] and electricity price increases. Similarly, in the case of England, Advani et al. (2013) argue that the observed fall in energy's share of total spending was a result, in part, of the increased energy efficiency of homes and heating methods.

2. Rebound effects can occur directly and indirectly. Direct rebound effects refer to increments in consumption of services as a result of efficiency improvements that make those energy services cheaper. Indirect rebound effects refer to greater consumption of energy-intensive goods/services due to savings originating in energy efficiency improvements in other goods/services. That is, even if increased efficiency of a particular good does not increase its use, it may increase the consumption of other energy-intensive goods. The indirect effect also includes potential increments in aggregate energy demand due to reductions in energy prices resulting from increased energy efficiency. All these channels reduce the overall expected gains from greater energy efficiency (Sorrell 2007).

3. Among other requirements, the building code requires the installation of more efficient water heating, heat pumps, air conditioning, and permanent lighting.

Energy Conservation

Conservation practices also affect energy consumption. Energy conservation refers to the adoption and promotion of behaviors that result in reductions in energy consumption. Such practices may be put in place as a response to price incentives, non-price stimuli, or end-user preferences. Although there has been little evaluation of the effectiveness of energy conservation policies in LAC, some evidence shows that recent initiatives have had significant success in reducing energy consumption. Regarding price-related effects on energy conservation, Bastos et al. (2015) examine the impact of a drastic change in the gas pricing scheme in Argentina and find a significant decline in residential gas use. In the United States, Allcott (2011) examines a non–price-related energy conservation program in which 600,000 residential utility customers received letters comparing their electricity use with that of their neighbors. The authors analyzed the response of these households and found that the effect of the program was a persistent 2 percent reduction in energy consumption, equivalent to a long-run response to an electricity price increase of 5 percent.

Conclusion

One of the main underlying themes in the literature is the interrelationships between the drivers of energy expenditure and the different consumption sources. Different households will hold distinct consumption patterns, energy expenses and diverse energy efficiency levels. Establishing the right empirical measurements has proven to be a complex issue yet, being critical for the construction of consequential conclusions. Important research requirements are difficult to ascertain due to the hurdle of establishing minimum thresholds for energy consumption (e.g., isolating the effect of each factor on household energy demand). Thresholds depending on the elusive cause of consumption levels and whether those are caused by under-consumption, low energy efficiency or both.

Nonetheless, the literature strongly suggests that income is a key determinant in which households consume energy. Other factors such as energy price changes, new technologies, changes in temperature, and conservation practices have a direct effect in energy consumption, however, are not as critical as income. Data on these differences will be examined in the following chapters in order to provide an extensive study of household energy use with income as the analytical cornerstone.

How is **energy distributed** in LAC?

Part II

Aggregate Energy Consumption in the Residential Sector

Chapter 3

Landscape of the Energy Transition in the Residential Sector

The two chapters in this part of the book examine residential energy use in 22 Latin American and Caribbean (LAC) countries from 1971 to 2013. It distinguishes between modern fuels (electricity and gas), transitional fuels (kerosene, diesel, charcoal, and coal), and traditional fuels (biomass), which helps in analyzing changes in the composition of energy consumption over time. This chapter and the next rely on yearly aggregate country-level data. Per capita gross domestic product (GDP) at purchasing power parity (PPP) in constant 2005 prices is used as a proxy for income.

A key finding is that over the past four decades the growth in residential energy consumption was driven by greater use of modern energy sources, specifically electricity and natural gas. During that span, per capita consumption of modern energy grew at a faster rate than income. At the same time, the use of modern fuels displaced less efficient ones, such as kerosene and biomass, leading to an overall reduction in total per capita energy consumption in low- and middle-income countries. This highlights the importance of distinguishing between alternative fuel types when evaluating future energy needs for sustained economic and social progress.

Another finding is that most of the growth in modern energy consumption has occurred in high- and middle-income countries, while households in low-income countries remain substantially dependent on traditional and transitional fuels. This shows that despite significant progress in broadening access to modern energy sources, reducing the use of dirty and inefficient fuels in the residential sector remains a challenge in less-developed economies. The analysis also shows that since 1971, increases in final energy consumption at the country level were driven by the transportation and industrial sectors, which together account for around 70 percent of total final energy use. As economic conditions improve in LAC, this translates into greater demand for energy-intensive goods and services, which affects energy consumption throughout the entire economy. This finding points to the need for coordinated energy policies across sectors, particularly in terms of fostering energy savings.

Evolution of Domestic Energy Consumption

In 2013, total final energy consumption in LAC amounted to 600 million tons of oil equivalent (MTOE). This is approximately three times the consumption of 1971, an increase mainly explained by the growth of the transportation and industrial sectors. This can be seen in panel a of Figure 3.1, which shows the trends in aggregate final energy consumption across sectors, with the transportation and industrial sectors growing faster than the residential sector. Over the last four decades the residential sector had the lowest average annual growth rate in energy consumption (1.3 percent), lower than the average annual growth rate of total final consumption (2.9 percent). As a result, the residential sector saw a significant reduction in its share of energy consumption, from 30 percent in 1971 to 16 percent in 2013.

Although residential energy use has had the lowest growth – increasing by 70 percent between 1971 and 2013, which is less than other sectors – its composition has changed markedly. Panel b in Figure 3.1 shows that since 1971, the composition of residential energy consumption has shifted toward greater dependence on modern fuels such as electricity and natural gas. This shift took place as households replaced dirty fuels with more efficient energy sources. In 1971, traditional and transitional fuels together represented over 80 percent of total energy consumption at the household level, with gas and electricity representing the remaining 20 percent. In 2013, the share of modern energy sources in total domestic energy consumption was over 60 percent.

Thus, the increase in overall residential energy use is explained by the growth in consumption of electricity and natural gas. The increase in the consumption of those fuels has exceeded the growth in total energy use from other sectors. As shown in Figure 3.1, between 1971 and 2013, annual growth rates in consumption of electricity and domestic gas were 5.5 percent and 3.7 percent, respectively, while energy use in the transportation sector grew at 3.6 percent and in the industrial sectors at 2.9 percent.

Several factors explain these trends – two in particular in LAC are the rate of urbanization and the rise of the middle class. Over recent decades, urbanization has been associated with increased access to modern energy sources, as well as increased energy consumption (Box 3.1). At the same time, as documented by Fereira et al. (2013), in most LAC countries the middle class has grown substantially since 2000, increasing its purchasing capacity, leading to the consequent ownership and use of appliances and higher energy consumption (Heltberg 2004; Wolfram, Shelef, and Gertler 2012).

Heterogeneous Patterns of Domestic Energy Consumption within Latin America and the Caribbean

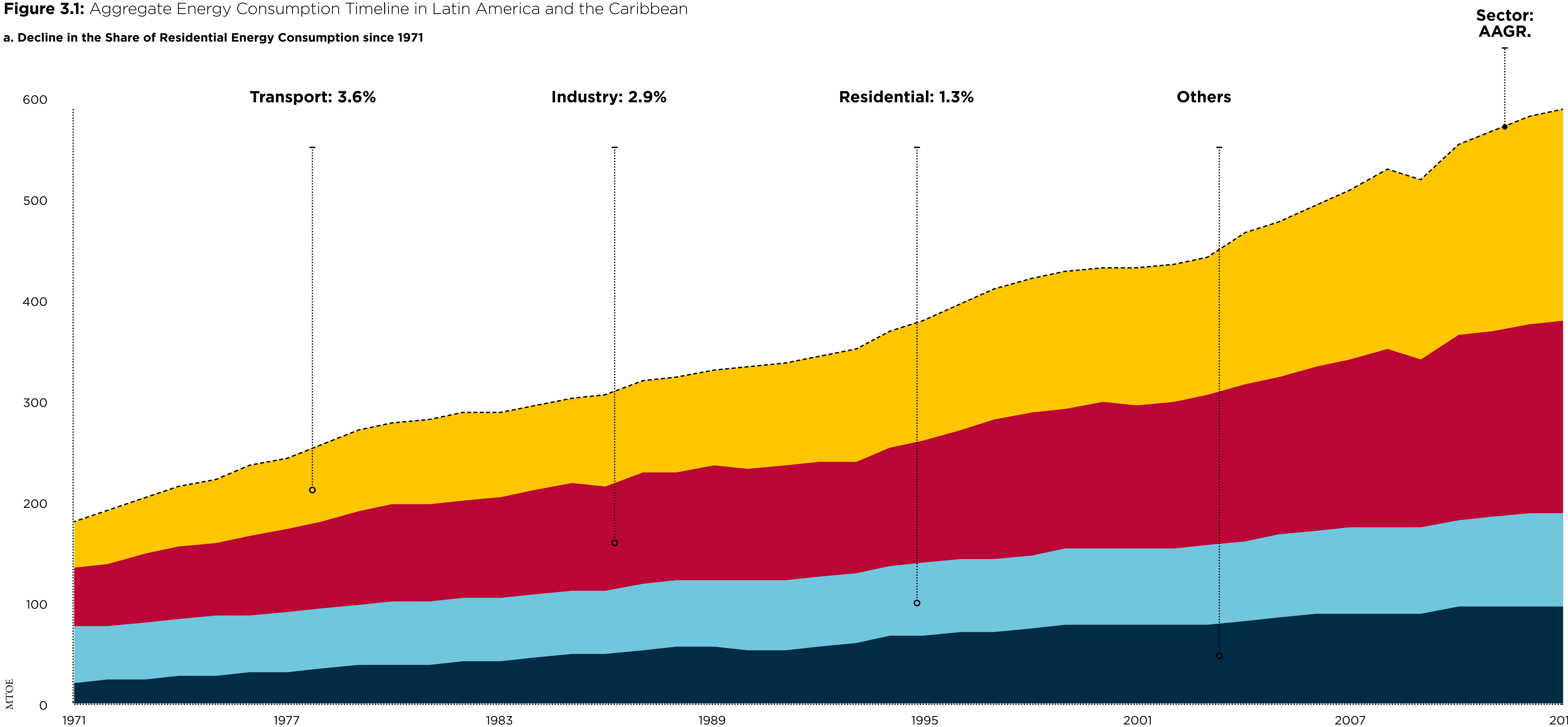
In spite of the observed regional trend toward greater use of modern fuels, the weight of transitional and traditional fuels is heterogeneous in LAC, and still significant in many countries. Table 3.1 presents a snapshot of residential total final consumption and its fuel structure. For example, as of 2013, residential energy consumption in Haiti, Guatemala, Honduras, and Nicaragua mainly relied on dirty fuels, which represented 98, 92, 89, and 87 percent of residential total final consumption, respectively. In contrast, such fuels account for less than 6 percent of residential energy consumption in Argentina and Trinidad and Tobago.

Table 3.1 presents the average annual growth rate by fuel classification over the study period. It shows that consumption of modern fuels grew in all LAC countries, and most saw a reduction in their consumption of traditional and transitional fuels. In countries like Argentina, Costa Rica, Trinidad and Tobago, and Venezuela, the growth in residential total final consumption can be entirely explained by the increase in modern fuels. Still, based on the snapshot of 2013, the pace of this transition has been slower in some countries than in others that continue to depend on non-modern fuels, such as El Salvador, Guatemala, Honduras, Haiti, and Nicaragua.

Annual growth in total energy use between 1971 and 2013 depended on the composition of residential total final consumption at the beginning of the period under review. In the case of Bolivia, the impressive annual 8 percent growth in modern fuel use resulted in a share of 63 percent by 2013, in contrast to around 10 percent in 1971. The substitution of modern fuels for traditional ones is clearly observed in El Salvador, where aggregate residential energy consumption has dropped (an average annual decline of -1 percent) despite an average annual growth rate of 6 percent in the use of modern fuels. This pattern is common in several countries, and reveals pronounced fuel substitution in the residential sector, which is even more marked in those countries where the use of dirty fuels declined.

Figure 3.1: Aggregate Energy Consumption Timeline in Latin America and the Caribbean

a. Decline in the Share of Residential Energy Consumption since 1971



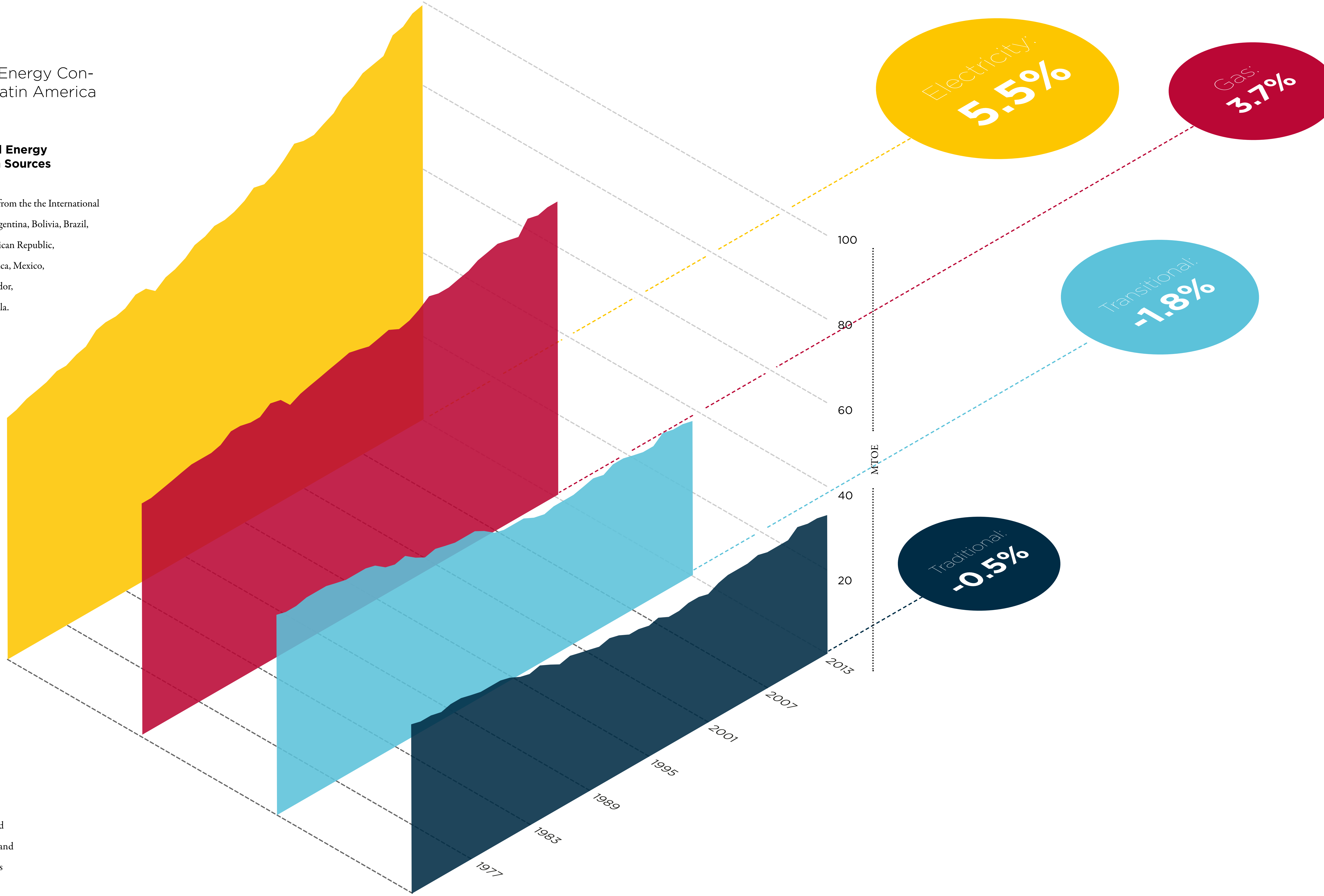
Total final consumption grew at **annual average rate of 2.9%**

Note: AAGR: average annual growth rate; MTOE: million tons of oil equivalent. "Others" includes commercial, agriculture, and other sectors. We do not book the AAGR for this classification because consumption was not homogeneously booked across countries at the beginning of the period under review. Therefore, this could lead to over-calculation of the annual growth rate.

Figure 3.1: Aggregate Energy Consumption Timeline in Latin America and the Caribbean

b. A Major Shift in Residential Energy Consumption Toward Modern Sources

Source: Authors' calculations based on data from the the International Energy Agency for 22 countries in LAC: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Peru, Paraguay, El Salvador, Trinidad and Tobago, Uruguay, and Venezuela.



Note: AAGR: average annual growth rate; MTOE: million tons of oil equivalent. Traditional fuels include solid biomass, and transitional fuels include kerosene, diesel, and carbon used within dwellings. Gas includes liquefied petroleum gas and natural gas.

Table 3.1: Residential Energy Consumption by Fuel Type and Country

Source: Authors' calculations based on data from the International Energy Agency.

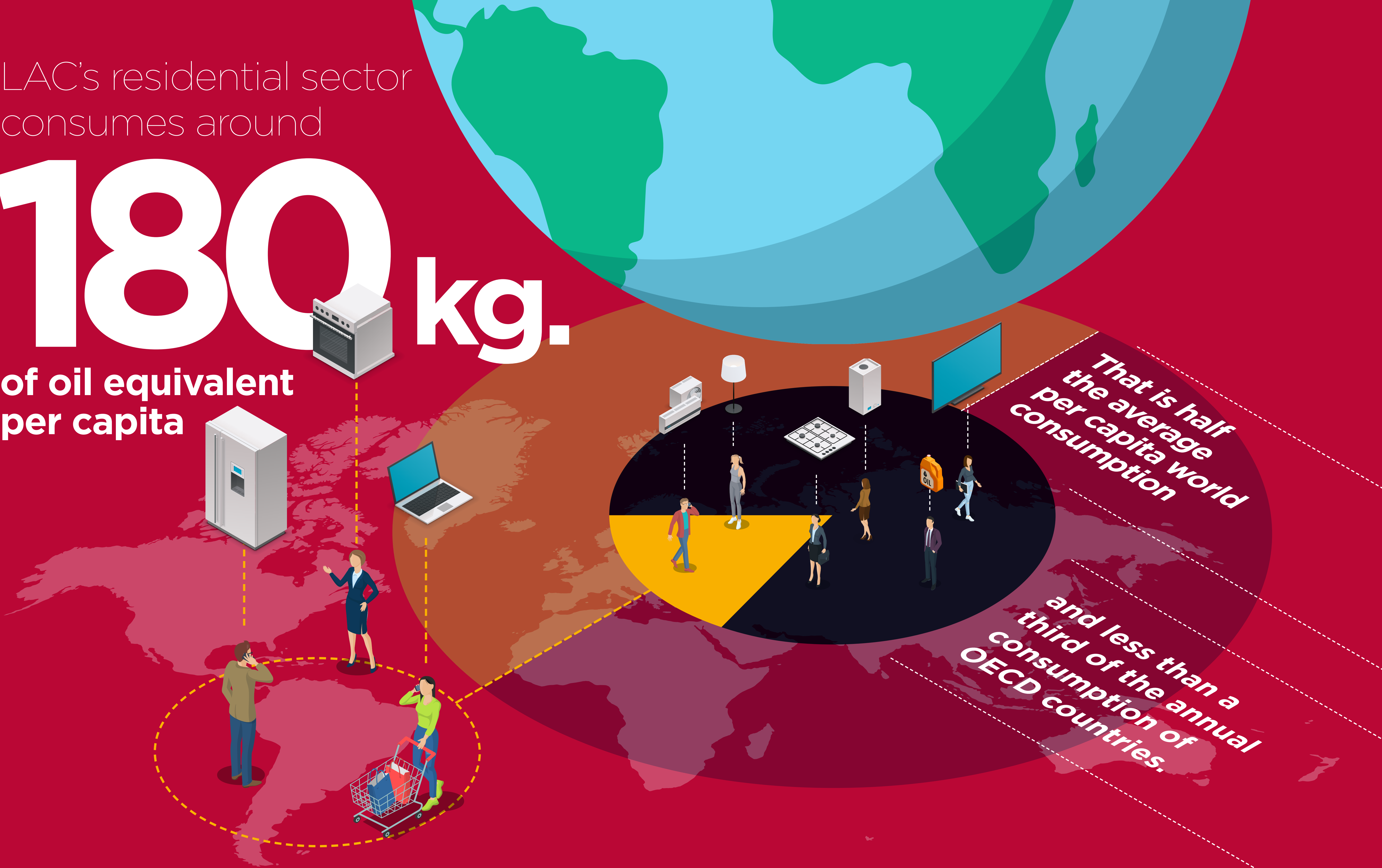
Note: Transitional fuels include coal, kerosene, and paraffin; traditional fuel refers to firewood. KTOE = kilotons of oil equivalent; LAC: Latin America and the Caribbean; n.a.: data not available; TFC: total final consumption.

Countries	Aggregate Annual Consumption in KTOE as of 2013					Annual Percent Change 1971-2013		
	Modern Fuels		Transitional Fuels	Traditional Fuels	TFC	Modern Fuels	Traditional and Transitional	TFC
	Electricity	Gas						
Argentina	3,448	9,728	593	87	13,856	4.0	-1.6	3.1
Bolivia	224	507	22	421	1,173	8.3	1.4	3.5
Brazil	10,741	6,825	406	5,740	23,713	5.0	-2.8	0.2
Chile	948	1,325	332	3,523	6,128	4.1	2.2	2.7
Colombia	1,844	1,438	265	1,744	5,291	4.2	-1.7	0.2
Costa Rica	298	53	6	157	514	4.2	0.6	2.4
Cuba	665	131	334	5	1,136	3.9	-3.2	-0.7
Dominican Republic	415	460	85	426	1,386	5.3	0.2	2.1
Ecuador	506	1,089	-	165	1,760	9.5	-4.3	1.2
El Salvador	166	217	1	374	758	6.1	-2.6	-1.0
Guatemala	234	253	74	5,389	5,951	6.8	3.2	3.4
Haiti	21	20	929	1,446	2,416	5.0	2.0	2.0
Honduras	191	38	28	1,801	2,058	6.3	1.7	2.0
Jamaica	85	44	10	44	182	2.5	0.7	1.8
Mexico	4,601	6,771	32	6,099	17,503	3.7	0.3	1.9
Nicaragua	89	43	8	881	1,021	4.1	1.2	1.5
Panama	207	194	2	246	650	5.3	-0.3	1.6
Peru	741	841	39	2,153	3,774	4.7	-0.8	0.4
Trinidad and Tobago	220	184	16	10	431	6.3	-1.3	4.2
Uruguay	341	142	22	291	796	3.4	-1.2	0.6
Venezuela	2,082	2,014	7	225	4,328	4.3	-2.1	3.0
LAC	**28,404**	**32,400**	**3,410**	**31,890**	**96,103**	**4.4**	**2.2**	**1.3**

LAC's residential sector consumes around

180 kg.

of oil equivalent per capita



That is half the average per capita world consumption

and less than a third of the annual consumption of OECD countries.

Drivers of Residential Energy Consumption

The variation in residential energy consumption across countries arises from an array of economic variables. Figure 3.2 presents a selection of the drivers of aggregate energy demand, including population size, resource availability, income level, access to modern energy, and energy prices. These variables, which complement the review in Chapter 1, capture the differences across countries and help to explain the patterns previously described.

Population size is a key determinant of aggregate energy consumption. In LAC, the three most populous countries (Brazil, Mexico, and Argentina) represent 60 percent of the region's population. Correspondingly, these countries account for approximately 58 percent of the region's total residential energy consumption. All else being equal, a larger population leads to greater energy demand, and while population growth in LAC is expected to slow over the next few decades, the region's population is still expected to increase by approximately 25 percent by 2050[2].

In terms of supply, ***access to modern energy sources*** is a necessary condition for the consumption of these fuels. Achieving the target of universal access to modern energy sources will increase the base of end users for both electricity and domestic gas. LAC has made important progress in rural access to electricity, and, as suggested by Figure 3.2, higher rural electrification rates have translated into greater quantities of power consumption. However, challenges remain – for example, providing access to natural gas or liquefied petroleum gas (cleaner energy sources for cooking and heating) to low-income households in rural areas has been particularly difficult.

A related point is that fuel consumption is associated with the ***availability of natural resources.*** This is particularly the case with natural gas, for which regional consumption is notably concentrated in countries endowed with abundant fossil fuels, such as Argentina, Trinidad and Tobago, Venezuela, and to a lesser extent, Ecuador. This suggests that a country's energy-use mix depends on its natural resource endowment, especially in terms of fossil fuels.

In the case of electricity, Figure 3.2 depicts the expected negative association between ***energy prices*** and energy consumption. This correlation appears even in the aggregate measures of electricity consumption and annual average electricity prices, despite large energy price discrepancies within and between countries. Pricing differences emerge from a variety of price formation schemes; thus average prices may not be fully representative. Moreover, price distortions also result from implicit and explicit subsidies that are common in LAC (Di Bella et al. 2015). In addition, as suggested by the literature reviewed in Part 1, the sensitivity of energy consumption to energy prices depends on the income level of the household or country.

As shown in Figure 3.2, ***income and population size*** provide the best fit to the determinants of modern energy consumption. This aligns with a large body of literature that underscores the role of income in determining the patterns and composition of energy consumption, both at the macroeconomic and microeconomic levels. Its impact on energy demand results from greater acquisition of appliances and choices about household comfort, such as heating and air conditioning, among others. The message, then, is that income is a variable that underpins energy consumption across households. Therefore, the following discussion uses income to characterize residential energy consumption in LAC since 1971. Energy consumption is also normalized by population, focusing on per capita energy consumption.

Distinctive Patterns by Income Classification

Figure 3.3 shows that the portfolio of energy sources is structured differently across country income classifications. In low-income countries, the share of traditional and transitional fuels is as high as 80 percent of total residential energy consumption, while in high-income countries the consumption of modern fuels makes up around 80 percent. That is, the share of modern fuels increases with higher income. This pattern echoes the concept of the energy ladder, by which economic progress translates into transitions from consumption of basic fuels (biomass, kerosene, and coal) to more efficient modern fuels (electricity and natural gas). Figure 3.4 shows per capita energy consumption by country and fuel type. It is interesting to note that in terms of quantities, per capita residential energy consumption in low-income countries tends to be as high as it is in high-income countries, although its composition is markedly different. At low income levels, energy use is mainly composed of traditional fuels, and as income increases, the share of modern fuels takes over. Also, the replacement of traditional fuels with modern ones seems to lead to an overall reduction of per capita energy use at the middle stage of economic development, while at the later stage, the consumption of modern fuels generally increases, explaining most of the energy consumption by the high-income group.

Such a U-pattern suggests that the level of per capita energy consumption is not necessarily an indicator of energy sufficiency in the residential sector given that a significant proportion of per capita energy consumption may consist of low-quality, dirty, and inefficient fuels. Furthermore, the context in which consumption takes place in poor and in rich countries is also vastly different – with better access to technology and higher purchasing power in the latter, thus leading to a more efficient use of energy. These factors taken together imply that effective energy use across households will be higher in advanced economies. This reinforces the pattern that modern fuels first displace traditional fuels and then drive the growth of energy consumption as income continues to increase.

It should be noted in Figure 3.4 that Argentina, Trinidad and Tobago, and Venezuela are natural-resource-abundant countries. In conjunction with income, this may help explain their higher observed energy consumption. As shown in Figure 3.2 before, there is a correlation between resource abundance and energy consumption, which could be the result of either through the availability of supply and/or lower energy prices derived from resource abundance.

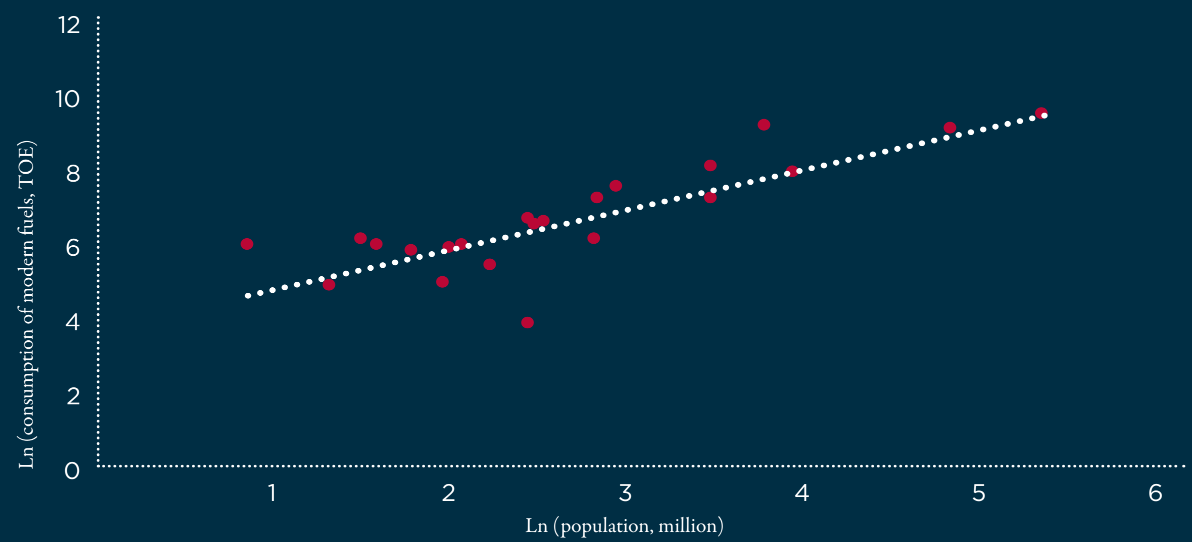
2. This is with respect to the population in 2013, according to the Statistical Yearbook of the Economic Commission on Latin America and the Caribbean.

Figure 3.2: Selected Drivers of Energy Consumption

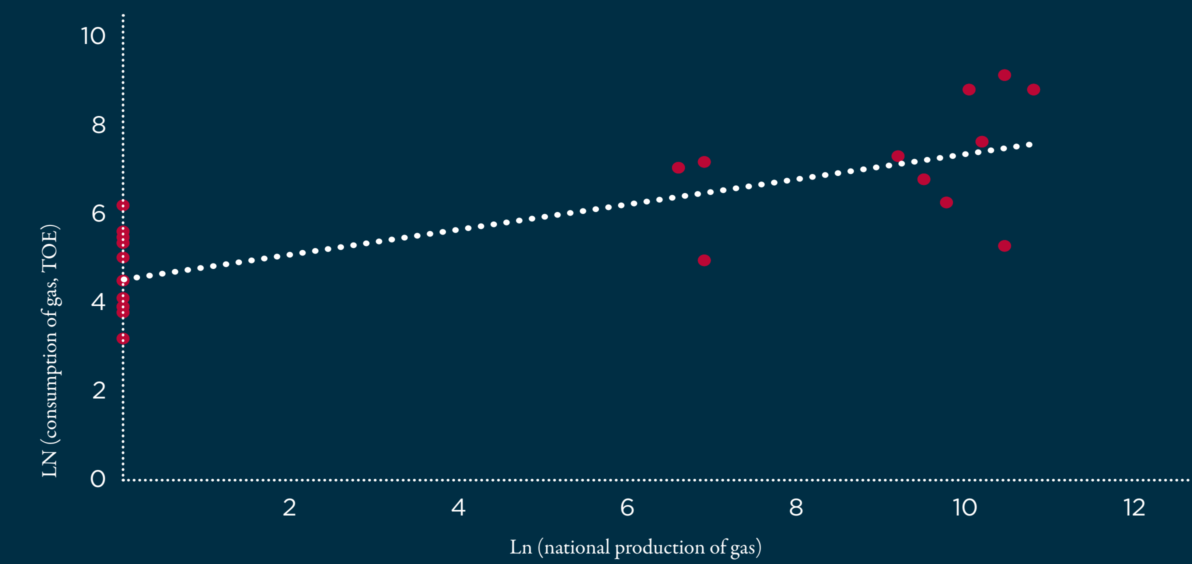
Source: Authors' calculations based on information from the International Energy Agency, the World Bank's World Development Indicators, and the Latin American Energy Organization.

Note: The figure includes 22 countries in Latin America and the Caribbean, except for the panel on urbanization, which excludes Trinidad and Tobago. PPP: purchasing power parity; TOE: tons of oil equivalent.

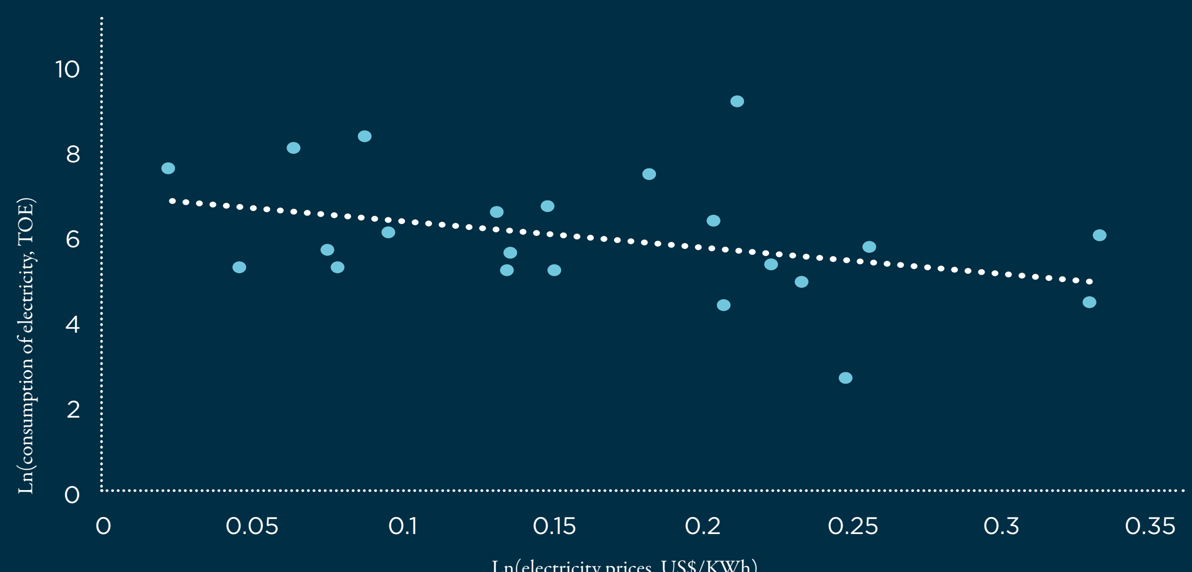
Population and Consumption of Modern Energy



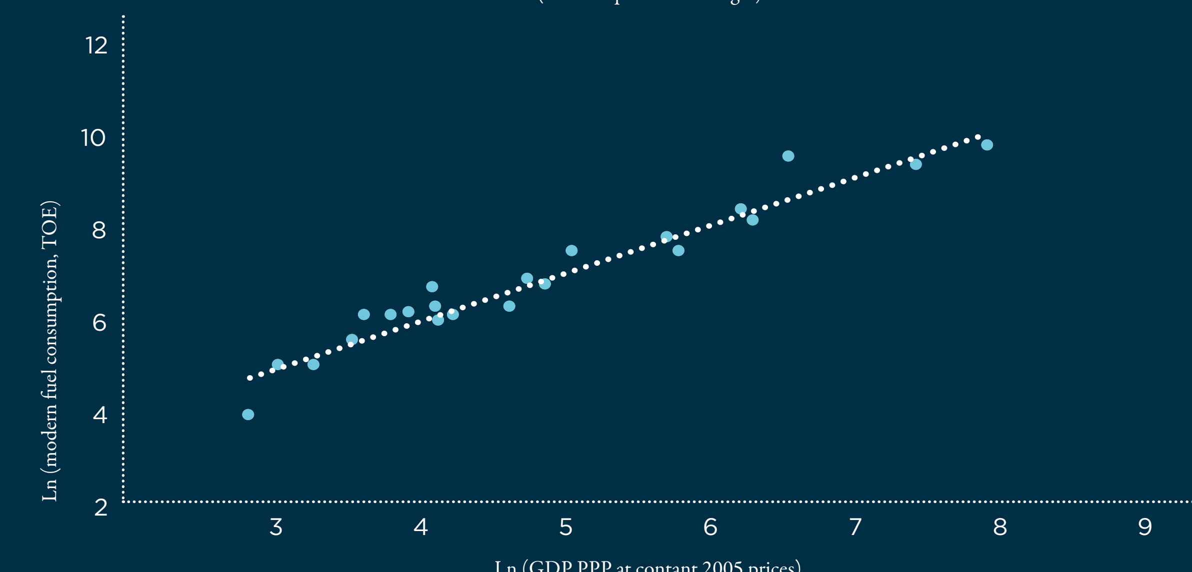
Endogenous Production of Gas and Consumption



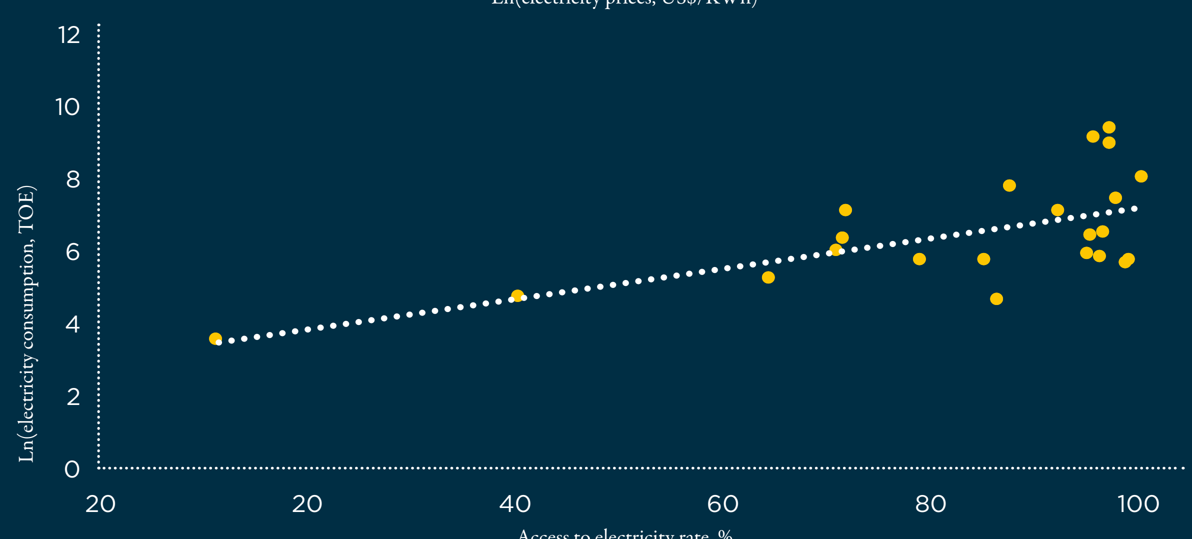
Prices and Consumption of Electricity



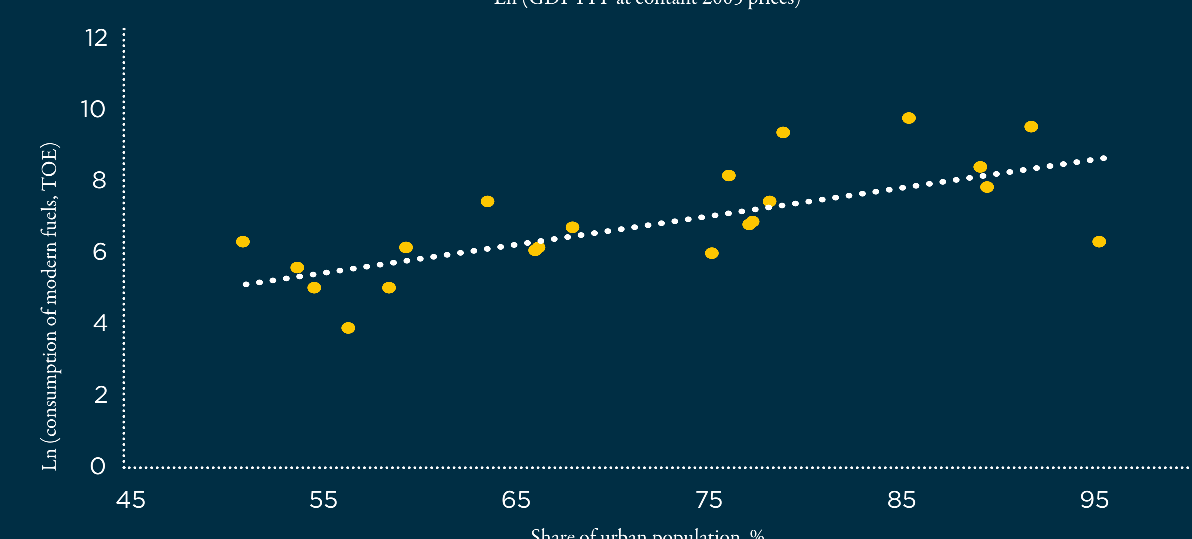
GDP and Consumption of Modern Fuels



Rural Electrification and Electricity Consumption



Urbanization and Consumption of Modern Fuels

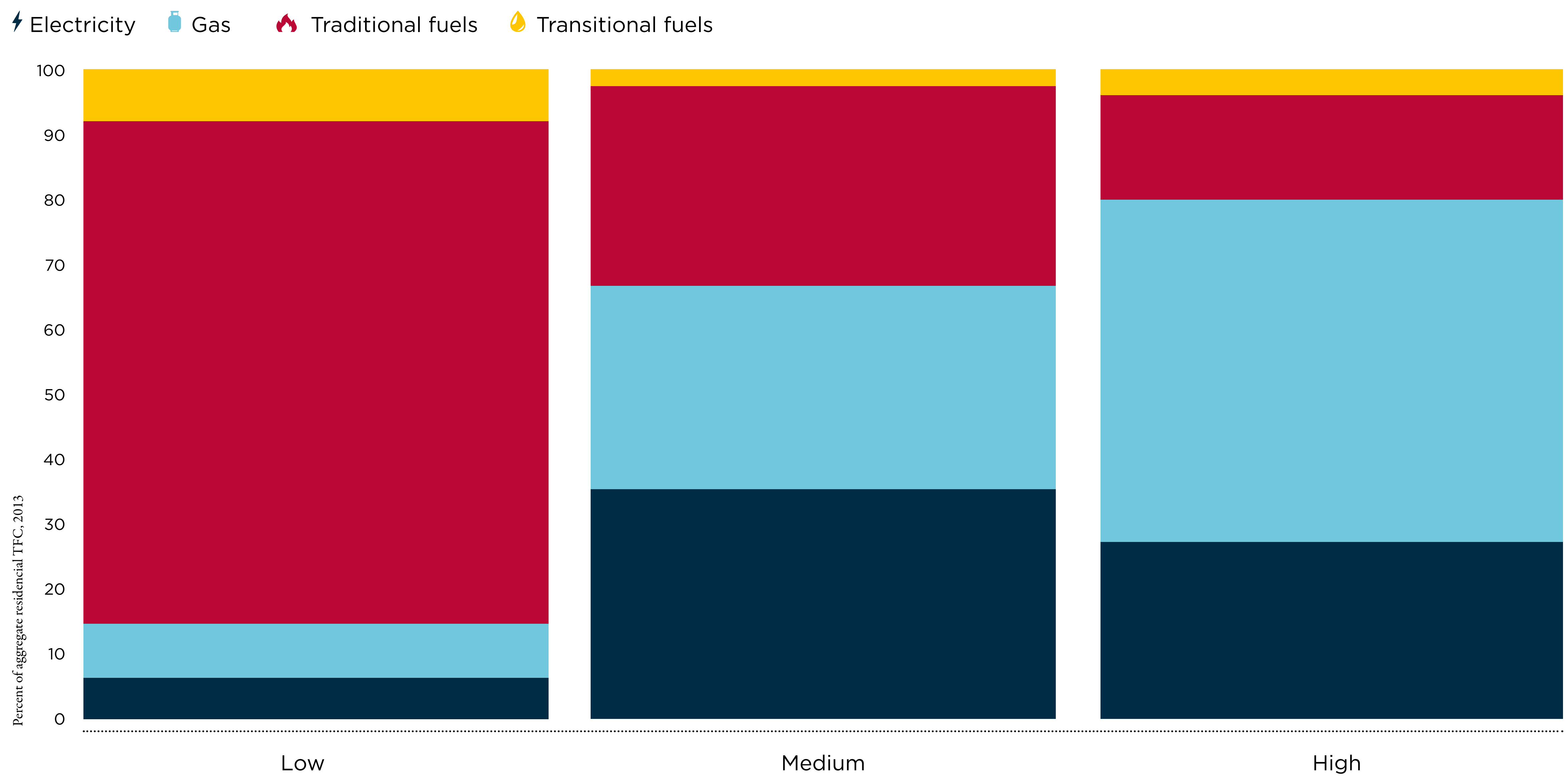


A longitudinal perspective allows for identifying distinctive patterns in the evolution of residential energy consumption across LAC countries at different stages of development (using income level as an approximate measure of development). A common feature is how modern fuels have gained ground in household energy portfolios in all country income groups, with higher-income countries having experienced the largest penetration. Also, as shown in panel b of Figure 3.5, the increase in per capita residential energy consumption since 1971 has been due to increased consumption of modern fuels in high-income countries given that medium- and low-income countries have seen a reduction in their aggregate energy consumption.

During the period under review, greater use of modern energy sources more than offset the consumption of non-modern fuels, leading to a small decrease in total energy consumption. This pattern is clearer in middle-income countries (such as Brazil, Colombia, Ecuador, and Paraguay), where consumption of electricity and natural gas has increased alongside sustained reductions in the use of traditional fuels. The same is true in low-income countries, though less marked. In low-income countries, traditional fuels still represent the bulk of energy consumption (as shown in Figure 3.3), and while per capita energy consumption in poor countries is high, it is mainly composed of non-modern fuels. This is in sharp contrast to relatively richer countries, where modern energy sources represent a greater share of per capita residential energy use.

This region's energy profile shows that traditional fuels are still relevant in LAC, even in high- and upper-middle-income countries. Table 3.1 shows that traditional fuels represent around half of residential energy consumption in Chile, a third in Mexico, and a quarter in Brazil. Although cultural preferences play a role in the use of traditional fuels, this pattern may also be caused by income differences and uneven access to modern energy sources within each country. This means that equitably increasing income and access to modern energy sources will lead to greater demand for modern fuels in all countries in LAC.

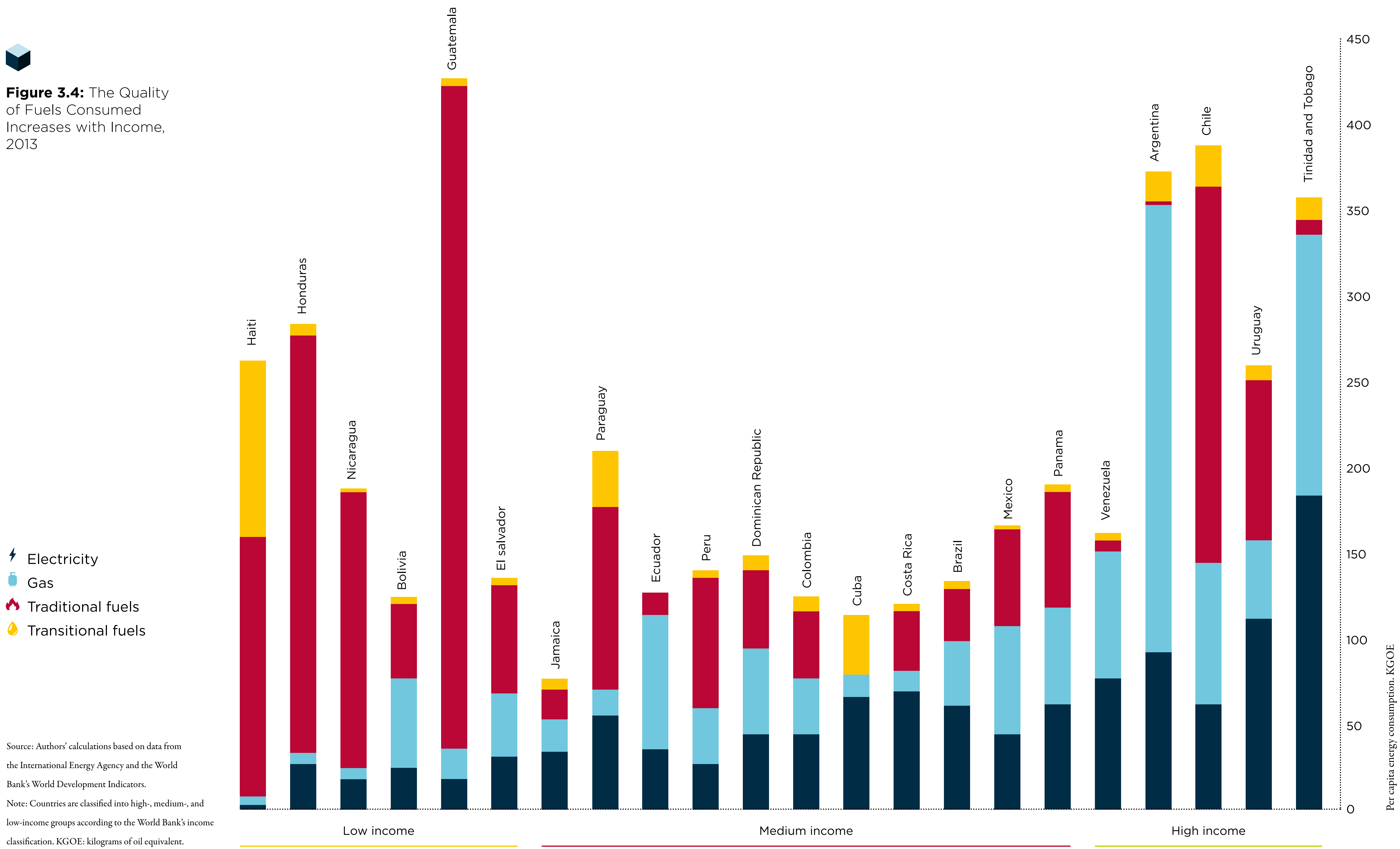
Figure 3.3: Residential Energy Consumption Mix by Income Classification in Latin America and the Caribbean



Source: Authors' calculations based on data from the International Energy Agency and the World Bank's World Development Indicators.

Note: The figure includes 22 countries in Latin America and the Caribbean. Countries are classified into high-, medium-, and low-income groups according to the World Bank's income classification. TFC: total final consumption.

Figure 3.4: The Quality of Fuels Consumed Increases with Income, 2013



Source: Authors' calculations based on data from the International Energy Agency and the World Bank's World Development Indicators.

Note: Countries are classified into high-, medium-, and low-income groups according to the World Bank's income classification. KGOE: kilograms of oil equivalent.

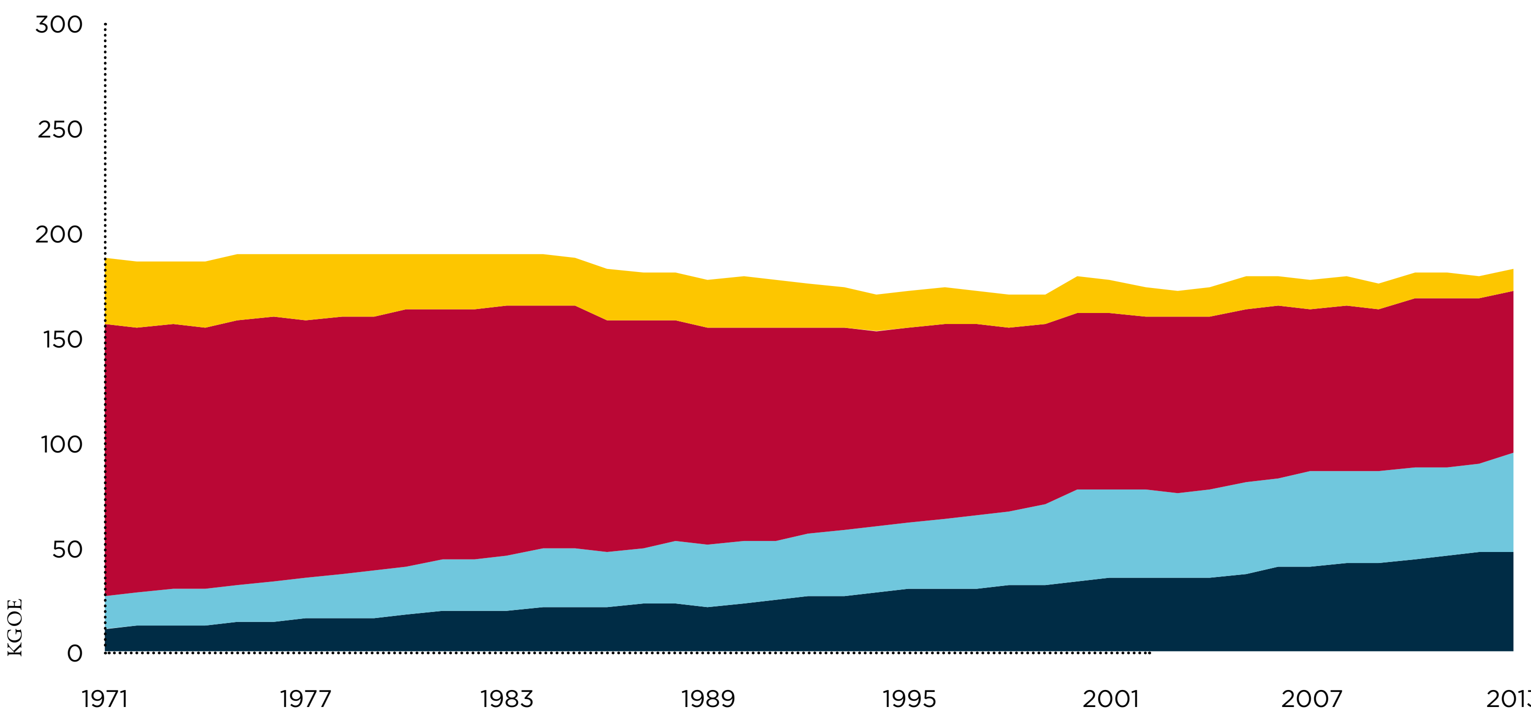
Figure 3.5: Trends in Per Capita Domestic Energy Consumption in Latin America and the Caribbean

- Electricity
- Gas
- Traditional fuels
- Transitional fuels

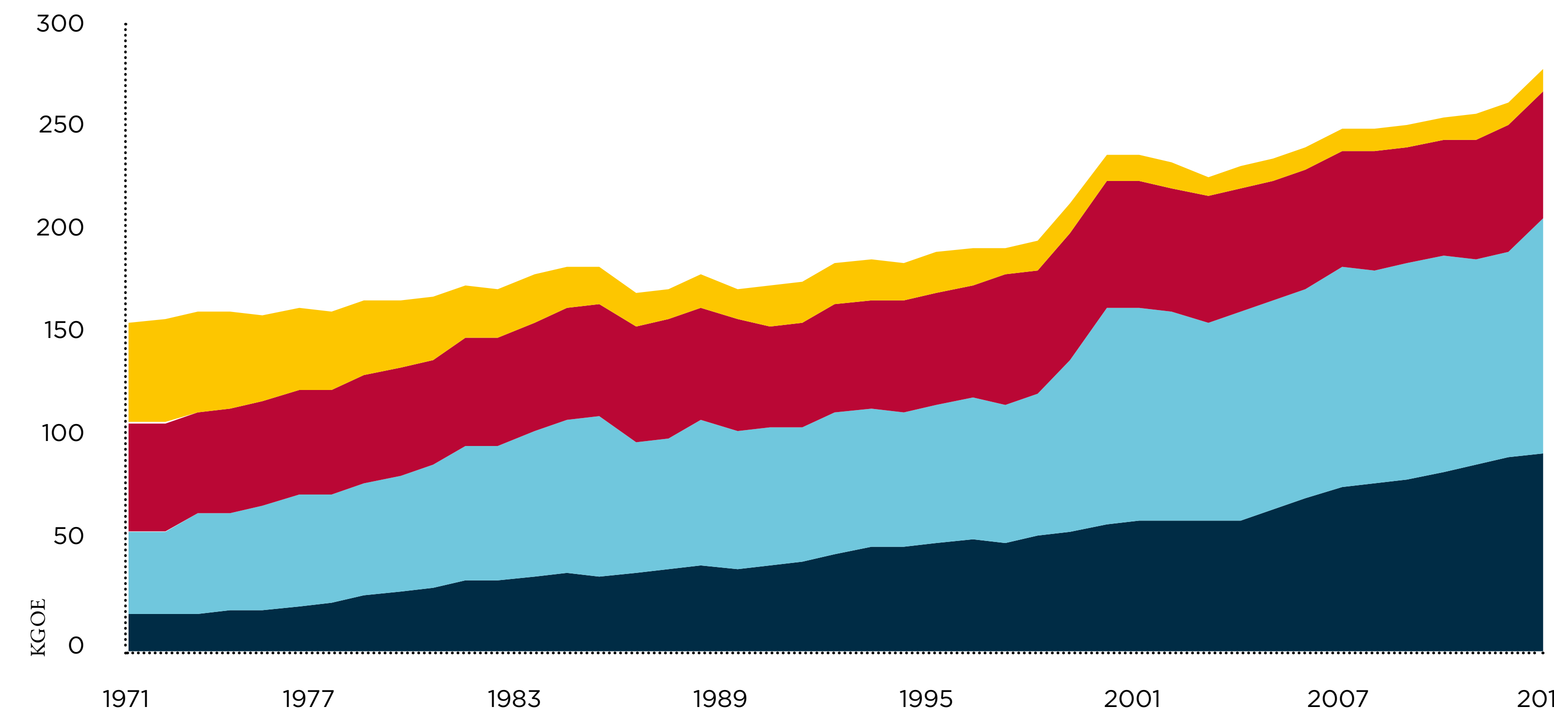
Source: Authors' calculations based on data from the International Energy Agency.

Note: Income groups are according to World Bank classifications. Low-income countries are Bolivia, El Salvador, Guatemala, Haiti, Honduras, and Nicaragua. Middle-income countries are Brazil, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, Jamaica, Mexico, Panama, Paraguay, and Peru. High-income countries are Argentina, Chile, Trinidad and Tobago, Uruguay, and Venezuela. KGOE: kilograms of oil equivalent.

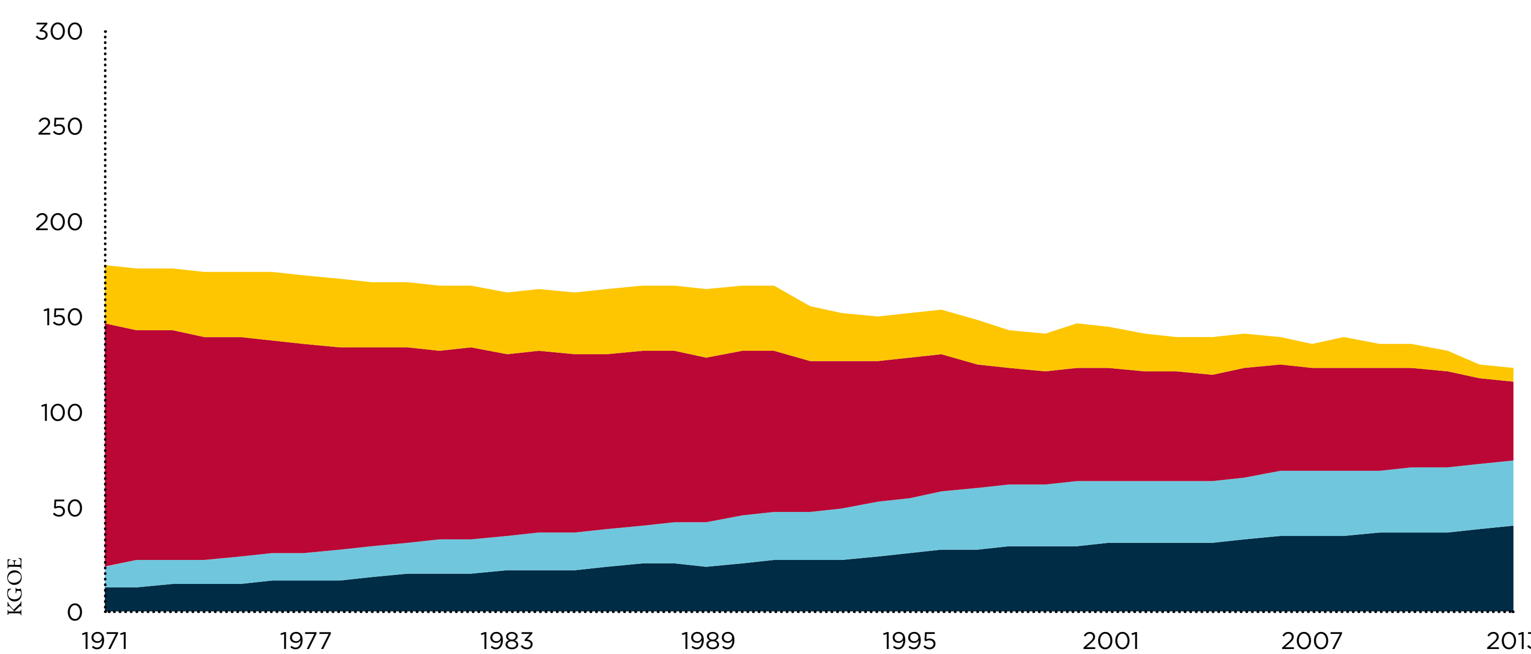
a. All Countries



c. Middle - income Countries



b. High - income Countries



d. Low - income Countries

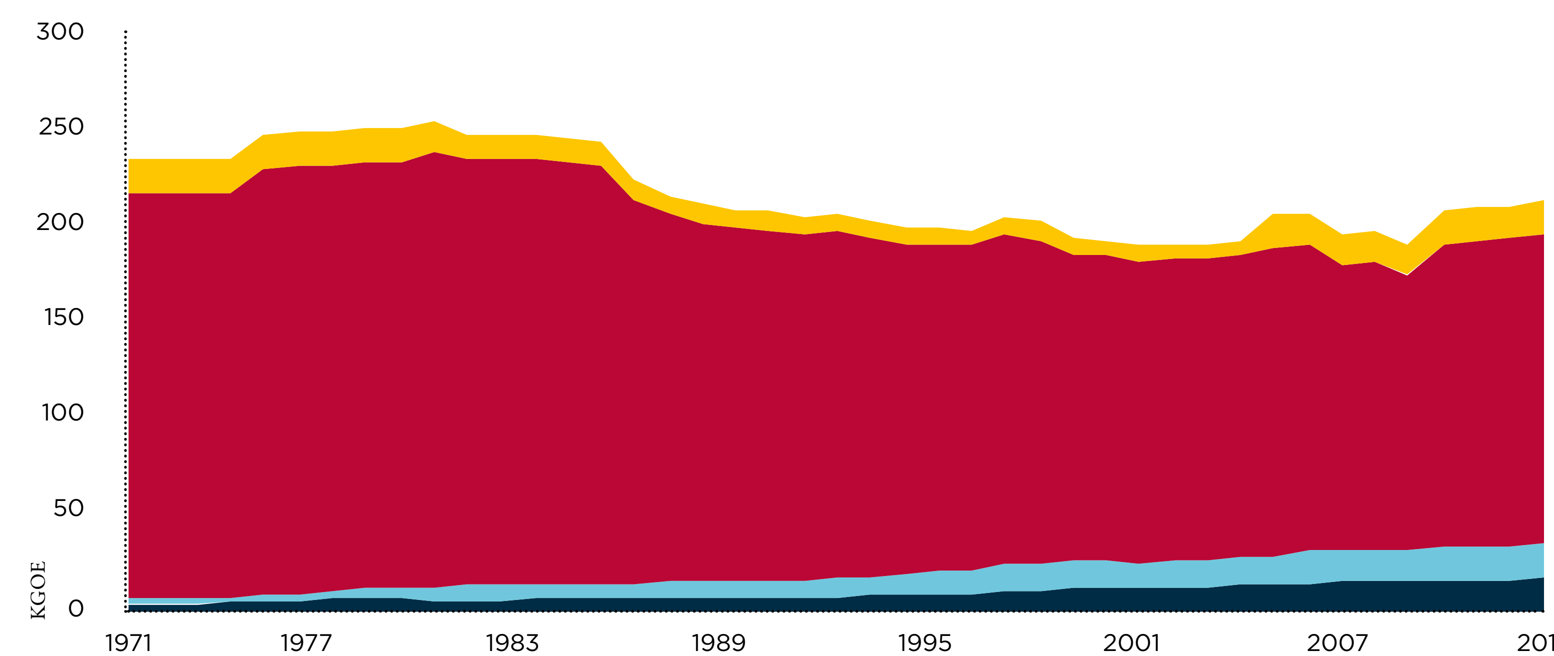
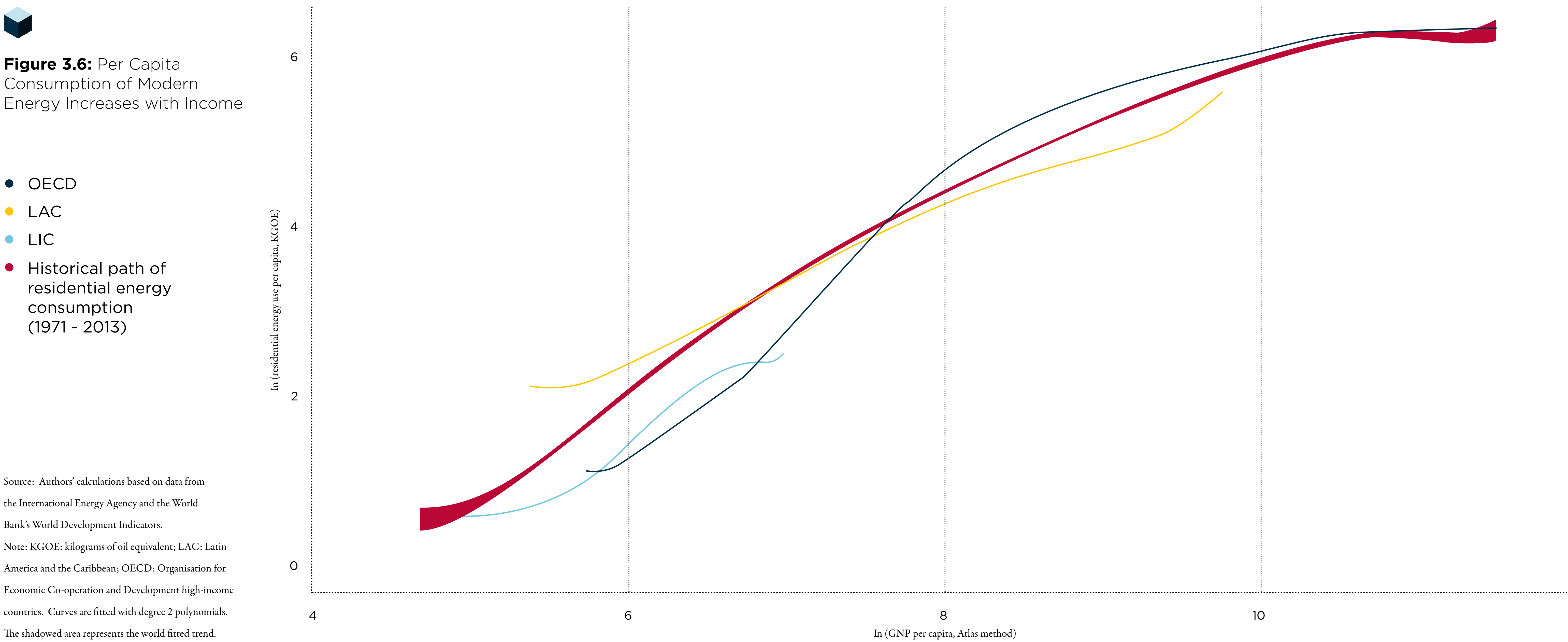


Figure 3.6: Per Capita Consumption of Modern Energy Increases with Income



Source: Authors' calculations based on data from the International Energy Agency and the World Bank's World Development Indicators.

Note: KGOE: kilograms of oil equivalent; LAC: Latin America and the Caribbean; OECD: Organisation for Economic Co-operation and Development high-income countries. Curves are fitted with degree 2 polynomials. The shadowed area represents the world fitted trend.

Latin American and Caribbean Trends Follow the Global Historical Path

The pattern of residential energy consumption in LAC follows world historical trends. Figure 3.6 presents the fitted curves of the relationship between income and modern energy consumption (shadowed area), showing the relative placement of LAC (blue line), high-income countries from the Organisation for Economic Co-operation and Development (OECD) (orange line), and low-income countries (dashed orange line). The figure illustrates how the observed shift toward greater use of modern energy in LAC's residential sector follows the global historical path over the period 1971–2013. In terms of composition, the share of non-modern energy significantly decreases from almost 90 percent in low-income countries to around 24 percent in OECD countries (Figure 3.7).

This stylized fact raises concerns about how to ensure a reliable and affordable modern energy supply to meet increasing demand as countries develop. Furthermore, this trend underscores the importance of fuel composition (focusing on electricity and natural gas) in forecasts of future energy requirements.

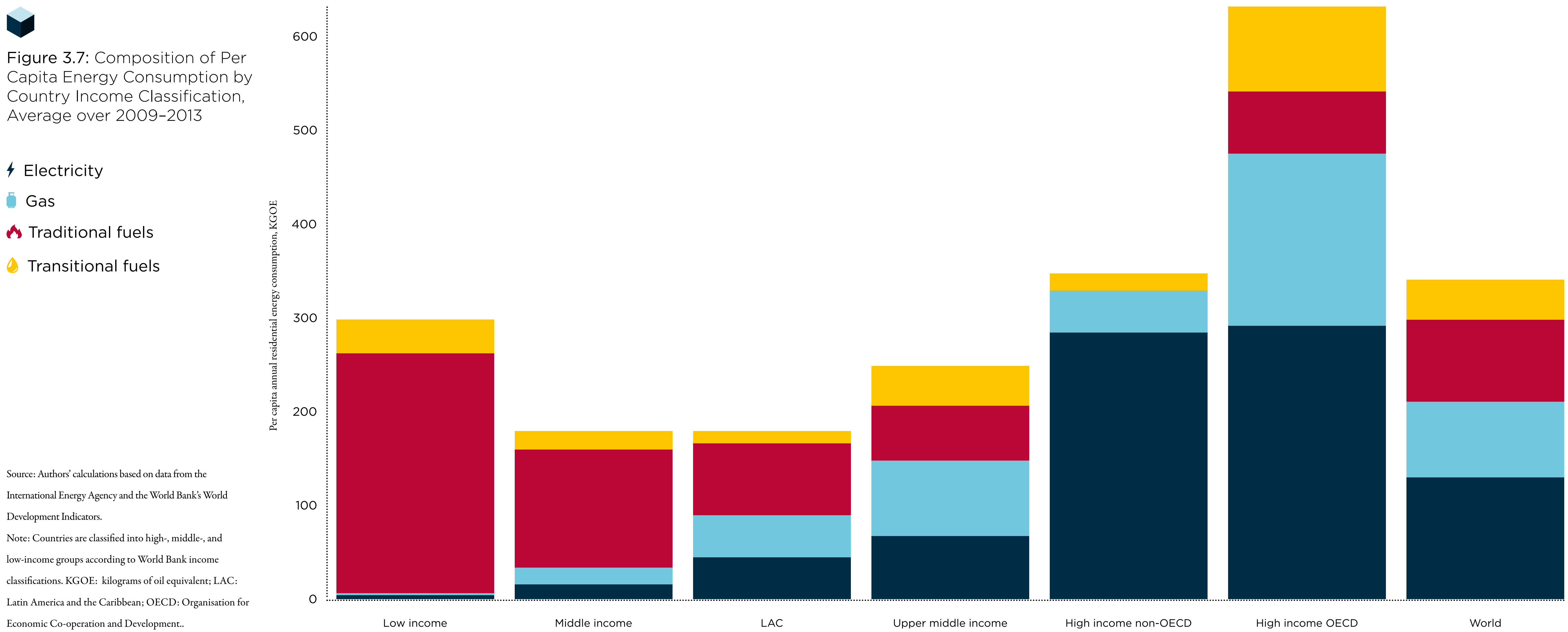
It is important to note that, on average, LAC presents one of the lowest levels of per capita residential energy consumption among country income groups (Figure 3.7). LAC's residential sector consumes around 180 kilograms of oil equivalent (KGOE) per capita, which is half the average world consumption, and less than a third of the annual consumption of OECD countries. This figure again suggests that per capita consumption of modern energy will increase as the region develops.

As a thought experiment one can ask: How much energy would LAC households need if the region were to reach the level of development of the OECD?

In a business-as-usual scenario, per capita electricity consumption in LAC would increase by a factor of six, with a fourfold increase in the per capita use of domestic gas; and residential consumption of modern energy would quintuple, assuming complete access to modern energy sources.[3] Reaching these levels would require an expansion in modern energy production of approximately 236 MTOE

3. These factors refer to the LAC average household reaching the average levels of consumption of electricity and domestic gas of high-income OECD countries.

Figure 3.7: Composition of Per Capita Energy Consumption by Country Income Classification, Average over 2009–2013



Source: Authors' calculations based on data from the International Energy Agency and the World Bank's World Development Indicators.

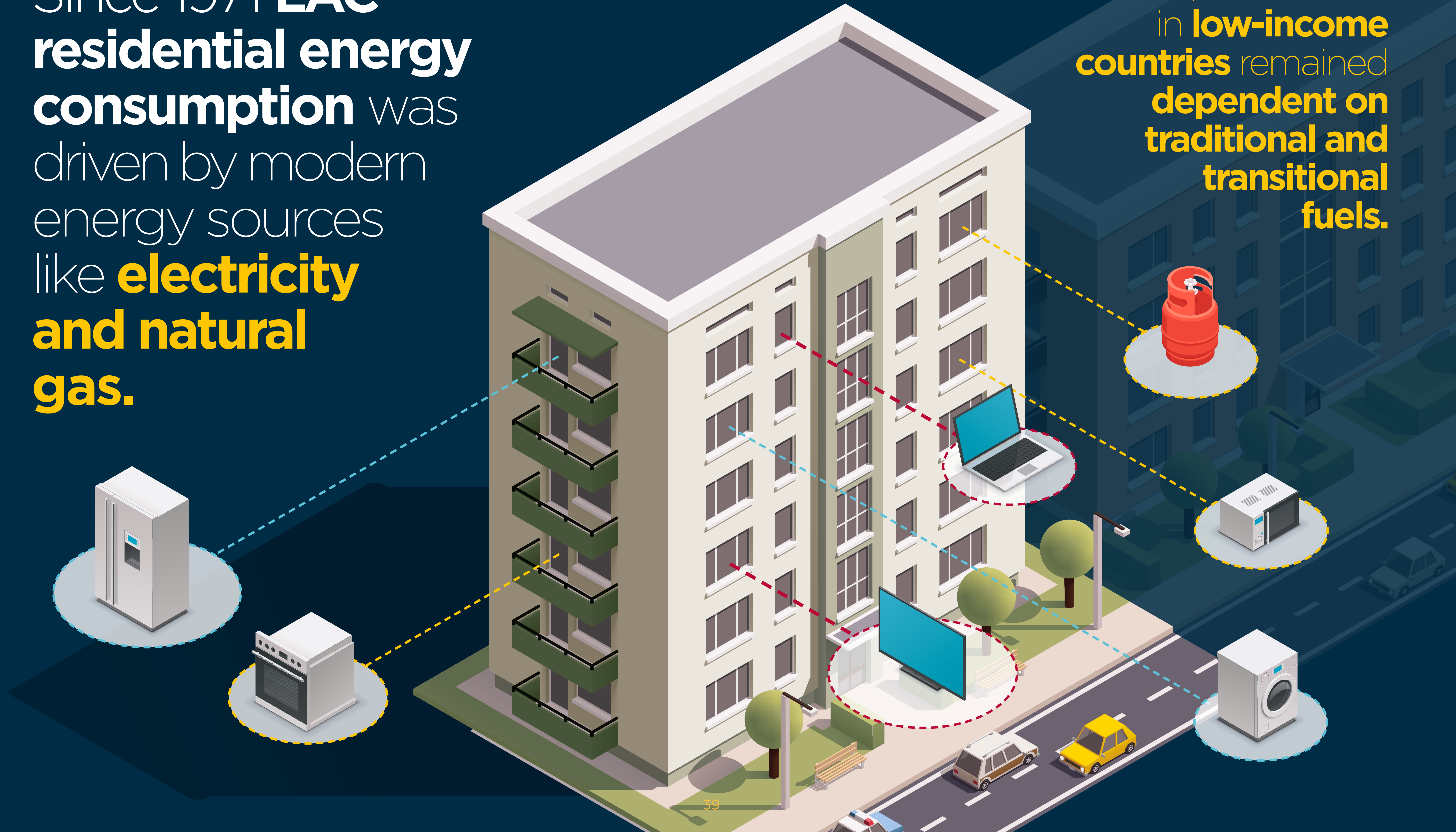
Note: Countries are classified into high-, middle-, and low-income groups according to World Bank income classifications. KGOE: kilograms of oil equivalent; LAC: Latin America and the Caribbean; OECD: Organisation for Economic Co-operation and Development..

just to meet the additional aggregate residential energy demand, equivalent to Brazil's total energy consumption in 2013. These calculations do not account for population growth, changes in conservation practices, or gains in energy efficiency, but they still highlight the challenge of meeting growing energy requirements.Consumption of Modern Fuels Grows Asymmetrically

Figure 3.8 shows the evolution of per capita energy consumption by sector, using average per capita energy consumption across countries to calculate the annual percentage change, with 1971 as the base year. This figure closely reflects the strong association between income growth and per capita energy consumption of different economic sectors: residential, industry, and transportation. In particular, per capita consumption of fuels by the transportation and industrial sectors is closely associated with growth in per capita income, while total fuel consumption in the residential sector – including modern and traditional fuels – shows a decline over the period in question. However, when distinguishing between different types of fuel used by households, the underlying force in residential energy consumption is dominated by modern fuels. While transportation and industry have grown at a pace similar to that of income, residential consumption of modern fuels has grown at a faster rate. These trends are aligned with previous empirical regularities that show the displacement of traditional and transitional fuels by electricity and natural gas, and highlight the asymmetric dependence on modern energy sources in the residential sector.

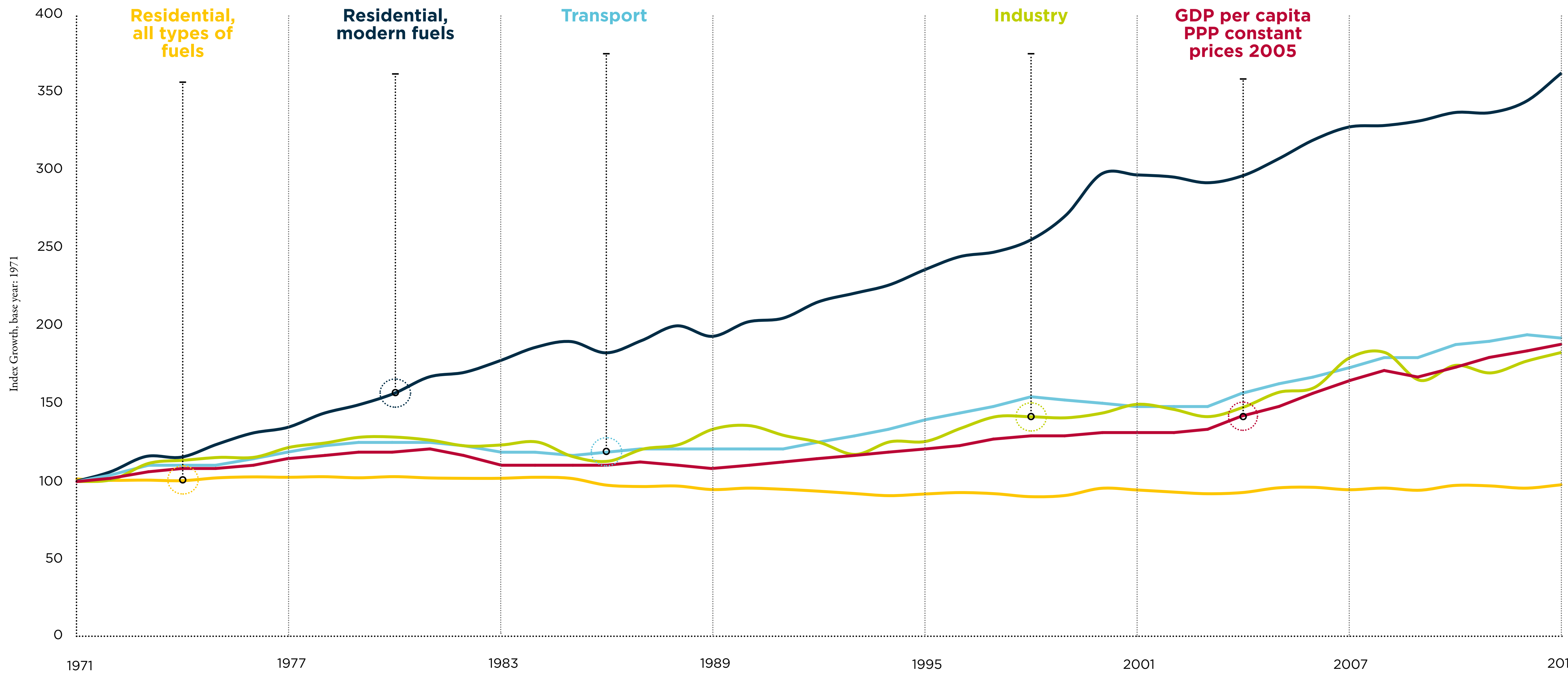
An important note regarding energy accounting is that residential energy use does not include fuels for public or private transportation. According to the national energy balances, public and private transport are included in the transportation sector, together with firms' consumption of transport fuels. Nonetheless, changes in household income have an indirect effect on energy demand across sectors, as it is widely documented for factors such as increased demand of liquid fuels from private transportation, as well as, sub-urbanization, among others.

Since 1971 **LAC residential energy consumption** was driven by modern energy sources like **electricity and natural gas.**



However, households in **low-income countries** remained **dependent on traditional and transitional fuels.**

Figure 3.8: Decoupling of Residential Consumption of Modern Fuels



Source: Authors' calculations based on data from the International Energy Agency and the World Bank's World Development Indicators. Note: PPP: purchasing power parity.

Household Consumption of Transport Fuels

Transport is one of the main drivers of energy demand, with the sector accounting for approximately one-third of total final energy consumption in LAC. Since 1971, energy consumption for transportation has grown by over 300 percent in absolute terms, and by over 100 percent in per capita terms. The breakdown of transport fuels is comprised of gasoline (60 percent), diesel (30 percent), biofuels[4] (6 percent), and natural gas (4 percent).

As previously noted, transport fuels are not accounted for as residential energy use.[5] However, household private transportation constitutes one of the main components of household energy consumption. And as will be seen in the text below, household-level data demonstrate the importance of transport fuels in household expenditures.

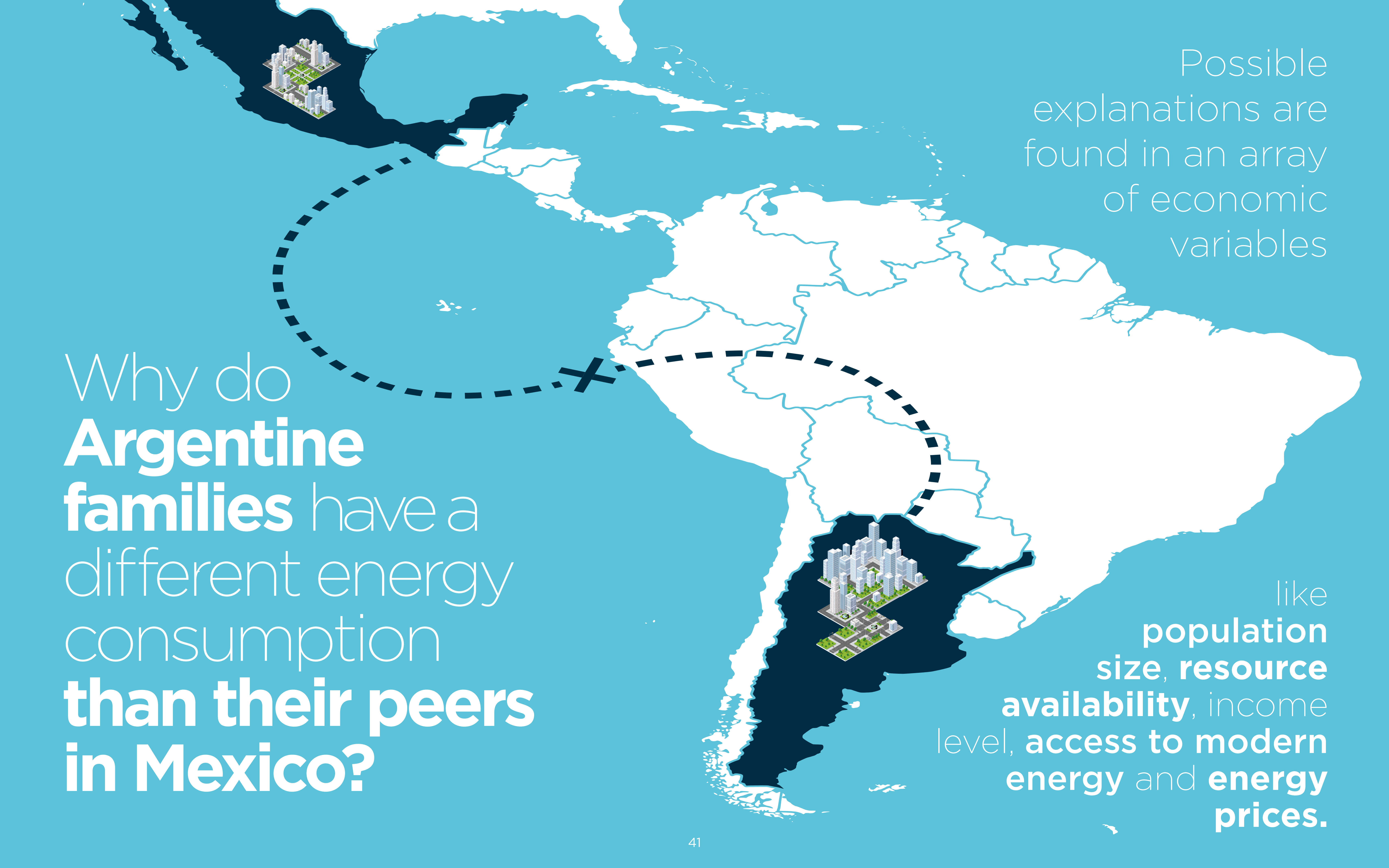
At the household level, the demand for transport fuels spans from private automotive vehicle ownership. Figure 3.9 presents vehicle ownership by income quintile for the period 1994–2014 for Mexico and Peru. Two important points deserve attention:

1. Private motor vehicle ownership rises with income. In Mexico in 2014, the percentage of households that owned a motor vehicle in the richest income quintile was seven times that of the poorest income group. Similarly, in Peru, ownership of motor vehicles in the richest segment of households was five times that of the poorest families.

2. Ownership of private motor vehicles has increased significantly across all income groups since the mid-1990s. Two decades ago, 4 percent of Mexican households and 2 percent of Peruvian households in the lowest income quintile owned a vehicle; by 2014, those figures had increased to 13 percent and 8 percent, respectively.

These facts are consistent with the empirical literature, which shows an increasing share of transport fuels in overall energy demand (Medlock and Soligo 2001; Fouquet 2014). The intensification of private transportation implies that as LAC continues to develop, households will be an important driver of fossil fuel demand. Energy policy design has to be informed about how energy consumption behaves along the income distribution. The subsequent chapter addresses this point in further detail.

4. Brazil is the primary consumer of biofuels in LAC's transport sector.
5. According to the energy balances of the International Energy Agency.

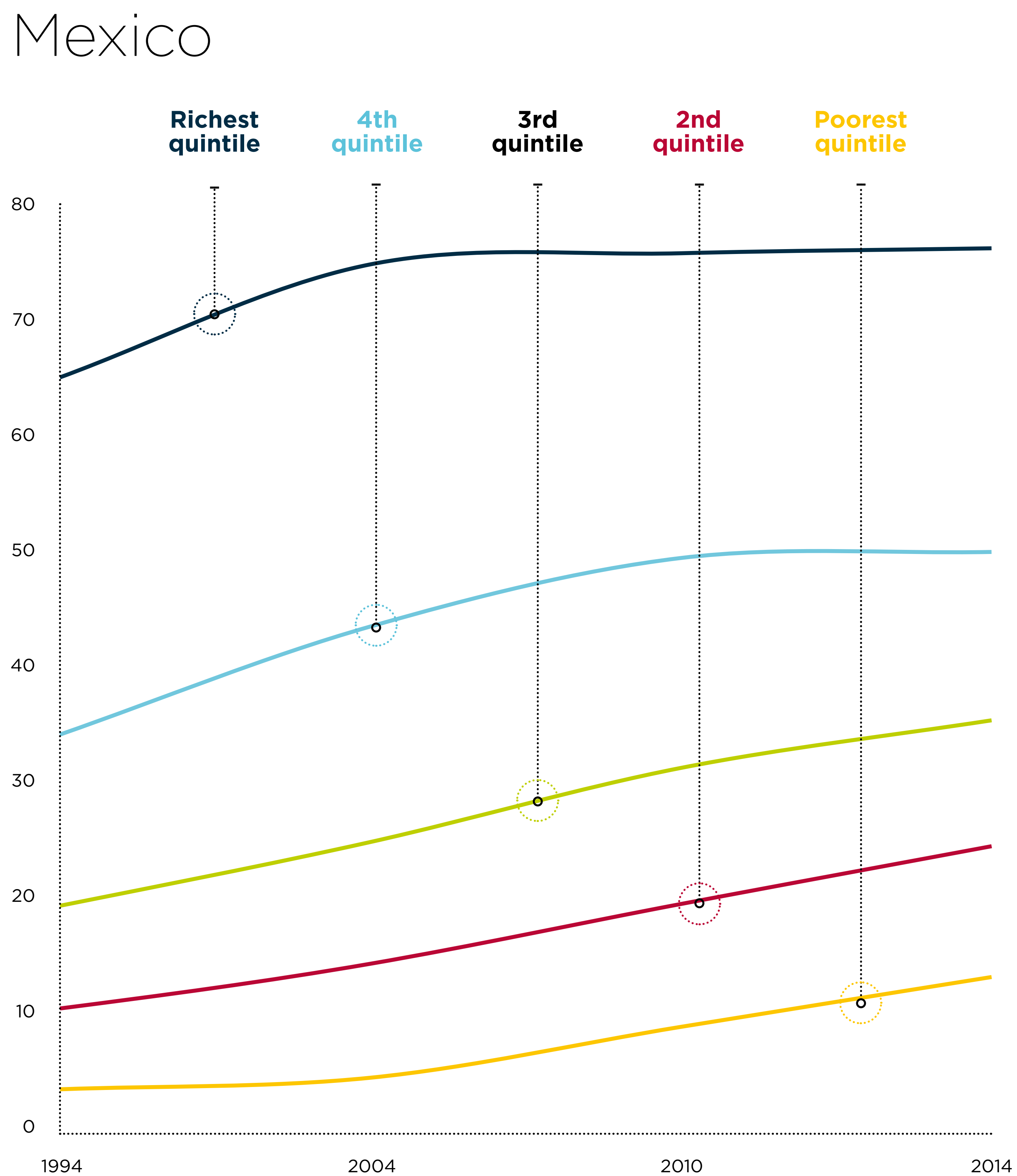


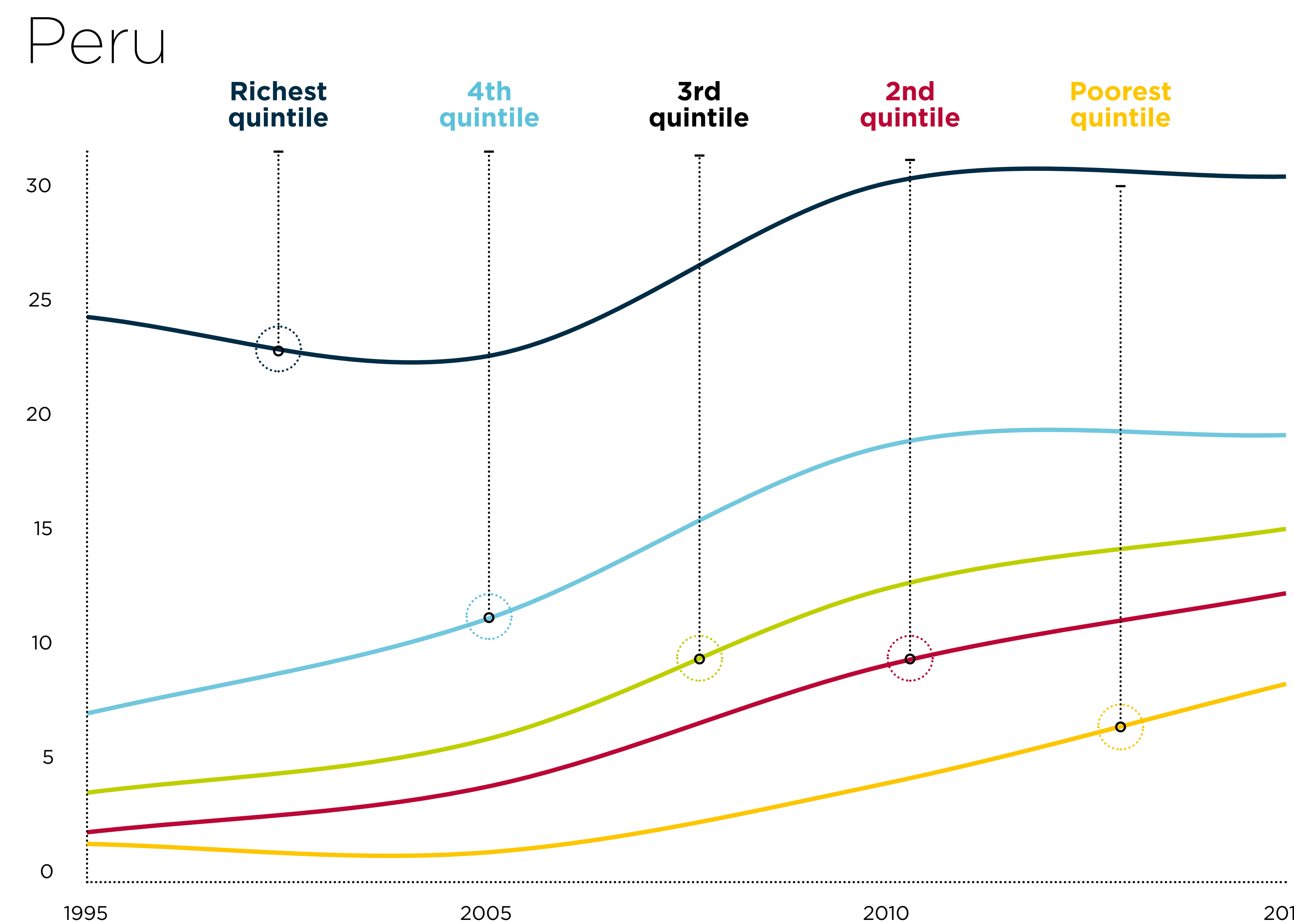
Why do **Argentine families** have a different energy consumption **than their peers in Mexico?**

Possible explanations are found in an array of economic variables

like **population size**, **resource availability**, income level, **access to modern energy** and **energy prices.**

Figure 3.8: Mexico and Peru: Increase in Motor Vehicle Ownership over Time for All Income Levels (percent of households with motor vehicles)





Source: Authors' calculations based on data from several years of national household surveys.

Final Remarks

Residential energy use has had a slow growth—increasing by 70 percent between 1971 and 2013, which is less than energy use growth in other sectors like transport and industry. The source of residential energy has shifted markedly since 1971 though, toward greater dependence on modern fuels such as electricity and natural gas. During that span, the use of modern fuels displaced less efficient ones, such as kerosene and biomass, leading to an overall reduction in total per capita energy consumption in low- and middle- income countries. This highlights the importance of distinguishing between alternative fuel types when evaluating future energy needs for sustained economic and social progress.

Among the factors explaining variations in residential energy consumption across countries are the access to modern energy sources, availability of natural resources (a country's energy-use mix depends on its natural resource endowment, especially in terms of fossil fuels), population size and income. The pattern observed in LAC's residential energy consumption follows world historical trends.

Conversely, energy consumption for transportation has grown by over 300 percent in absolute terms since 1971, and by over 100 percent in per capita terms. Household private transportation is one of the main components of household energy consumption.

Box 3.1: Urbanization and Modern Energy Use in the Residental Sector

Box Figure 3.1.1: Per Capita Residential Energy Consumption of Modern Fuels and Urbanization

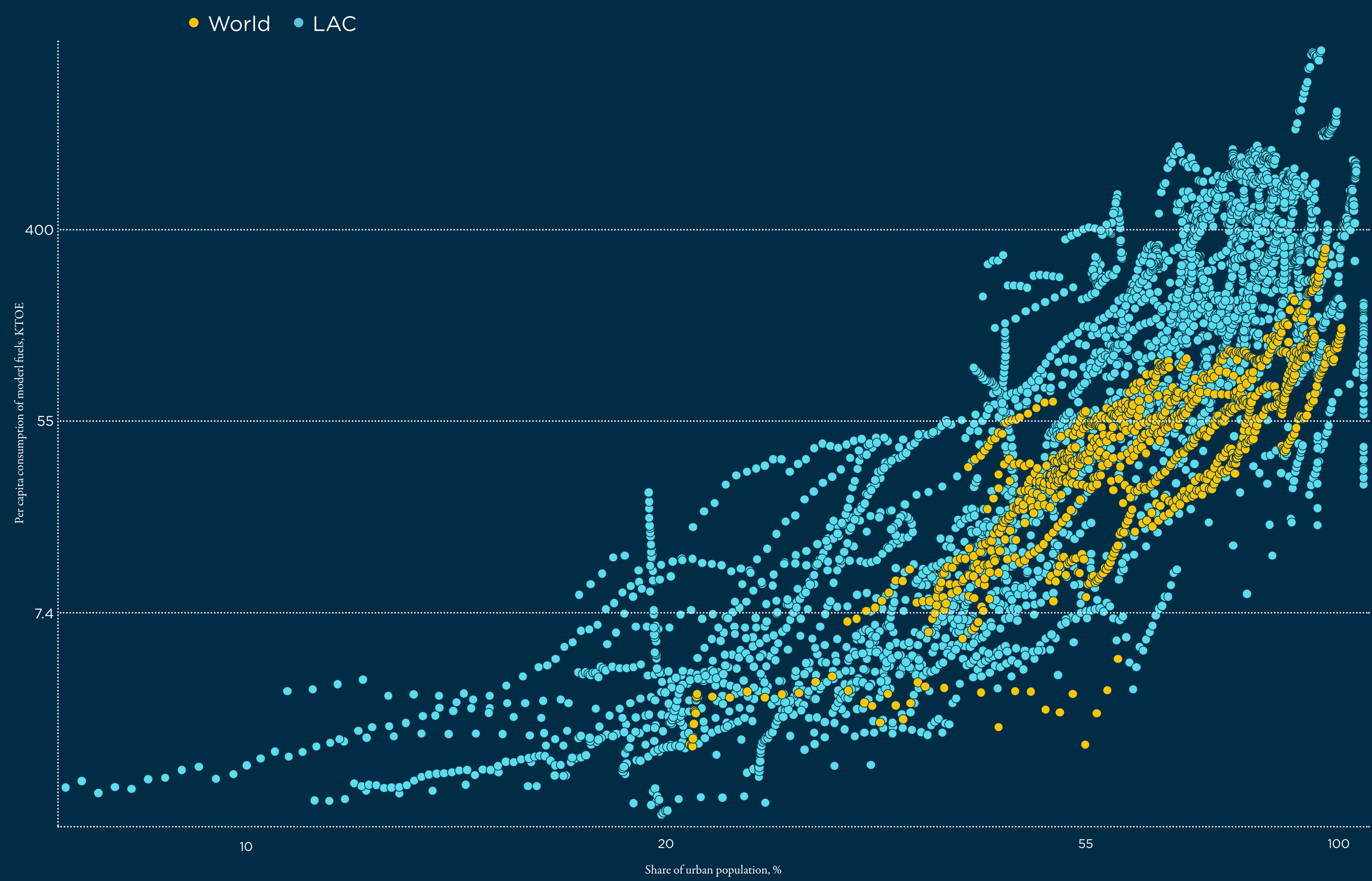
Source: Authors' calculations based on data from the International Energy Agency and the World Bank's World Development Indicators.
Note: Figure includes 130 countries, including 22 countries in Latin America and the Caribbean (LAC), over the period 1971–2013. Axes in log scale. KTOE: kilotons of oil equivalent.

Cities play a major role in all dimensions of human activity, to an extent that the United Nations Intergovernmental Panel on Climate Change discusses their role in mitigating climate change (Seto et al. 2014). Cities are on average responsible for around three-quarters of their country's GDP and energy consumption, and for up to 80 percent of the world's total greenhouse gas emissions (Seto et al. 2014).

The impact of urbanization on energy demand has been increasingly studied over the last few years (Jones 1991; Parikh and Shukla 1995; Madlener and Sunak 2011; Creutzig et al. 2015). With regard to private energy consumption, urbanization is mainly associated with switching from traditional fuels to modern energy sources, such as electricity and gas. Given that the process of urbanization is paramount in economic development, as urban dwellers become wealthier household consumption patterns shift towards more energy-intensive products such as refrigerators, air conditioning, and automobiles. Furthermore, human agglomeration puts pressure on the transportation sector, with the associated incremental demand for transport fuels due to commuting.

At the same time, however, agglomeration and economies of scale in urban locations offer opportunities for energy savings. Creutzig et al. (2015) suggest that if appropriate policies are put in place, cities in developing countries could reduce their expected energy use by 2050 from 730 to 540 exajoules. In rapidly growing cities, these policies – which include changes in urban planning, appropriate energy pricing, and transportation plans – should be aimed at shaping energy-efficient infrastructure.

In Latin America and the Caribbean (LAC), energy demand in urban areas is growing rapidly. The United Nations Development Programme (UNDP) estimates that as of 2012 around 80 percent of the LAC population lived in cities, a figure greater than the world average (54 percent).[1] Box Figure 3.1.1 plots the relationship between residential use of modern fuels and urbanization rates, showing an exponential increase in energy needs during the urbanization process. These trends make the region highly energy-dependent and highlight the need for coordinated policies to foster energy savings across sectors, such as transportation, utilities (e.g., water, public lighting), and buildings and facilities, among others.



1. UNDP, "About Latin America and the Caribbean" (http://www.latinamerica.undp.org/content/rblac/en/home/regioninfo).

Chapter 4

Economic Development and Residential Energy Consumption

Chapter 3 described patterns and recent trends in residential energy consumption in Latin America and the Caribbean (LAC), with an emphasis on income and on distinguishing between the different types of energy needed to sustain economic progress. This chapter further examines the relationship between income and the components of domestic energy consumption, with an eye on LAC's growing use of modern fuels. The objective is to investigate the sensitivity of residential energy consumption to changes in income in comparison with other sectors and regions, and to look at how such sensitivity might be expected to evolve as the region develops.[6] The chapter continues to rely on annual country-level data and to use per capita gross domestic product (GDP)[7] as a proxy for income.

This chapter provides a comprehensive analysis of how modern domestic fuels, which grow at a faster rate than income, underpin the growth of residential energy consumption. Such dynamics explain the pronounced switch from traditional to modern fuels over the last four decades. However, the income elasticity of residential energy demand is lower than in other sectors such as transportation and industry. This means that, although residential consumption of modern energy is highly correlated with per capita income, other economic sectors in LAC are even more responsive to income changes. Therefore, improving household economic conditions would have important indirect effects on total energy demand. The findings also suggest that LAC is in an income range where it is highly dependent on energy supply and that, as the region reaches higher levels of economic development, the income elasticity of residential energy demand is expected to decrease.

Transition of Residential Energy Consumption in Latin America and the Caribbean

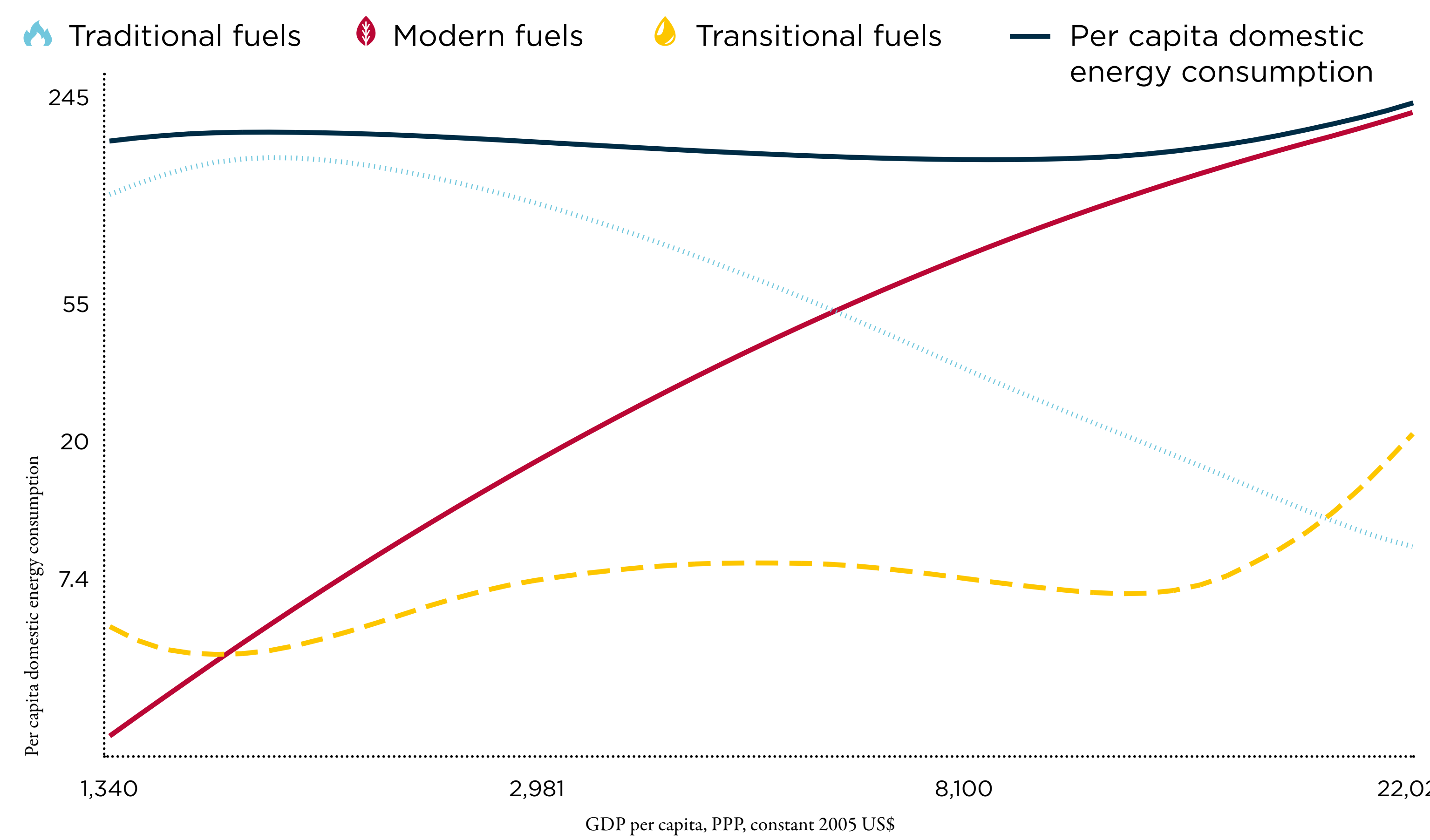
For a first glance at how domestic energy consumption has evolved with economic development, Figure 4.1 plots the trend lines of residential energy consumption by fuel type along the LAC income distribution. The trend lines reflect the relationship between energy consumption and income (both in per capita terms) over the period 1971–2013 for the 22 countries under review. The figure exploits all the variability across time and countries, thus providing an overview of the patterns in domestic energy consumption along the entire historical income distribution in the region. Energy consumption tends to be high at lower income levels, where usage of traditional fuels is prevalent. Moving to the (wealthier) right side of the income distribution, there is a pronounced substitution of traditional fuels with transitional and modern fuels. However, consumption of transitional fuels increases with income, which is mainly explained by the region's stage of development. As income in LAC expands (that is, the distribution shifts to the right), it is expected that the use of transitional fuels will also start to decrease (Jimenez and Yépez-García 2016).

In accordance with the energy consumption hypotheses, there is a clear substitution of fuels as income increases. The observed transition toward greater use of modern energy sources is conceptually well aligned with the energy stacking or portfolio

6. This section is based on Jimenez and Yépez-García (2016)

7. At purchasing power parity in constant 2005 U.S. dollars..

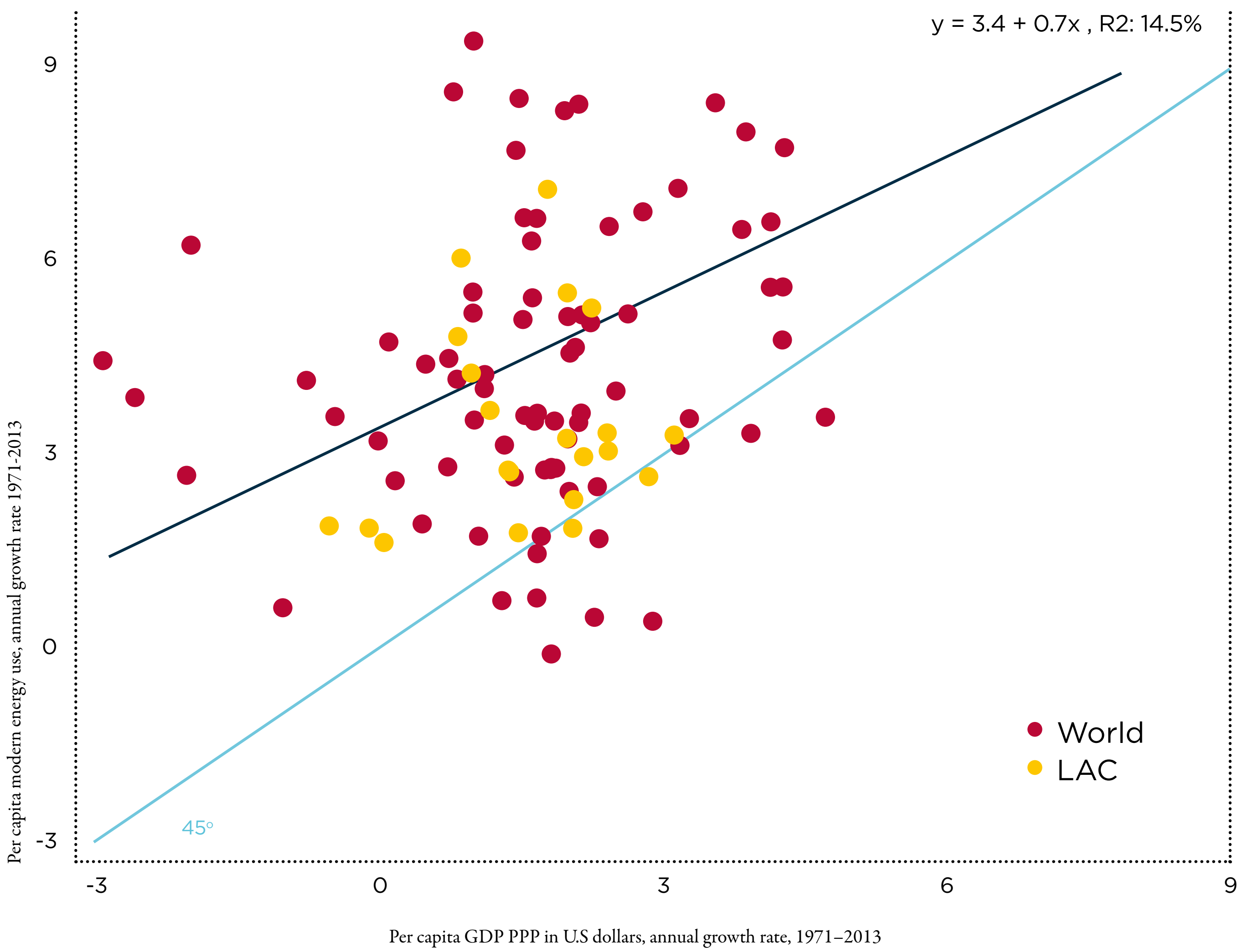
Figure 4.1: Consumption of Domestic Fuels in Latin America and the Caribbean by Income Distribution Levels



Source: Authors' calculations based on data from the International Energy Agency and the World Bank's World Development Indicators.

Note: Figure includes 22 Latin American and Caribbean countries over the period 1971–2013. Axes in log scale. Curves are fitted with second-degree polynomials. KGOE: kilograms of oil equivalent; PPP: purchasing power parity.

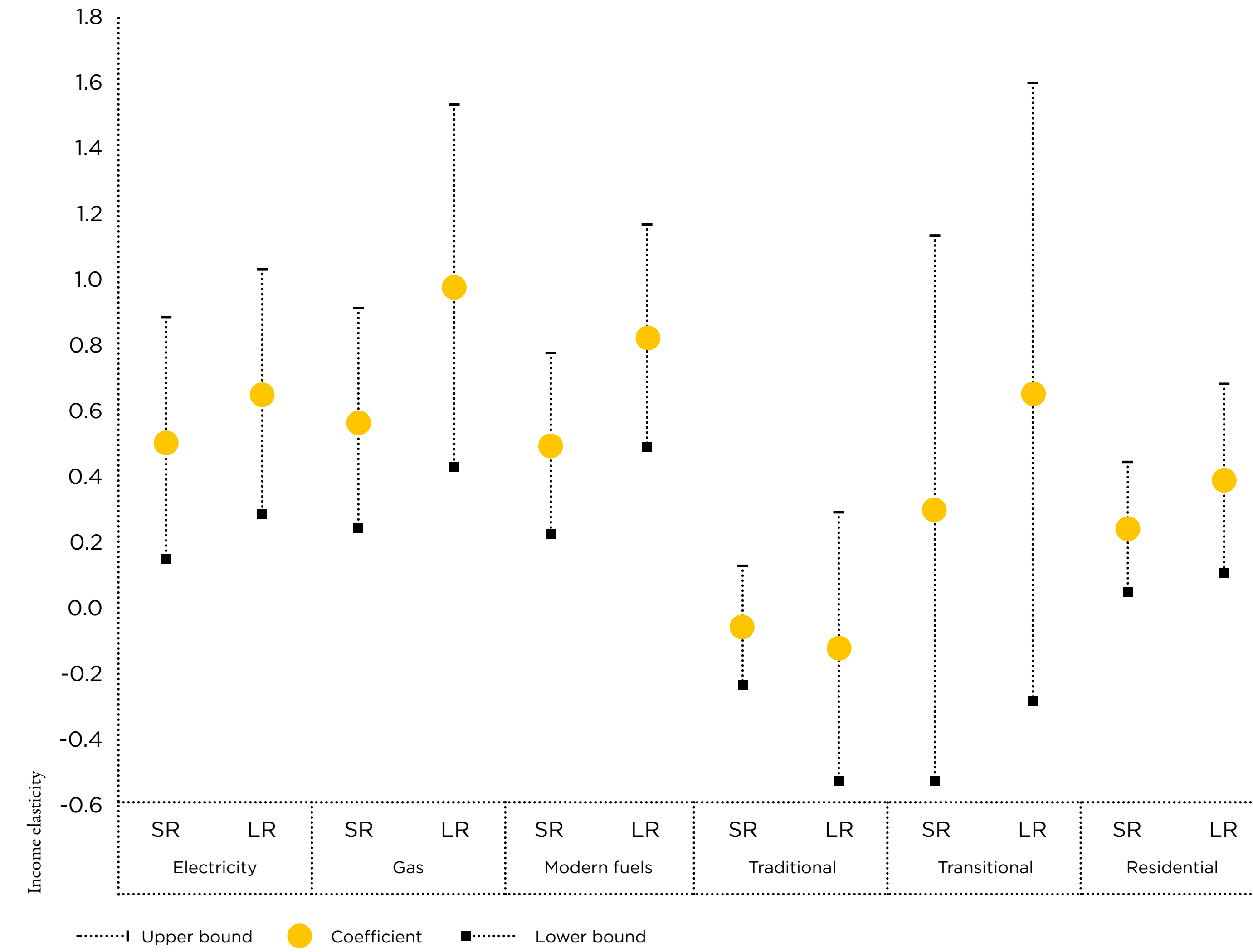
Figure 4.2: Modern Energy versus Income Growth in Latin America and the Caribbean



Source: Authors' calculations based on data from the International Energy Agency and the World Bank, World Development Indicators.

Note: The sample is composed of 104 countries, including 22 from Latin America and the Caribbean (LAC). Average annual growth rate by country over the period 1971–2013. PPP: purchasing power parity.

Figure 4.3: Short- and Long-Run Income Elasticities in the LAC Residential Sector



Source: Authors' calculations based on data from the International Energy Agency.

Note: Upper and lower confidence intervals are at 95 percent. Estimated elasticities account for international oil prices, country-specific trends, and coefficient heterogeneity. See estimation details in Appendix 2. SR: short run; LR: long run.

hypothesis, highlighting income as the main underlying driver behind the compositional change. The interaction and phasing in and out of fuels results in a nonlinear pattern of overall energy use per capita, a process in which the use of modern fuels grows continuously until it accounts for most of per capita energy consumption at the highest income levels. This pattern, which has been documented before by Jamasb and Meier (2010), for example, shows the strong effect of income on the consumption of better-quality fuels.

In this context, the portfolio hypothesis seems to be more suitable for reconciling the degree and speed at which the composition of household energy consumption has evolved. Access to modern energy sources, energy prices, household incomes, and cultural factors are all determinants of fuel choice and the intensity of fuel use, explaining the variability in the consumption patterns among households (Arseneau 2011; Heltberg 2004; Leach 1992). Moreover, at the country level, the portfolio hypothesis is compatible with the continued consumption of traditional and/or transitional fuels at higher income levels. For example, as shown in Chapter 2, relatively high-income countries in LAC (Uruguay and Chile) present a substantial share of biomass consumption. In general, this may be explained by underlying cultural practices, or by income inequality within a country, meaning that most of the lower-quality fuels are consumed by poorer households.

A corollary from this analysis is that it is important to distinguish energy sources when studying the relationship between income and energy consumption. Previous examination shows that economic development drives the consumption

of modern fuels, not traditional or transitional ones. Thus, reliable measures of the association between income and energy consumption require focusing on modern fuels instead of overall energy consumption. The latter may lead to biased interpretations due to the nonlinear relationship between income and energy use.

To take a closer look at the link between income growth and modern energy use, Figure 4.2 presents the average annual growth rate of income and modern energy use, by country, for the period under review. The figure shows that residential consumption of modern fuels has grown at a faster rate than income (above the 45 degree line), and that the relationship has been positive, as expected. The plot also shows significant variation in the relationship between income and energy consumption, meaning that income elasticity may vary pronouncedly from country to country and across time, as just noted above.

Income Elasticity of Residential Energy Demand

This section presents estimates of energy income elasticity by fuel type and economic sector. The comparison of the results provides a look at the implications of higher incomes on energy demand in LAC households. The estimates are based on country-level annual data.[8]

Figure 4.3 summarizes the estimates of short- and long-run income elasticities by fuel source in the residential sector, along with the 95 percent confidence interval. The figure measures the sensitivity of energy consumption to changes in per capita income, controlling for international oil prices and country heterogeneity. On average, a 1 percent increase in income translates into a 0.5 percent increase in electricity consumption in the short run and a 0.7 percent increase in the long run. In the case of natural gas, a 1 percent increase in income translates into a 0.6 percent increase in natural gas consumption in the short run and an approximate 1 percent increase in the long run. Overall, the income elasticity of modern fuel consumption is greater than that of total residential energy consumption. This supports the idea that economic growth is tied to the greater consumption of modern fuels, with the corresponding implications for planning the future supply of energy in the region. Forecasts based on total residential energy consumption would underestimate the requirements for modern energy.

In the case of traditional fuels, income elasticities tend to be negative, indicating that increases in income would reduce the average consumption of biomass. Such negative elasticities would be consistent with both energy consumption hypotheses (ladder and portfolio), but the income elasticities of traditional fuels are not statistically different from zero (the interval band crosses zero). Although not statistically significant, the previous stylized patterns suggest that transitional fuels can behave as an inferior good.

The consumption of transitional fuels seems to respond positively to income improvements, although there is high variation in such estimates. Using a world sample, Jimenez and Yépez-García (2016) find that the income elasticities of transitional fuels present an inverted U-shape along the world income distribution, suggesting that the observed elasticity in LAC is intrinsically tied to its stage of development. These findings would suggest that, in the long run, income growth has a net negative effect on the use of dirty fuels, suggesting that households appear to subscribe to the health benefits of using modern fuels.

A related question is how does the income elasticity of residential energy consumption in LAC compare with other sectors? To provide a comparative view, Figure 4.4 presents the estimated income elasticities of energy consumption across sectors (residential, industrial, and transportation) as well as for total final energy consumption. The average income elasticities are higher for the industrial and transportation sectors – even higher than those of residential modern fuels presented in Figure 4.3. In the long run, a 1 percent increase in GDP per capita translates into approximately 0.9 percent higher energy consumption in the industrial sector. Correspondingly, in the transportation sector, the same increase in income translates into a 1.3 percent increase in energy consumption. To some extent, the higher elasticities in the transportation and industrial sectors highlight the cross-sector effects of higher household income on aggregate energy demand.

Income Elasticities Decrease as Income Levels Increase

The next question is whether (aggregate) energy-income elasticities are constant across income levels. To examine this question, we estimate energy consumption at different income levels based on a nonlinear parametric specification detailed in Appendix 2. The estimation is based on 104 countries for the period 1971–2013. The main results, presented in Figure 4.5, yield a concave curve that suggests that the elasticity decreases as a country's income rises. That is, energy demand increases with increases in income, but tends to peak at middle-to-high-income levels[9] and then gradually declines as income continues to increase. This concavity may be due to efficiency gains, which are more pronounced in developed countries.

Figure 4.5 also pins down the position of LAC countries with respect to all countries in the world in terms of per capita GDP. According to these estimations, LAC's stage of development coincides with an almost linear association between energy consumption and income, indicating its high dependence on modern energy sources. Furthermore, as LAC countries are spread along the middle-income level (blue area), it is likely that over the next few decades the region will move to the right and concentrate at the high-middle-income level, implying significant future increases in energy requirements.

The heterogeneity across countries may be better appreciated in Figure 4.6, which summarizes the income elasticity of modern fuel consumption by country income group and for the entire LAC region. This figure shows that while there is indeed significant heterogeneity within each income group, the estimated elasticities tend to decrease as the countries reach higher income levels, thus supporting the concavity observed in the previous figure.

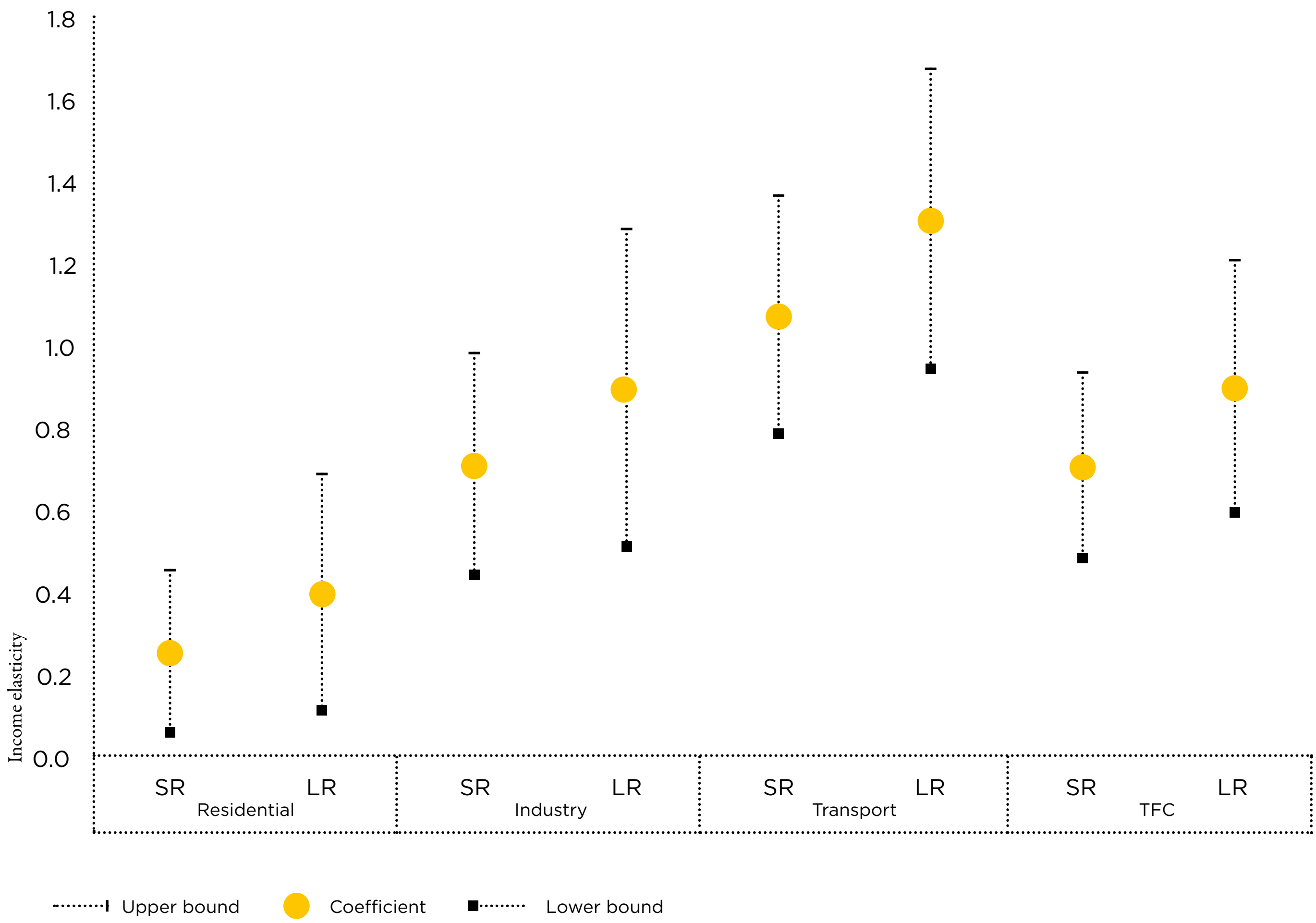
As analyzed before, the income elasticity of energy consumption depends on the type of fuel and sector. In the case of domestic energy (electricity and gas), income elasticity tends to decrease as income rises. However, in the case of transport fuels, income elasticity tends to increase along the country income classification. This pattern may have to do with increased car ownership and use that goes along with higher incomes. Table A2.2 in Appendix 2 provides the estimated income elasticities by sector.

The elasticity estimations presented in this chapter represent correlations between energy and income (both per capita) that are conditional on international oil prices and country-specific trends (see estimation details in Jimenez, Macedo and Yépez-García 2018). These estimations do not take into account any potential endogeneity between prices, income, or energy consumption. For example, as energy is an input to production, an exogenous shock in energy consumption could lead to a change in production (and energy demand) and therefore in income per capita. In this sense, the estimated elasticities show how energy use varies with income,

8. See Appendix 2 for further details on the methodology and complete results.

9 According to income-level classifications by the World Bank.

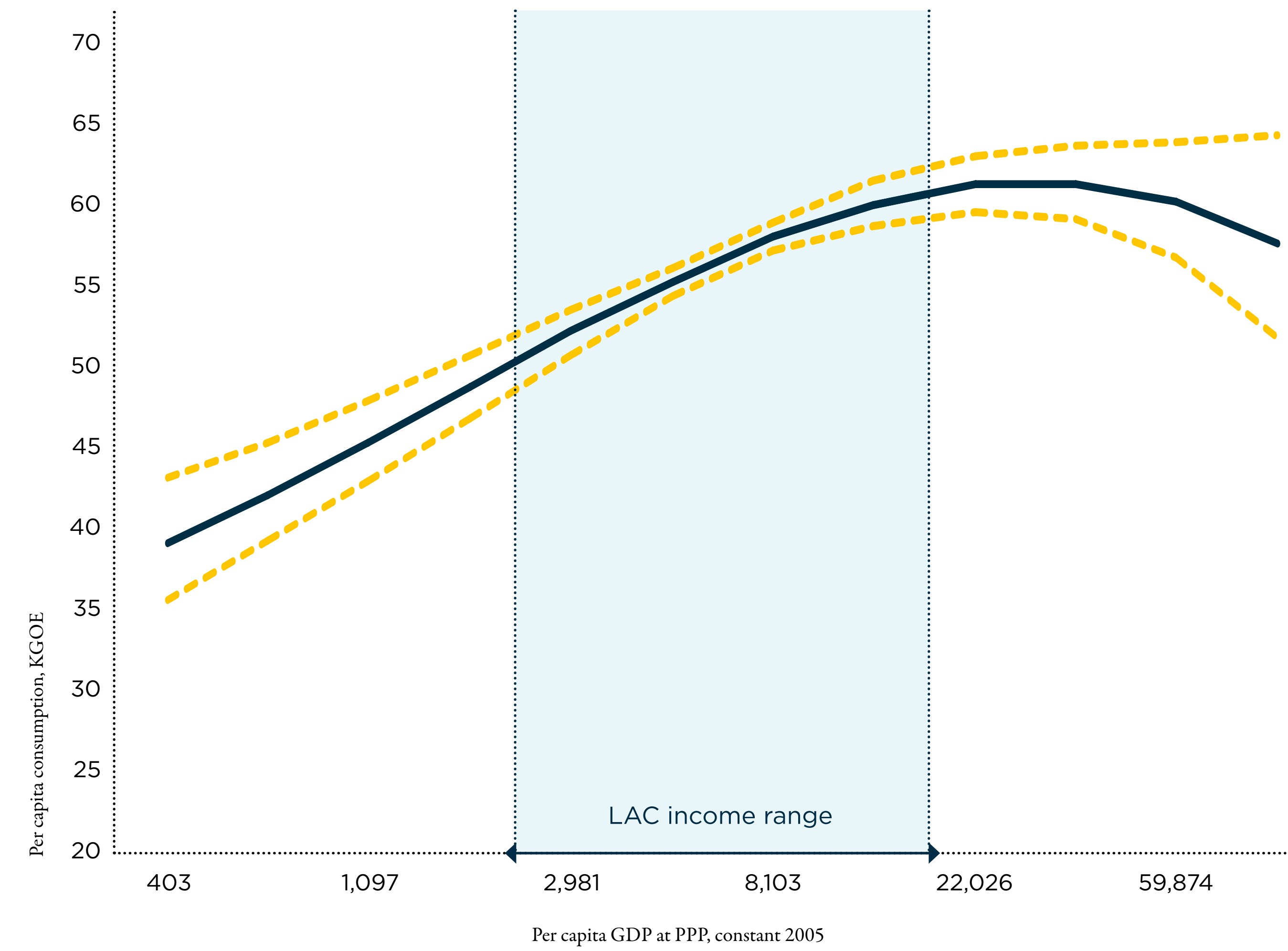
Figure 4.4: Short- and Long-Run Income Elasticities by Sector in LAC



Source: Authors' calculations based on data from the International Energy Agency.

Note: Upper and lower confidence intervals are at 95 percent. Estimated elasticities account for international oil prices, country-specific trends, and coefficient heterogeneity. See estimation details in Appendix 2. SR: short run; LR; long run; TFC: total final consumption.

Figure 4.5: Long-run Estimated Income Effect of Modern Energy on Consumption



Source: Authors' calculations based on data from the International Energy Agency.

Note: Scales are in logs. Dash lines represent confidence intervals at the 95 percent level. Estimations are based on 104 countries, including 22 in Latin America and the Caribbean (LAC). In-sample predictions. Estimated elasticities account for international oil prices, country-specific trends, and coefficient heterogeneity. See estimation details in Appendix 2. KGOE: kilograms of oil equivalent; PPP: purchasing power parity.

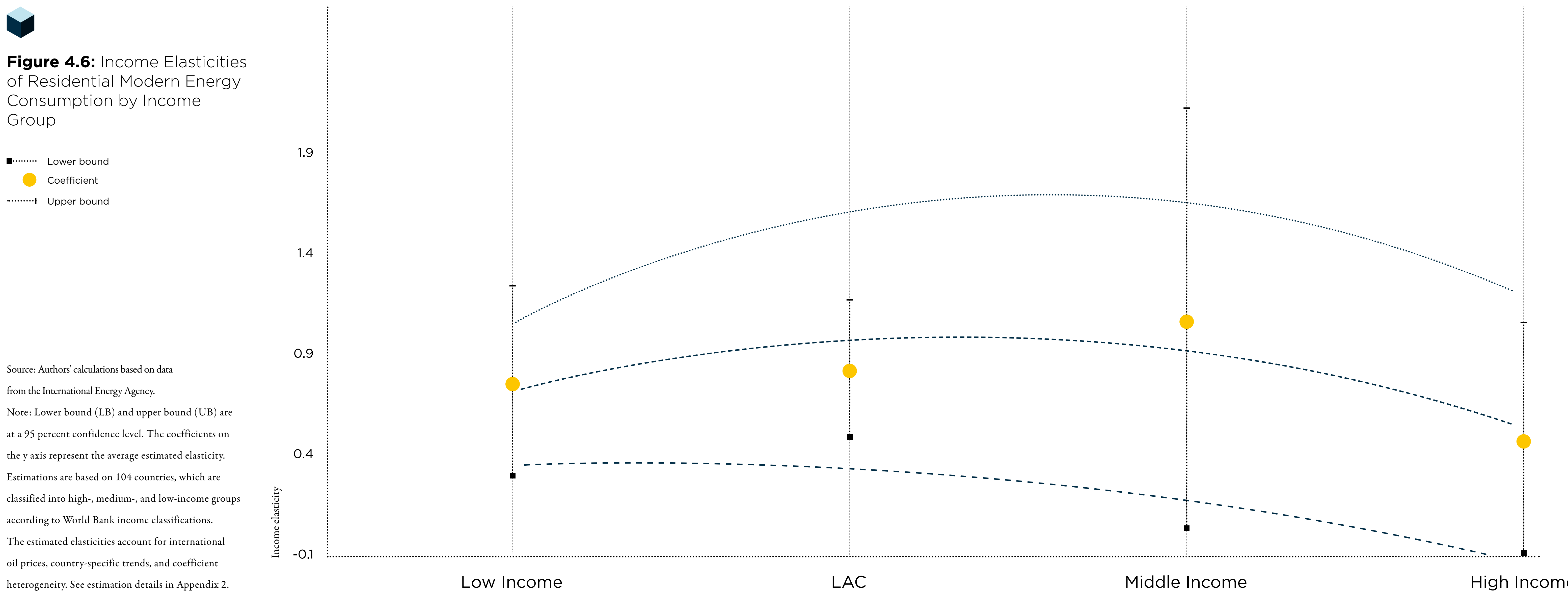
without any causal interpretation. With respect to the potential direction of a bias, Csereklyei and Stern (2015) calculate an upward bias on the order of 0.05 in the relationship between total energy use and GDP.

Beyond the estimation of causal parameters, the analysis of bidirectionality, or reverse causality, provides insights into the role of energy in income growth and economic development. One approach to studying this interrelationship is to test for Granger causality. Therefore, to complement our results, Appendix 2 presents the results of Granger tests for four estimation methods, indicating strong statistical causality between residential energy consumption and income (both per capita). The results suggest that there is indeed reverse causality, so increasing income per capita would raise energy consumption in the residential sector, which would in turn lead to higher income per capita. The literature in this regard is inconclusive, and this exercise just aims to reveal such feedback effects in our sample.

It is important to emphasize that the income elasticities presented in this study are estimates based on country-level data. As with all empirical analyses, these estimations may vary across methodologies, samples (cross-sectional versus panel data), and units of observation (households, firms, countries, etc.). For developing countries, more detailed analyses are constrained by the lack of information on key variables, such as energy prices, and the availability of micro-data on energy consumption or expenditures. While our estimated elasticities lie within the estimates found in the literature (see Table 1.1 in Chapter 1), the nature of the data imposes limitations on a better understanding of the underlying behavior of LAC households in terms of energy consumption.

In particular, at the microeconomic level, energy consumption figures are not universally available for LAC countries. However, the strong relationship between energy consumption and income has been documented on the basis of some case studies (Navajas 2009; Foster, Tre,

Figure 4.6: Income Elasticities of Residential Modern Energy Consumption by Income Group



Source: Authors' calculations based on data from the International Energy Agency.

Note: Lower bound (LB) and upper bound (UB) are at a 95 percent confidence level. The coefficients on the y axis represent the average estimated elasticity. Estimations are based on 104 countries, which are classified into high-, medium-, and low-income groups according to World Bank income classifications. The estimated elasticities account for international oil prices, country-specific trends, and coefficient heterogeneity. See estimation details in Appendix 2.

and Wodon 2000). Although those studies do not allow for comparisons across countries, or for a comprehensive examination of fuel use at the regional level, they do show how increasing income levels are strongly associated with different patterns and levels of household energy consumption. Box 4.1 examines a rich cross-sectional survey from Argentina, and shows that domestic energy consumption tends to increase with income to the extent that the total consumption of modern fuels is concentrated in the top two income quintiles, which together represent almost 60 percent of electricity consumption, 50 percent of total natural gas consumption, and 80 percent of total gasoline consumption.

Conclusions

With rising income, energy consumption increases, and the type of fuel utilized shifts toward modern and more efficient fuels. This empirical fact has been clearly observed in the residential sector over the past four decades, where demand for electricity and gas has grown at higher rates than in the transport and industry sectors, replacing demand for dirty fuels. With this process, the income elasticity of residential energy demand evolves, forming an inverted U-shape along the world income distribution. This suggests that household energy use will find a satiation point beyond which net energy savings will begin to reduce per capita energy consumption at higher income levels. The pattern prevails in different regression specifications.

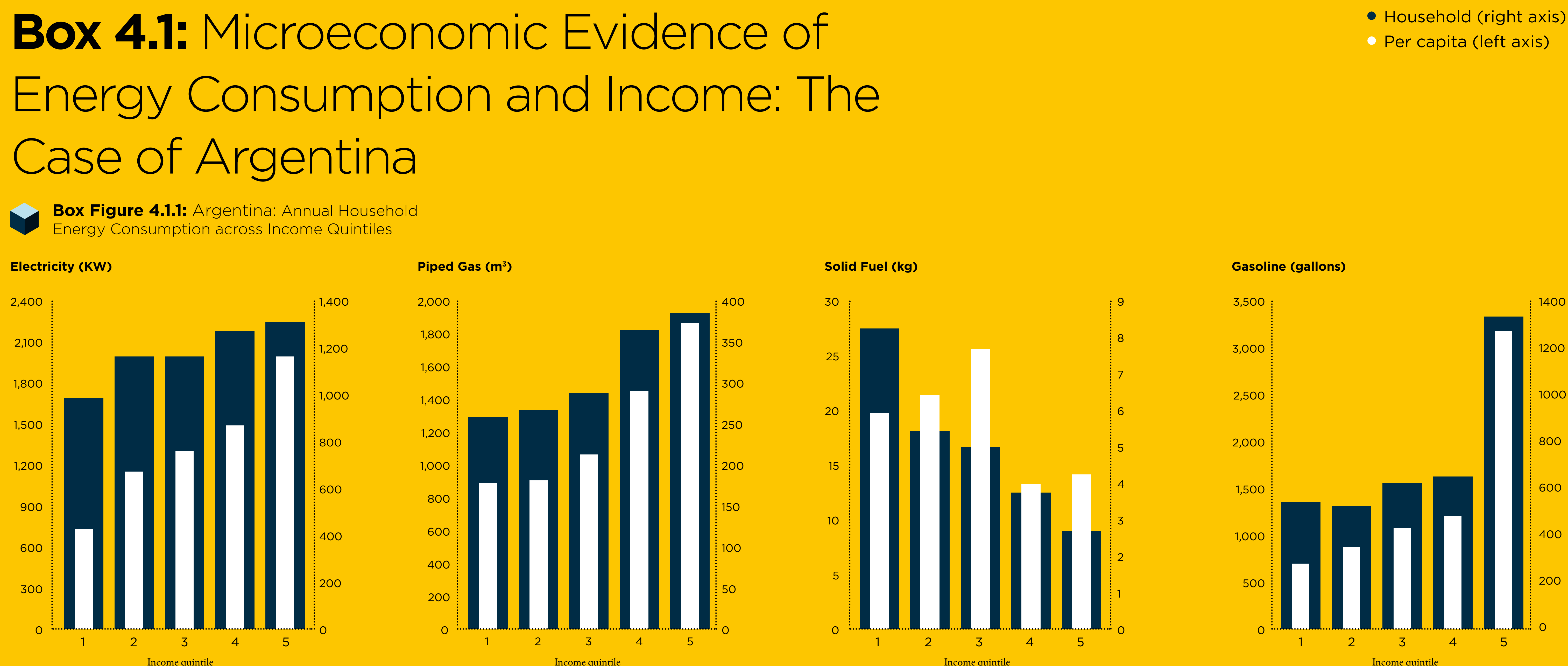
This chapter also highlighted the importance of taking country heterogeneity into account and distinguishing between energy sources when analyzing the relationship between income and energy use, showing that economic growth is fueled by modern energy sources, rather than traditional or transitional fuels. The results are consistent with previous studies that have emphasized the increasing energy demands of the developing world. In particular, LAC is at a stage of economic development where it is highly dependent on modern fuels, implying a significant need for energy infrastructure to sustain its path of economic growth.

At the same time, the results suggest that the demand for traditional fuel behaves as if such fuels are an inferior good (that is, decreasing in income), meaning that households attach significant value to the health benefits of switching to modern fuels. Because in poor countries a substantial share of residential energy use is composed of dirty fuels, finding ways to help poor families access and afford modern energy sources is an important policy challenge. Programs facilitating access to modern energy sources have been effective at fostering fuel switching. On the supply side, development of a diversified sustainable energy matrix may reduce energy costs and help ensure the stream of energy services. Energy efficiency and conservation measures may also reduce costs while promoting energy savings.

New evidence shows that **as a household in LAC gets wealthier, it begins to replace traditional fuels such as biomass with transitional and modern fuels like electricity and natural gas.**

Box 4.1: Microeconomic Evidence of Energy Consumption and Income: The Case of Argentina

Box Figure 4.1.1: Argentina: Annual Household Energy Consumption across Income Quintiles



Source: National Expenditure Survey, 2012.

Note: All values are expanded using the population factor.

Argentina is one of the few countries in Latin America and the Caribbean to collect data on household consumption in its periodic national expenditure survey. This valuable information allows for the characterization of energy consumption across income groups and the estimation of price and income elasticities based on available information at the household level. Box Figure 4.1.1 shows the annual quantities of energy consumed by each income quintile.

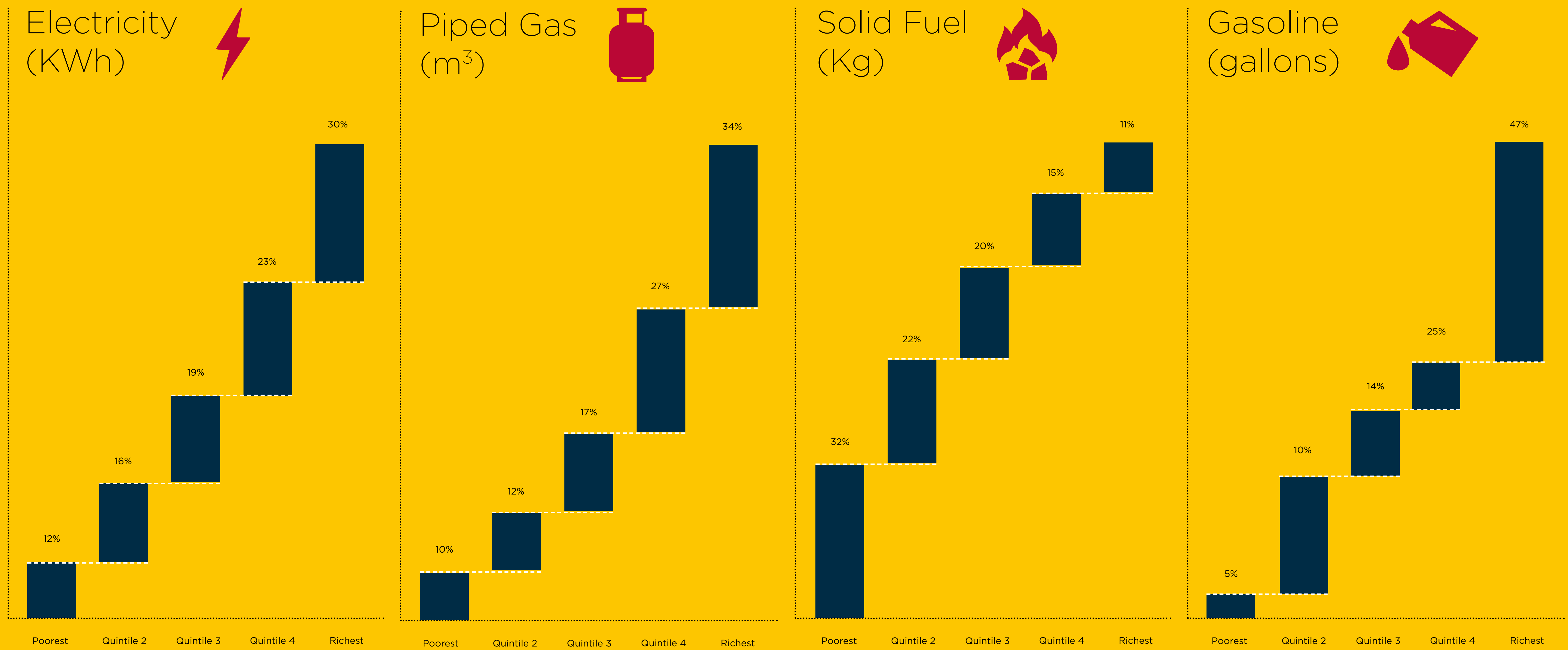
As expected, household consumption of electricity, piped natural gas, and gasoline (blue bars) increases with income, a relationship that is more pronounced after accounting for household size (orange bars). Among these fuels, gasoline consumption increases most in the highest income quintile. In contrast, consumption of biomass tends to decrease with improvements in household economic conditions. However, the patterns are less clear in per capita terms, mainly because of the high variance in self-booked consumption.

In terms of how the aggregate consumption of fuels is distributed among household income groups, better-off households tend to account for most of the national consumption of modern energy, particularly in the case of transport fuels (Box Figure 4.1.2). The richest quintile accounts for 30 percent of total electricity use, 34 percent of piped gas use, and almost half of gasoline consumption in the household sector. In contrast, the poorest income groups consume 12 percent of total electricity, 10 percent of piped gas, and 5 percent of gasoline. Given such a low consumption level of modern fuels, poorer households seem to meet their energy needs mostly with dirty fuels, with the first (poorest) quintile accounting for 32 percent of national consumption of solid fuels.

Box Figure 4.1.2: Argentina: Percentage Structure of National Aggregate Household Energy Consumption across Income Quintiles

Source: National Expenditure Survey, 2012.

Note: All values are expanded using the population factor.



Box Table 4.1.1:
Argentina: Cross-Sectional Regressions of Energy Consumption

Variable	Ln (Electricity Consumption)	Ln (Pipe Gas Consumption)	Ln (Gasoline Consumption)
Ln (household income)	.1714***	.1188*	.3048***
Ln (fuel price)	-.896***	-.901***	-.5739***
Observations	12,099	5,099	7,930
Adjusted R^2	0.9047	0.7534	0.4137
F-stat	3671	730.3	115

Source: Jimenez Mori (2017c)

Note: All regressions include as covariates household size, ownership of cellular phones, motor vehicles, and air conditioners; and province fixed effects. Regressions are weighted using the population factor. * Significant at the 10 percent level; ** Significant at the 5 percent level; *** Significant at the 1 percent level.

The data set allows for measuring households' responses to price and income variations, which is of interest to businesses and policymakers alike. To investigate these responses, we regress the log of fuel consumption on household income and fuel prices, controlling for household characteristics such as ownership of cellular phones, motor vehicles, and air conditioners, as well as account for provincial fixed effects. For the exercise, fuel prices were calculated implicitly from the booked expenditures on each type of fuel, and only for electricity, piped natural gas, and gasoline. Prices for solid fuels were not calculated because booking on their consumption is less reliable. For most household members at lower income levels, information about the actual quantities of and expenditures on those types of fuels tends not to be representative of actual expenditures and consumption. The estimated coefficients are interpreted as cross-sectional elasticities for 2012 (survey year). This last point is important, since price variation may be reduced because we are not including the time dimension. Still, in the case of Argentina, there is great variation in production technologies for both fuels and independent providers, so significant price variations are expected.

A summary of the estimates is presented in Box Table 4.1.1. Given that the estimates can be directly interpreted as elasticities, we find that a 1 percent increase in income translates into greater consumption of approximately 0.17 percent for electricity, 0.12 percent for piped natural gas, and 0.30 percent for gasoline. This suggests that among these fuels, gasoline consumption responds the most to changes in household income. With regard to price elasticities, those for the consumption of electricity and piped natural gas are similar, at around -0.90, while the price elasticity for gasoline is lower, at around -0.57. In other words, domestic fuel consumption is more sensitive to price changes than transport fuel consumption.

Part III

A Microeconomic View of Household Energy Expenditures

Chapter 5
A Distributive Overview of Household Energy Expenditures

Previous chapters have shown the key role of income in determining energy consumption patterns across countries and fuel types, along with the growing relevance of modern fuels in economies in Latin America and the Caribbean (LAC). This chapter extends the analysis to microeconomic data on household energy expenditures, emphasizing energy consumption as an essential component of household budgetary decisions. The attributes of household energy expenditures across income groups are a key input for the analysis and design of energy policies related to pricing and affordability. Particular attention is paid to the fraction of energy expenditures relative to household disposable income, which constitutes a widely used indicator of energy poverty and vulnerability to shocks in energy prices.

In addition to domestic fuels, the analysis incorporates expenditures on transport fuels used for private (household) consumption and covers the complete range of fuels used by households. As in the previous chapters, domestic energy includes electricity, natural gas, and solid and liquid fuels used in the home.[1] Transport fuels for private household transportation include gasoline, diesel, biofuels, natural gas, and liquefied petroleum gas (LPG). Since not all surveys provide the same level of disaggregation, domestic fuels other than electricity and gas are grouped into "other fuels." This classification allows for maintaining the distinction between modern fuels and traditional and transitional fuels grouped under the label "other fuels." Similarly, all fuels for private transportation are labeled "transport fuels."

The two main analytical categories in this chapter are income level and geographic area (urban and rural). While it is clear that income plays a role in increasing the ownership of household assets (such as cellular phones, refrigerators, computers, and automobiles), to a great extent it is geographic location that determines households' access to modern energy sources such as electricity and natural gas. Access, in turn, determines consumption and expenditures for those specific fuels.

This and the subsequent chapters in this part of the book analyze nationally representative household surveys from 20 LAC countries. The selected surveys include detailed expenditure modules, which allows for calculating total household expenses and expenditures in specific items that are comparable across countries. In each country, we use data from the last available survey (mostly 2014). However, in cases where the most recent survey corresponds to an earlier year, we account for growth in household expenditures in order to provide values as of 2014. This extrapolation does not affect the household expenditure structure. (See Appendix 1 for details on the data.)

Following Advani et al. (2013) and EIA (2014b), we use total annual household expenditures as a proxy for household income.[2] The expenditure categorization is presented in Table 5.1. In general, household spending tends to be more stable over time, and to reflect better household consumption and well-being, compared with monetary income. Moreover, in the case of the poorest groups, income may be difficult to capture and measure. At the same time, labor income may not account for all expenditures, and consumption may also be funded by remittances, subsidies, and other sources.

Following Bacon, Bhattacharya, and Kojima (2010) and Advani et al. (2013), energy expenditures and their shares of total expenditures are computed across all households, regardless of whether they consume a given fuel (or item). This allows for examining the structure of average energy expenditures taking into account all energy sources. Also, such averaging across households is more useful in terms of policy formulation. Nonetheless, it is important to note that this approach may underestimate the budget weight of expenditures on specific fuels in some household segments. For instance, this may be the case in countries with high rates of electricity theft, where access but zero expenditure would lead to underestimating energy expenditures.[3] These caveats call for careful interpretation of the results.

Energy in the Annual Budget of Latin American and Caribbean Households

The breakdown of household budgetary structures is useful when assessing the potential distributional effects of price shocks and/or policy reforms. Such analysis requires distinguishing between different income groups and identifying the corresponding weights of energy expenditures compared with expenditures on other goods and services. In order to understand the importance of energy expenditures in household consumption, we calculate the annual household budget structure of 17 LAC countries by income quintiles. The average household allocates around 8 percent of its total annual expenditures to energy, including domestic energy and fuels for private transportation. When adding energy and fuels together, the overall energy expenditure share remains roughly stable along the income distribution, from the poorest consumers (where the share is approximately 8.9 percent) to the richest income groups (where the share is approximately 7.4 percent).

In line with the results from the analysis on energy consumption, the composition of energy expenditures is markedly different across income quintiles. Domestic fuels constitute most of the energy expenditures of the poorer groups, and this share tends to decrease as household income increases. That pattern is consistent for all domestic energy sources: electricity,

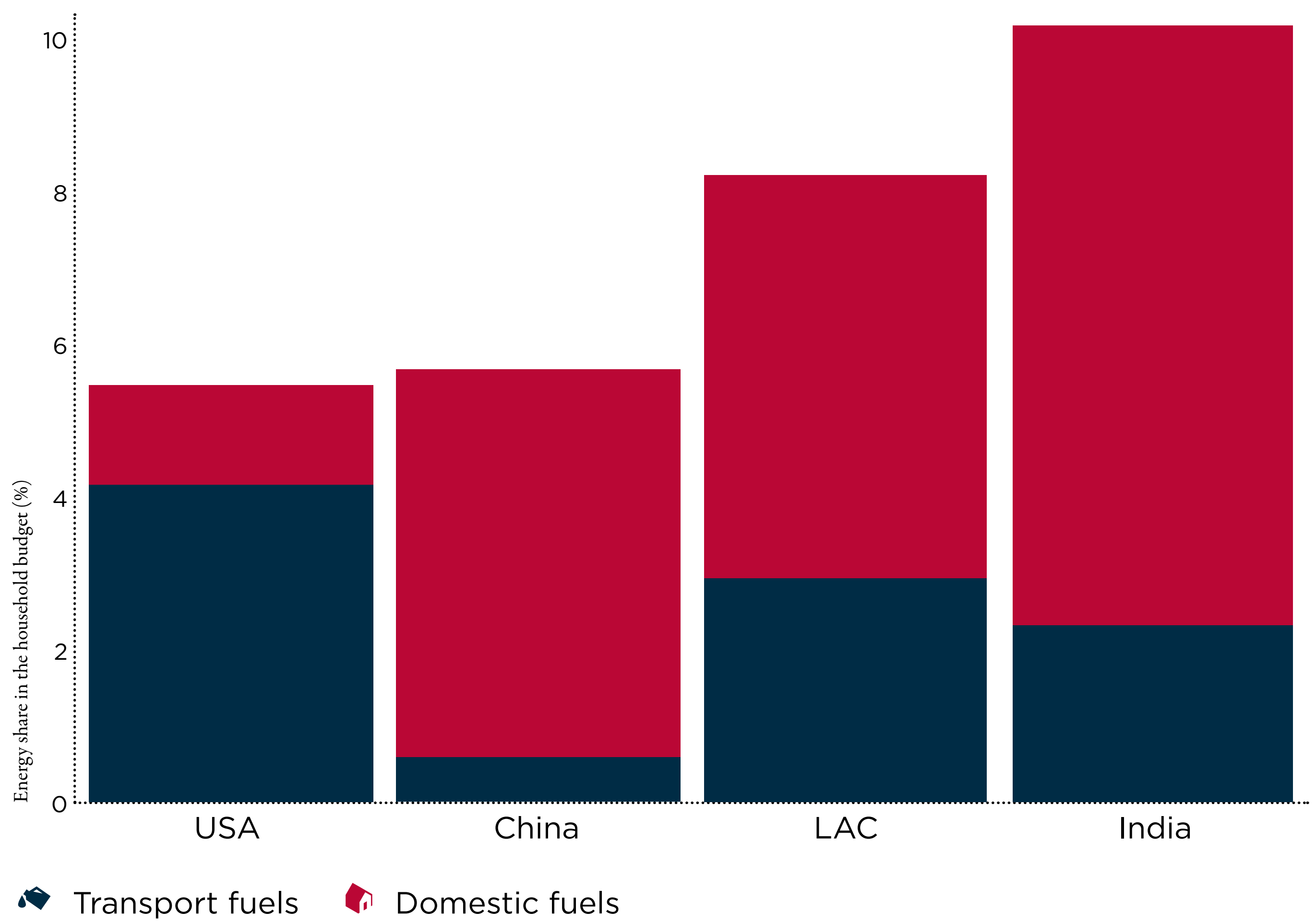
1. Specific solid and liquid fuels may vary among countries and surveys. Solid fuels mainly include firewood and charcoal. Liquid fuels include kerosene and alcohol.

2. Current expenditures can also be used, which will lead to higher shares of energy commodities. In this case, it means excluding the categories of "household equipment" and "transport–others" from total household spending.

3. Although these magnitudes also come from household surveys, they may not be perfectly comparable with our estimates because of different procedures in harmonizing the expenditure items. However, they provide a general indicative reference for the results presented here.

4. An important caveat in accounting for the monetary values of other fuels, such as biomass, is that they do not tend to have a market value because they are usually self-collected. Therefore, a monetary perspective on the consumption of traditional fuels may lead to underestimation of actual consumption. This is indeed an important drawback of the present analysis. Previous chapters showed that traditional fuels constitute a significant part of residential energy consumption, so figures presented in this chapter with regard to traditional fuels may be underestimated. In addition, the collection of traditional fuels takes up an important amount of household members' time, representing a significant opportunity cost, which is also not accounted for in the present study.

Figure 5.1: Latin American and Caribbean Energy Share in the Global Context



Sources: Data for China and India come from World Bank (2010); data for the United States are from EIA (2014b); and data for Latin America and the Caribbean (LAC) are the authors' estimations.

gas, and other fuels.[4] On the other hand, the consumption of transportation fuels increases with income in absolute and in relative terms, going from 1.3 percent in the first (poorest) quintile to 4.9 percent in the fifth (wealthiest) quintile, where it makes up the largest part of energy expenditures.

To put these shares in context, Figure 5.1 compares the share of energy expenditures in LAC with those of some developed and developing countries from other regions. In 2013, in the United States, the average household spent roughly 5 percent of its disposable income on energy, including both domestic energy and transport fuels (EIA 2014b). This overall share is similar to that of China, although with a markedly different composition, as in China most energy expenditures are on domestic energy. At the other end of the spectrum, India is among the countries where energy expenditures constitute a higher percentage of the average household budget, also largely concentrated on domestic fuels.[5]

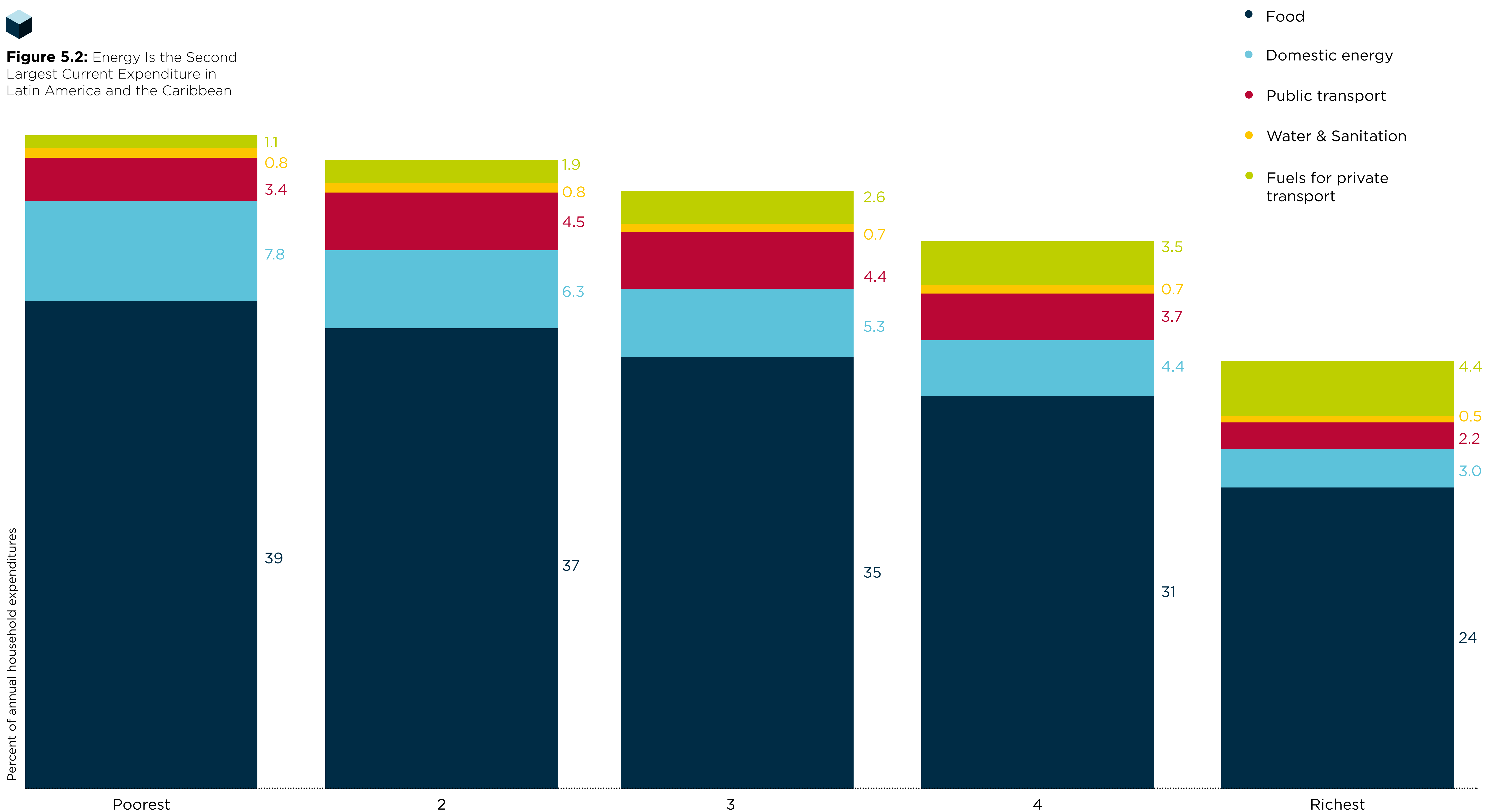
The relevance of energy-related expenditures becomes clear when considering current expenditures, which are recurrent expenditures realized on a monthly or bimonthly basis. Figure 5.2 shows that direct energy expenditures constitute the second largest budgetary component after food for all income groups. This figure also shows that low-income households spend the highest share of income on energy; mainly on electricity and natural gas.

This budgetary structure also provides a good indication of the vulnerability of families to changes in energy prices. These expenditure shares may be interpreted as (short-run) budget multipliers for variations in energy prices. Hence, the distributional effects of price variations depend on the type of fuel and the income group. In line with the literature, the weight of energy commodities on household budgets indicates that energy price shocks have a greater effect on the living costs of the poorest households. For instance, in the case of modern domestic energy sources (electricity and natural gas), a 10 percent increase in prices for these energy sources would translate into a 0.7 percent increase in the total expenditures of the poorest households. Put another way, all else being equal, the poorest households would need to increase their income by 0.7 percent to cope with the energy price increase. In contrast, in the richest income group, a 0.3 percent increase in expenditures would be needed to keep their energy purchases constant for the same price increase. The impact on an average LAC household would be around 0.52 percent.

With respect to transport fuels, the effect of price changes tends to be more pronounced in the higher income segments of the population. In this case, a 10 percent increase in gasoline prices would translate into expenditure increases equivalent to 0.1 percent in the poorest income quintile and 0.44 percent in the richest quintile, while the average impact would be around 0.27 percent. Overall, population-wide, households are particularly vulnerable to shocks in electricity and natural gas prices.

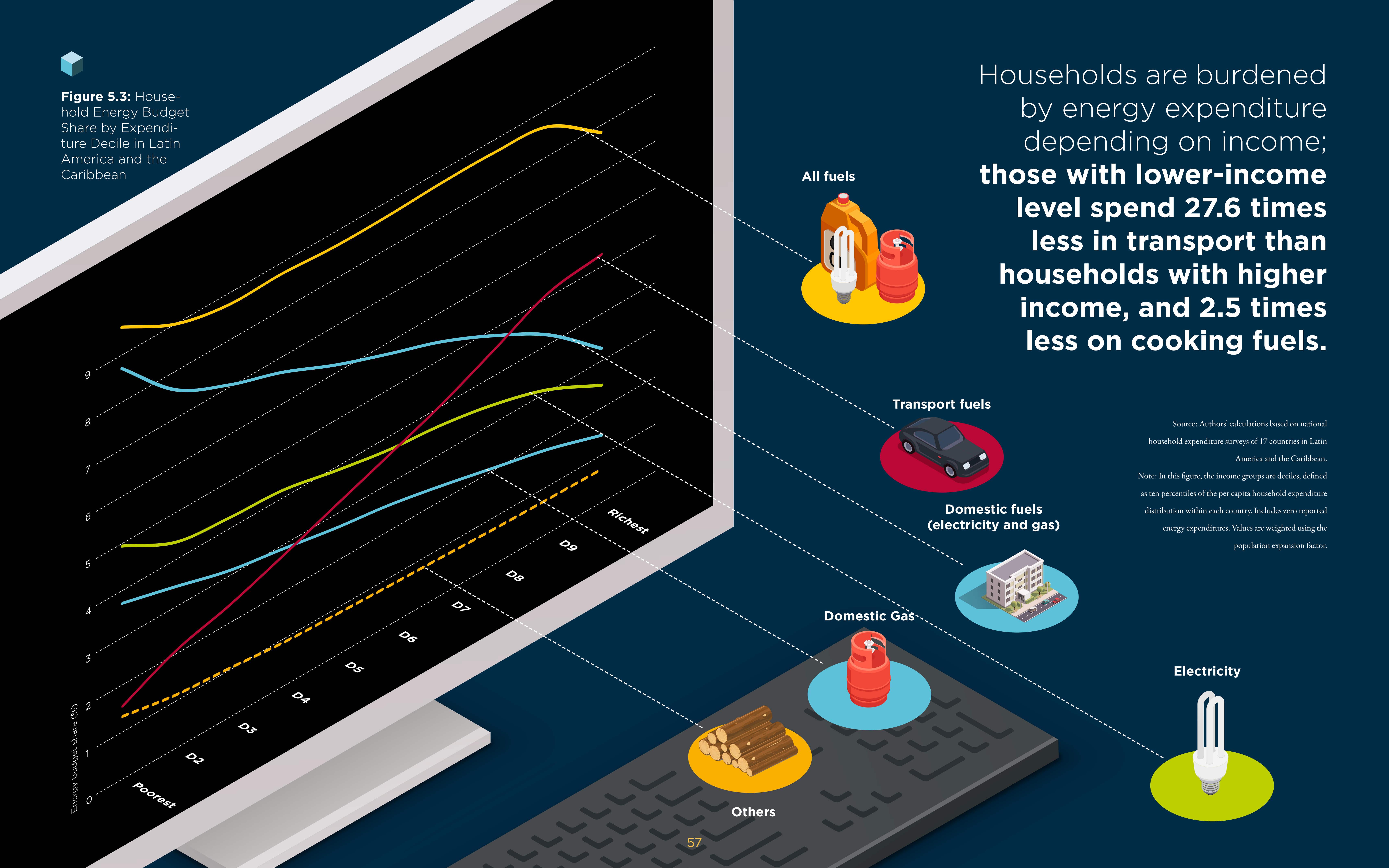
5. Although these magnitudes also come from household surveys, they may not be perfectly comparable with our estimates because of different procedures in harmonizing the expenditure items. However, they provide a general indicative reference for the results presented here.

Figure 5.2: Energy Is the Second Largest Current Expenditure in Latin America and the Caribbean



Source: Authors' calculations based on national household expenditure surveys of 17 countries in Latin America and the Caribbean.

Figure 5.3: Household Energy Budget Share by Expenditure Decile in Latin America and the Caribbean



Households are burdened by energy expenditure depending on income; **those with lower-income level spend 27.6 times less in transport than households with higher income, and 2.5 times less on cooking fuels.**

Source: Authors' calculations based on national household expenditure surveys of 17 countries in Latin America and the Caribbean.

Note: In this figure, the income groups are deciles, defined as ten percentiles of the per capita household expenditure distribution within each country. Includes zero reported energy expenditures. Values are weighted using the population expansion factor.

Rather than by quintiles, these ratios can be plotted along the whole income distribution. Figure 5.3 plots these energy shares by decile. In contrast to energy expenditure in levels – where all expenditures increase in income – the associated budget shares for electricity and gas tend to decrease toward the right (wealthier end) of the income distribution. Only the budget share of transport fuels increases, reaching a greater share than that of domestic energy. That is, while the budget share of domestic fuel decreases along the income distribution, the total energy budget share remains roughly stable, a result of the increasing budget allocation for transport fuels. These interrelations between different types of energy seem to explain the S-shaped curve in total energy (bold blue line), portraying dissimilar energy spending patterns across income groups.

Based on these patterns, electricity and domestic gas may be considered necessity goods, while spending on transport fuels seems to have the characteristics of a luxury good. As far as affordability concerns, these are concentrated in changes in expenditures on electricity and gas in the lower income deciles. Together, gas and electricity constitute around 8 percent of household annual total expenditure in the first decile, which is the most vulnerable of population segments.

In general, the main lesson is that each fuel has a very distinctive weight in the energy portfolio of each income group, and thus provides an indication of the relative vulnerability of families to changes in energy prices. For example, modern domestic energy sources (electricity and natural gas) behave like food, suggesting that both are normal and also necessity goods. Solid and liquid fuels that are used at home behave as inferior goods in the sense that households replace them with modern energy sources once their income allows them to do so. Expenditures on transport fuels behave similarly to expenditures on leisure activities to the extent that they become the main type of fuel expenditure among higher-income groups, with both increasing alongside income. These patterns repeat in any breakdown of the data regardless of the specific countries under review (see Table 5.1 and Appendix 3 for further disaggregation by country).

Household Energy Expenditures Increase with Income, but Unevenly

Figure 5.4 shows energy expenditures in U.S. dollars (panel a) and as a share of total household expenditures (panel b) by income group and geographic location. On average, while expenditure on energy increases along the income distribution, its share tends to decrease. However, the composition of the patterns is noticeably different across fuels. Transport fuel expenditures show a greater increase in absolute terms and as a share, ranging from around 1 percent of household expenditure (US$50 per year) in the poorest quintile to 4 percent of household expenditure in the richest quintile (US$1,380 per year). In contrast, expenditure shares on domestic fuels decrease from around 7.8 percent (US$295) in the poorest quintile to around 3 percent (US$750) in the richest quintile. That is, the main energy expenditures in poor households are on electricity and natural gas, while in the richest households transport fuels make up a significant share of energy expenditures. The share of transportation expenditures increases noticeably along the income distribution, becoming the largest energy expenditure category in the richest families, greater than electricity and natural gas combined.

This analysis reinforces the type of goods that each specific fuel represents. Absolute energy expenditures increase with income, but the share consistently decreases in the case of electricity and natural gas, implying that these categories may be considered normal goods. However, the share of transport fuels increases to the right (the wealthier side) of the income distribution, which indicates that such fuels have the characteristics of luxury goods. In contrast, expenditures on other fuels decrease with rising income levels, both in absolute terms and as a share of total income, indicating that they are inferior goods. These patterns are systematic across countries, and they are congruent with the findings discussed in Chapters 2 and 3. See Table 5.1 for energy shares across economic segments by country.

These patterns also hold when energy expenditures are broken down into urban and rural locations. However, it is important to note that absolute levels of energy expenditures are significantly lower for rural households, whose overall energy shares are slightly smaller than those observed in urban areas, for all income groups. The exception is transport fuel, for which rural dwellers tend to allocate a higher share of their energy expenditures (Figure 5.4, panel b). See Appendices 4 and 5 for energy expenditures and energy shares across areas and economic segments by country.

Average Household Energy Expenditures by Country

In monetary terms, the LAC region's average household energy expenditures are around US$1,000 per year. As observed in Figure 5.5, there is significant heterogeneity in these expenditures across countries, with total energy expenditures ranging from around US$330 in Bolivia to US$4,800 in The Bahamas. The two main components of energy expenditures are transport fuels (50 percent) and electricity (34 percent), while the share of gas (which averages 15 percent) varies considerably across countries. This range does not include El Salvador and Barbados because the surveys in these countries do not collect information on transport fuels (or other fuels in the latter country). See Appendix 4 for details of energy expenditures across areas and income quintiles by country.

It is relevant to recall that these energy expenditures – and their corresponding shares – greatly depend on energy prices. Therefore, there may be differences in such indicators in countries where those prices have changed recently and should not be extrapolated to recent years. In particular, the downward trend in international oil prices could have considerable effects on energy expenditure in net importer countries. For example, Chile and The Bahamas are highly dependent on fossil fuels for electricity generation, and consequently, they have lately experienced reductions in electricity rates, so more recent expenditures could be lower than those presented in Figure 5.5.

Figure 5.4: Composition of Latin American and Caribbean Energy Expenditure by Income Quintile

- Electricity
- Others
- Gas
- Transport fuels

Source: Authors' calculations based on national household expenditure surveys of 17 countries in Latin America and the Caribbean (LAC).

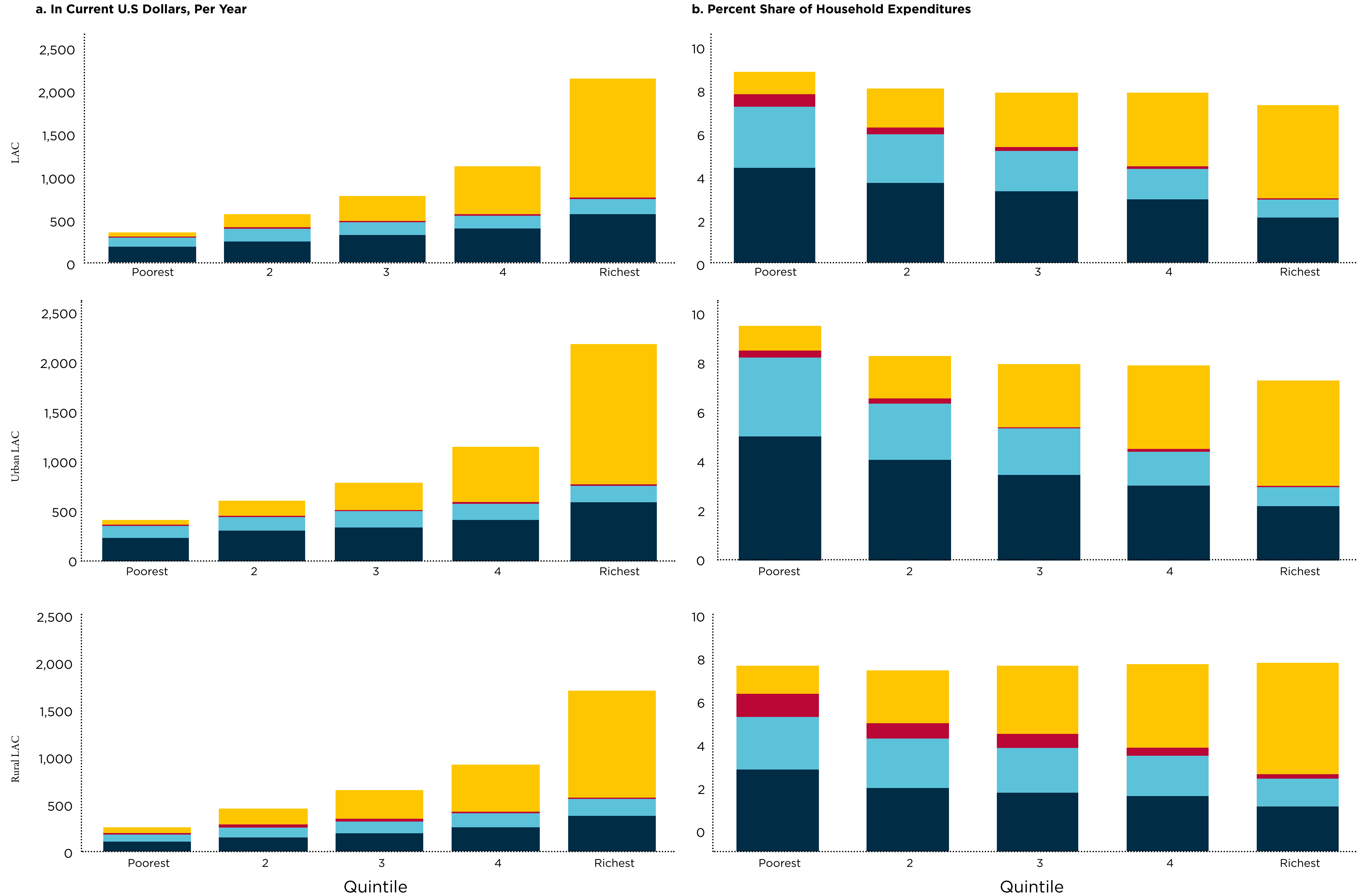
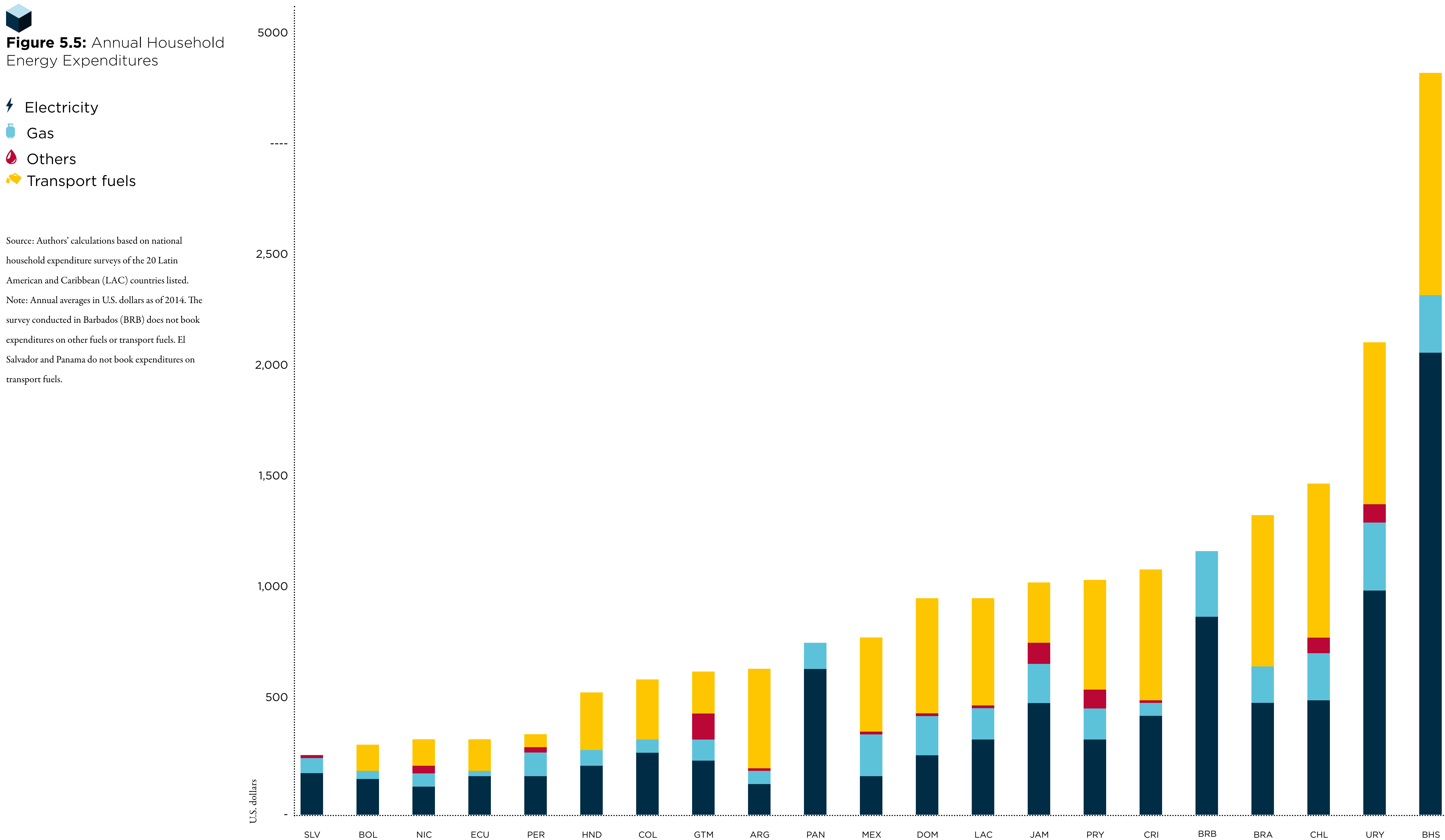


Figure 5.5: Annual Household Energy Expenditures



Source: Authors' calculations based on national household expenditure surveys of the 20 Latin American and Caribbean (LAC) countries listed.

Note: Annual averages in U.S. dollars as of 2014. The survey conducted in Barbados (BRB) does not book expenditures on other fuels or transport fuels. El Salvador and Panama do not book expenditures on transport fuels.

Share of Household Energy Expenditures by Country
Energy shares vary considerable by country, ranging from 2.9 percent in Ecuador to around 13 percent in Uruguay (Figure 5.6). Notably, in countries where electricity prices are higher (Barbados, Chile, Jamaica, The Bahamas, and Uruguay), expenditures on electricity and their corresponding shares tend to be higher, indicating some degree of inelasticity to price changes. This finding is also consistent with previous documented patterns suggesting that electricity is a necessity good. See Appendix 5 for details of energy shares across areas and income quintiles by country.

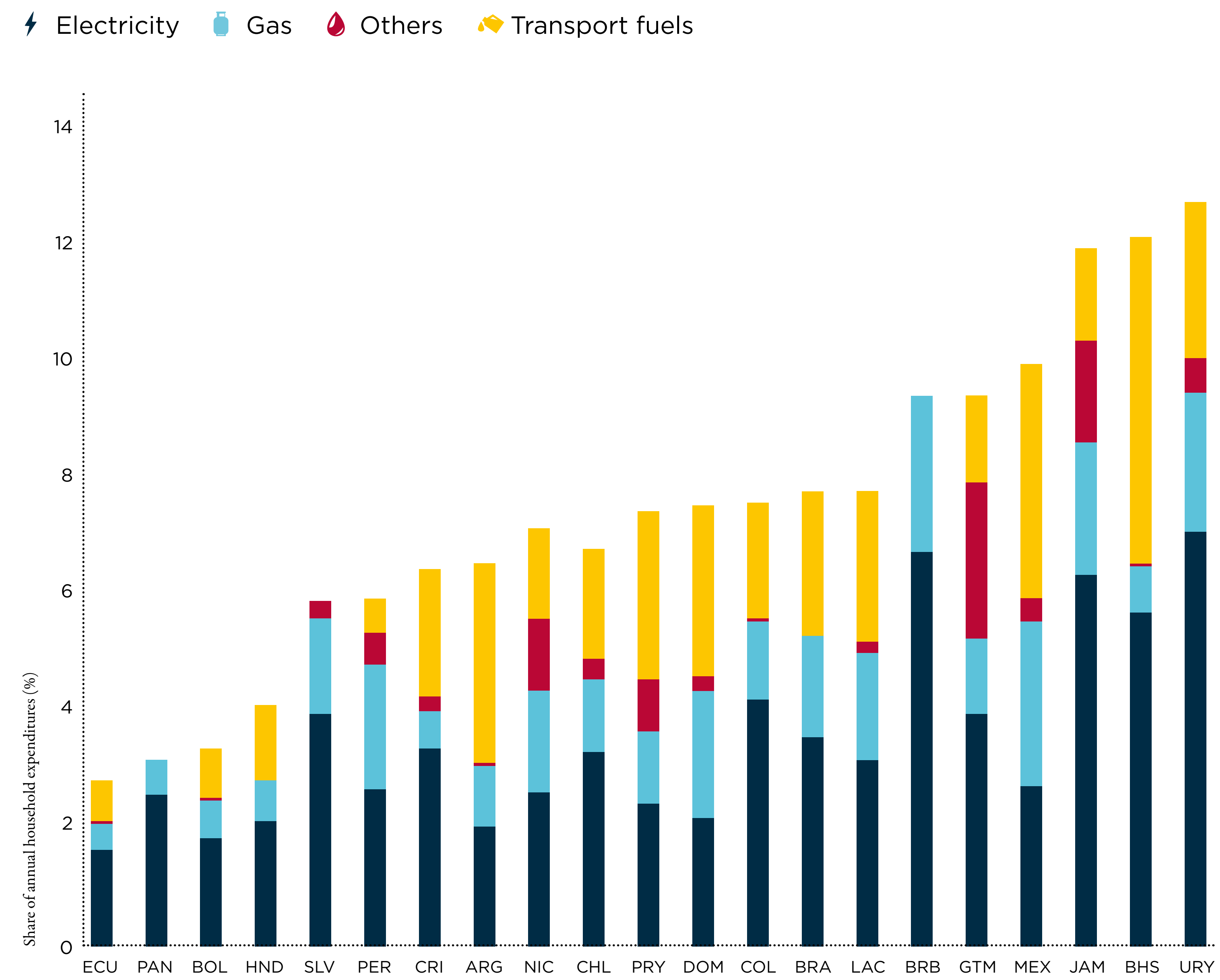
The expenditure share of domestic gas ranges from around 0.5 percent in Ecuador to around 2.7 percent in Barbados, and 2.9 percent in Mexico. However, it is important to emphasize that expenditures depend on the availability of the fuel, and in the case of natural gas, availability may be a severe restriction. This is particularly the case in rural areas, where distribution networks are scarce, or fuels may be priced higher because of transportation costs, potentially leading to affordability problems. Both issues limit the use of natural gas, which is one of most widespread and cleanest fuels for cooking and heating.

Other domestic fuels have heterogeneous expenditure shares across countries. Regardless of the prevalence of biomass in the residential sector, as observed in Chapters 1 and 2, expenditures on these fuels are low in most LAC countries, and their use is concentrated in relatively low-income countries such as Guatemala, Honduras, Jamaica, Nicaragua, and Paraguay. However, the low weight of biomass in expenditures may be due to the fact that household members typically collect biomass rather than purchase it. Thus, the recording of biomass use in expenditure surveys may not reflect the actual share of energy consumption. As seen in Box 4.1 in Chapter 4, even in a relatively high-income country such as Argentina, biomass makes up a substantial share of domestic energy consumption, a fact that is not reflected in the corresponding expenditures.

Cooking fuels constitute one of main components of domestic energy consumption, and natural gas and biomass represent the most important energy sources in that regard. Indeed, on average, the main cooking fuels for households are domestic gas (used by around 80 percent of households in LAC), and firewood (used by around 17 percent of households).[6] In lower income groups and rural areas, the percentage of the population still relying on less efficient and dirtier fuels is even higher. In fact, the use of firewood is higher than 60 percent in the first (poorest) income quantile in rural areas. Geographic location and income explain most of the use of traditional fuels for cooking in LAC. As will be shown in Chapter 6, after accounting for location and income group, the share of rural households using dirty fuels goes from around 63 percent in rural households in the poorest quintile to around 1 percent in households in the richest (fifth) income quintile. Even at the highest income quintile, the prevalence of biomass as a cooking fuel is significant (15 percent) in rural areas. Although to some extent cultural factors may explain the use of firewood, extensive evidence indicates that the relative availability and affordability of energy sources are determinants of the adoption of cleaner fuels (Masera and Navia 1997; Foell et al. 2011).

6. Authors' calculations based on national household surveys.

Figure 5.6: Energy Expenditure Shares



Source: Authors' calculation based on national household expenditure surveys of the 20 Latin American and Caribbean (LAC) countries listed.

Note: Barbados (BRB) does not book expenditures on other fuels or transportation fuels. El Salvador and Panama do not book expenditures on transport fuels.

Table 5.1: Table 5.1: Energy Expenditure Structure by Income Group by Type of Fuel (as a percentage of total household expenditures)

		Quintile				
Country		Poorest	2	3	4	Richest
Argentina (ARG)	**Energy**	**7.9**	**7.1**	**6.3**	**6.8**	**5.8**
	Electricity	3.8	2.5	1.8	1.5	0.9
	Gas	2.0	1.2	1.0	0.7	0.5
	Others	0.1	0.1	0.1	0.0	0.0
	Transport fuels	2.1	3.3	3.4	4.5	4.4
The Bahamas (BHS)	**Energy**	**12.2**	**14.8**	**13.1**	**11.5**	**10.8**
	Electricity	7.3	7.0	5.9	5.0	4.1
	Gas	1.2	1.1	0.8	0.7	0.5
	Others	0.1	0.1	0.0	0.0	0.0
	Transport fuels	3.7	6.6	6.5	5.8	6.2
Bolivia (BOL)	**Energy**	**3.3**	**3.5**	**3.5**	**3.7**	**3.5**
	Electricity	1.8	1.9	2.0	2.0	1.8
	Gas	0.9	0.8	0.7	0.6	0.4
	Others	0.1	0.0	0.0	0.0	0.0
	Transport fuels	0.5	0.7	0.8	1.1	1.3
Brazil (BRA)	**Energy**	**9.4**	**8.1**	**7.9**	**7.7**	**6.9**
	Electricity	5.1	4.3	3.8	3.2	2.2
	Gas	3.5	2.2	1.5	1.0	0.5
	Others	0.1	0.0	0.0	0.0	0.0
	Transport fuels	0.8	1.6	2.6	3.5	4.2
Barbados (BRB)	**Energy**	**19.9**	**10.8**	**8.4**	**5.9**	**3.6**
	Electricity	13.6	7.8	6.2	4.4	2.8
	Gas	6.3	3.0	2.2	1.4	0.8
	Others	-	-	-	-	-
	Transport fuels	-	-	-	-	-
Chile (CHL)	**Energy**	**8.1**	**7.5**	**7.5**	**7.4**	**6.4**
	Electricity	5.9	4.1	3.3	2.4	1.4
	Gas	1.4	1.7	1.6	1.4	0.4
	Others	0.3	0.4	0.4	0.3	0.3
	Transport fuels	0.4	1.1	2.0	2.7	3.5

		Quintile				
Country		**Poorest**	**2**	**3**	**4**	**Richest**
Colombia (COL)	**Energy**	**9.8**	**8.2**	**7.7**	**7.0**	**6.3**
	Electricity	6.0	5.0	4.4	3.9	2.5
	Gas	2.7	1.7	1.2	0.8	0.3
	Others	0.2	0.1	0.0	0.0	0.0
	Transport fuels	0.9	1.4	2.0	2.3	3.5
Costa Rica (CRI)	Energy	9.4	6.6	5.9	5.9	5.4
	Electricity	6.3	3.9	3.1	2.5	1.6
	Gas	1.3	0.8	0.6	0.3	0.1
	Others	0.9	0.3	0.1	0.1	0.0
	Transport fuels	1.0	1.6	2.0	3.0	3.7
Dominican Rep. (DOM)	Energy	7.3	7.2	7.2	7.8	9.3
	Electricity	1.9	2.1	2.3	2.4	2.7
	Gas	3.1	2.6	2.3	1.9	1.2
	Others	0.5	0.3	0.2	0.1	0.1
	Transport fuels	1.8	2.1	2.5	3.4	5.4
Ecuador (ECU)	Energy	2.9	2.7	2.7	3.0	3.4
	Electricity	1.8	1.7	1.7	1.7	1.5
	Gas	0.8	0.5	0.4	0.3	0.2
	Others	0.1	0.0	0.0	0.0	0.0
	Transport fuels	0.2	0.4	0.6	0.9	1.6
Guatemala (GTM)	Energy	10.2	9.9	9.8	9.4	9.2
	Electricity	4.6	4.0	4.2	4.1	3.5
	Gas	0.2	1.1	1.9	2.1	1.5
	Others	5.1	4.2	2.6	1.4	0.5
	Transport fuels	0.3	0.7	1.1	1.9	3.8
Honduras (HND)	Energy	4.4	3.5	4.8	5.7	8.0
	Electricity	0.8	1.9	2.8	2.8	2.9
	Gas	0.0	0.4	1.0	1.3	0.7
	Others					
	Transport fuels	0.0	0.1	0.6	1.5	4.3

		Quintile				
Country		**Poorest**	**2**	**3**	**4**	**Richest**
Jamaica (JAM)	Energy	13.8	12.5	12.3	11.7	11.3
	Electricity	7.3	6.9	7.1	6.3	5.0
	Gas	2.5	2.8	2.7	2.4	1.6
	Others	3.8	2.3	1.5	0.9	0.4
	Transport fuels	0.1	0.5	1.0	2.2	4.3
Mexico (MEX)	Energy	9.7	10.3	10.2	10.8	10.3
	Electricity	3.8	3.2	2.7	2.6	1.9
	Gas	3.1	3.5	3.4	2.8	1.8
	Others	0.9	0.5	0.3	0.2	0.1
	Transport fuels	1.8	3.1	3.9	5.3	6.5
Nicaragua (NIC)	Energy	5.6	6.9	7.2	7.6	9.4
	Electricity	2.0	2.8	2.8	2.9	3.2
	Gas	1.0	1.9	2.2	2.2	1.7
	Others	2.6	1.8	1.0	0.7	0.3
	Transport fuels	0.1	0.5	1.2	1.8	4.2
Panama (PAN)	Energy	3.9	3.4	3.4	3.0	2.5
	Electricity	3.0	2.8	2.9	2.6	2.2
	Gas	1.0	0.6	0.5	0.5	0.3
	Others					
	Transport fuels					
Peru (PER)	Energy	8.1	6.6	5.9	5.2	4.8
	Electricity	3.1	2.7	2.8	2.7	2.4
	Gas	2.9	2.9	2.4	1.8	1.2
	Others	1.8	0.6	0.3	0.1	0.0
	Transport fuels	0.4	0.4	0.5	0.5	1.1
Paraguay (PRY)	Energy	6.6	7.4	8.1	7.9	8.3
	Electricity	2.1	2.4	2.7	2.8	2.7
	Gas	0.8	1.5	1.4	1.4	1.1
	Others	1.5	1.2	0.9	0.6	0.2
	Transport fuels	2.2	2.3	3.0	3.1	4.3

Country		Poorest	2	3	4	Richest
		Quintile				
El Salvador (SLV)	Energy	6.1	6.3	6.3	6.1	5.7
	Electricity	3.5	3.9	4.2	4.3	4.5
	Gas	2.0	2.1	1.8	1.5	1.0
	Others	0.6	0.3	0.3	0.2	0.2
	Transport fuels					
Uruguay (URY)	Energy	16.7	14.9	12.6	11.1	10.2
	Electricity	10.0	8.9	7.3	5.9	4.4
	Gas	4.2	3.0	2.3	1.7	1.1
	Others	0.9	0.7	0.5	0.5	0.4
	Transport fuels	1.5	2.3	2.5	3.0	4.2
Latin America and the Caribbean	Energy	8.9	8.1	7.9	7.9	7.3
	Electricity	4.4	3.7	3.3	2.9	2.1
	Gas	2.9	2.3	1.9	1.4	0.8
	Others	0.5	0.3	0.2	0.1	0.0
	Transport fuels	1.1	1.8	2.6	3.4	4.3

Source: National household expenditure surveys of 20 countries.

Note: All values were calculated using the most recent expansion factor.

Energy Expenditures Vary Considerably within Income Groups

In addition to the pronounced differences across countries and income groups, there is also considerable variation even within each quintile. Within each income group, energy expenditures not only tend to have a significantly higher weight in lower-income households, they also have a significantly more skewed distribution in terms of energy shares. Following Advani et al. (2013), such variation can be observed through a box plot. Figure 5.7 shows variation in energy expenditure shares across income groups, with the distribution within the group depicted from the 10th percentile (bottom whisker) to the 90th percentile (top whisker), with a box bounded by the lower quartile (bottom) and the upper quartile (top), and the median depicted by the box's central line. The variability is greater for poorer households: in the poorest quintile, 1 in 10 households spends more than 15 percent of its budget on energy, while more than 1 in 10 actually book zero energy spending. In the top quintile, by contrast, 75 percent of all households have energy budget shares in the narrow range of 1 to 4 percent.

It is important to recall that this analysis explores energy expenditures, which do not necessarily reflect consumption patterns because of price differences. In particular, electricity prices generally include cross-subsidies such that, given their lower electricity consumption, low-income families may face lower prices than richer families do. This implies that differences in electricity consumption may be smaller than initially inferred from Figure 5.5.

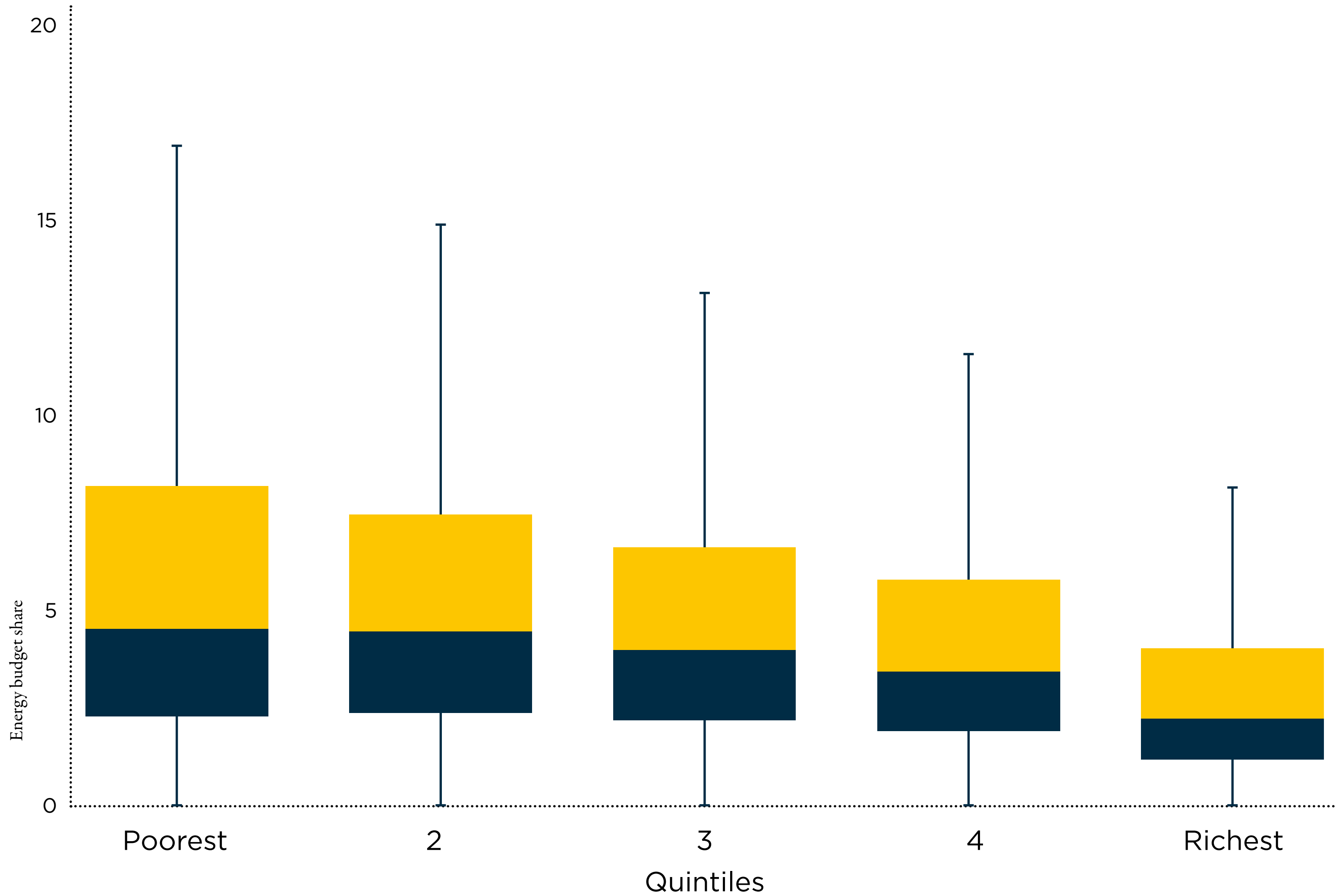
Aggregate Energy Expenditures Are Concentrated among the Richest Income Groups

Taking another perspective, this section presents the concentration of national aggregated energy expenditures by income group. Figure 5.8 shows that the 20 percent of the population in LAC with the highest incomes accounts for more than 40 percent of total expenditures on energy. In contrast, the bottom 20 percent of the population accounts for around 8 percent of total energy expenditures. This means that the richest income group in LAC spends five times more on energy than the poorest income group.

Figure 5.8 also shows the fuel composition within each income quintile, indicating that transport fuels constitute the bulk of energy expenditures in the richest group. Around 64 percent of total energy expenditures in the fifth (wealthiest) quintile go toward private transportation. In contrast, expenditures on domestic energy sources make up the largest share of energy expenditures in the poorest income group, at 76 percent.

This aggregate view depicts the distributive characteristics of energy expenditures. While the poorest households are the most vulnerable to price shocks given the energy share in their expenditure, their share of national energy expenditures is less than 10 percent. This pattern is clearest in the case of fuels for private transportation, where the poorest households account

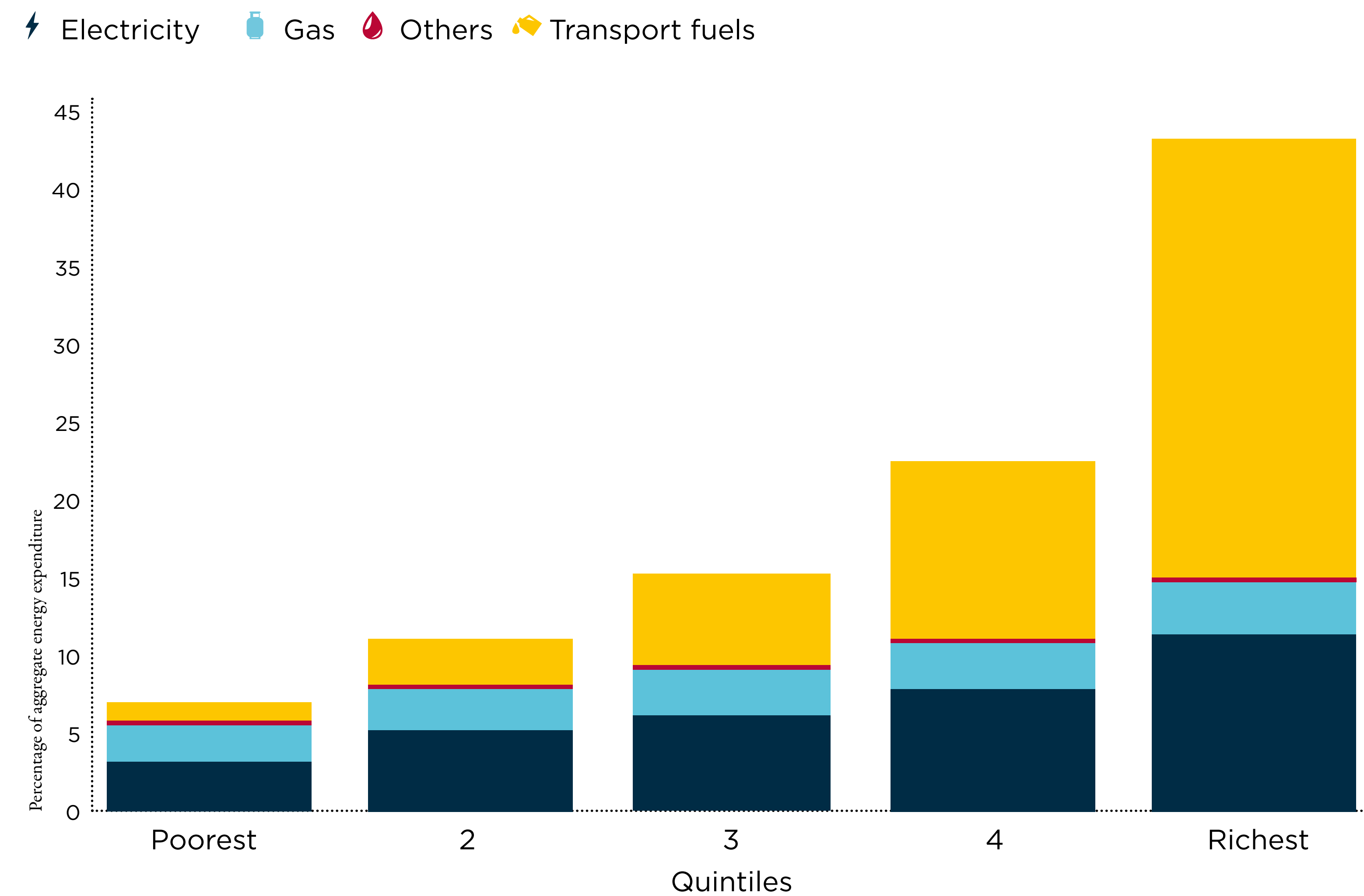
Figure 5.7: Within-Quintile Variation in Domestic Energy Budget Shares in Latin America and the Caribbean (percent)



Source: Authors' calculations from national household expenditure surveys of 20 Latin American and Caribbean countries.

Note: The figure does not include outside values.

Figure 5.8: National Energy Expenditures by Income Group in Latin America and the Caribbean



Source: Authors' calculations based on national household expenditure surveys of 17 Latin Americana and Caribbean countries.

for only 2 percent of aggregate expenditures on transport fuels, while the richest quintile accounts for 30 percent.

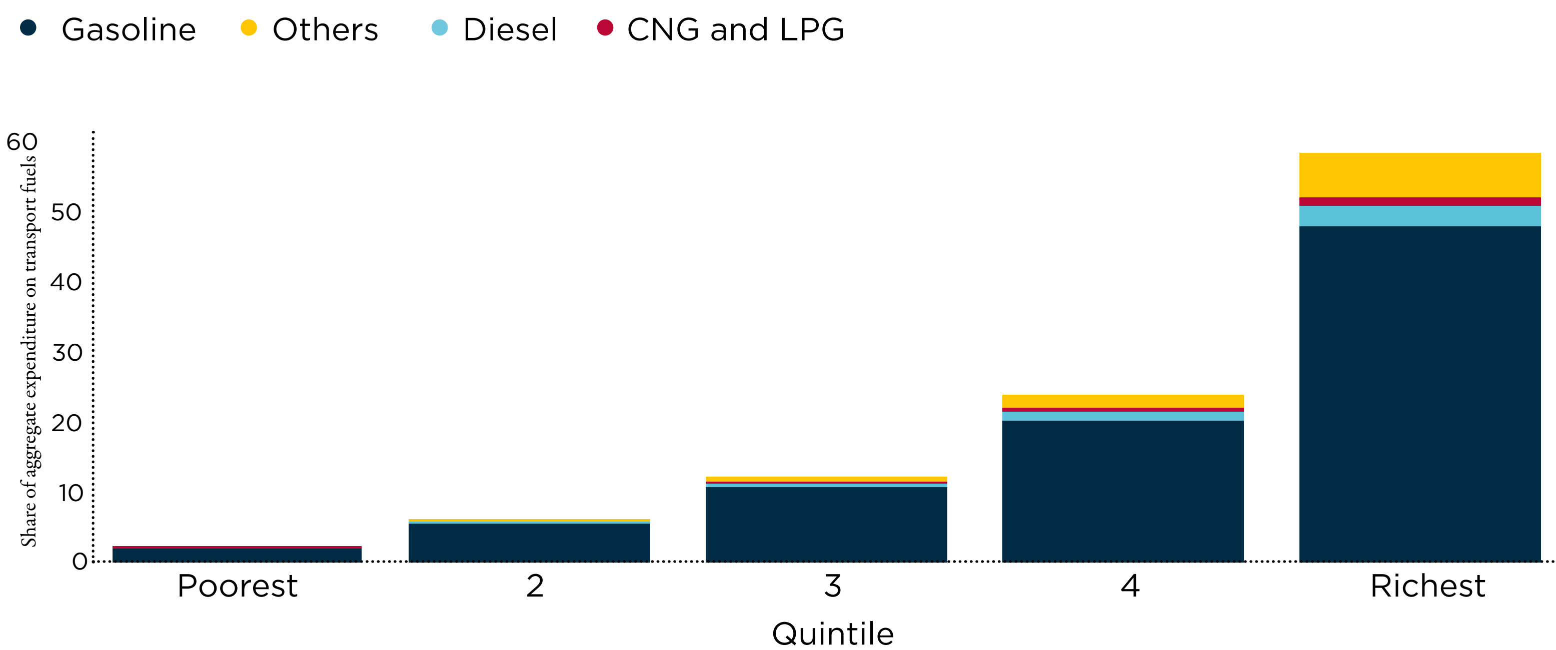
Gasoline Accounts for over 80 Percent of All Transport Fuel Expenditures

To provide a closer look at the structure of expenditures on transport fuels, Figure 5.9 uses information from 12 national household surveys (of the sample of 20 countries) that disaggregate the type of transport fuel consumed by households. The figure presents the national aggregate expenditures on private transportation by type of fuel and income group. It shows that, among transport fuels, gasoline accounts for most of household expenditures on private transportation (80 percent). The figure also shows the high concentration of transport fuel expenditures by the richest income groups, with around 79 percent of aggregate expenditures on gasoline concentrated in the two richest quintiles, while the poorest quintile account for less than 2 percent of spending on gasoline. These aggregate patterns are representative of those observed in each country, as can be seen in detail in Appendix 3.

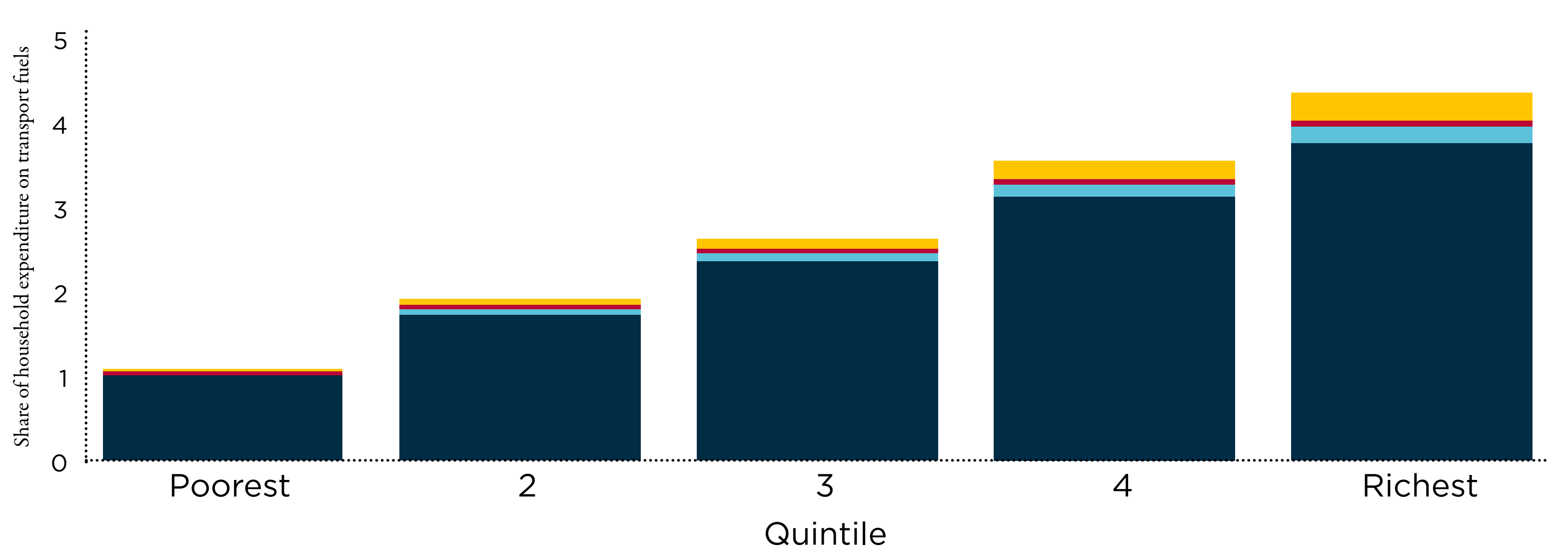
The low penetration of compressed natural gas (CNG) and LPG in private transportation suggests that there is room for greater effort in expanding the use of these relatively cleaner fuels. This low penetration remains similar across most LAC countries, with the main exception being countries with significant endowments of gas, such as Argentina, Bolivia, and Peru, where expenditures on CNG and LPG are more pronounced. In this context, developing the natural gas industry and fostering energy integration may help to broaden access to such cleaner transportation fuels in LAC.

Figure 5.9: Structure of Transport Fuel Expenditures in Latin America and the Caribbean

a. National Aggregate Expenditures on Transport Fuels



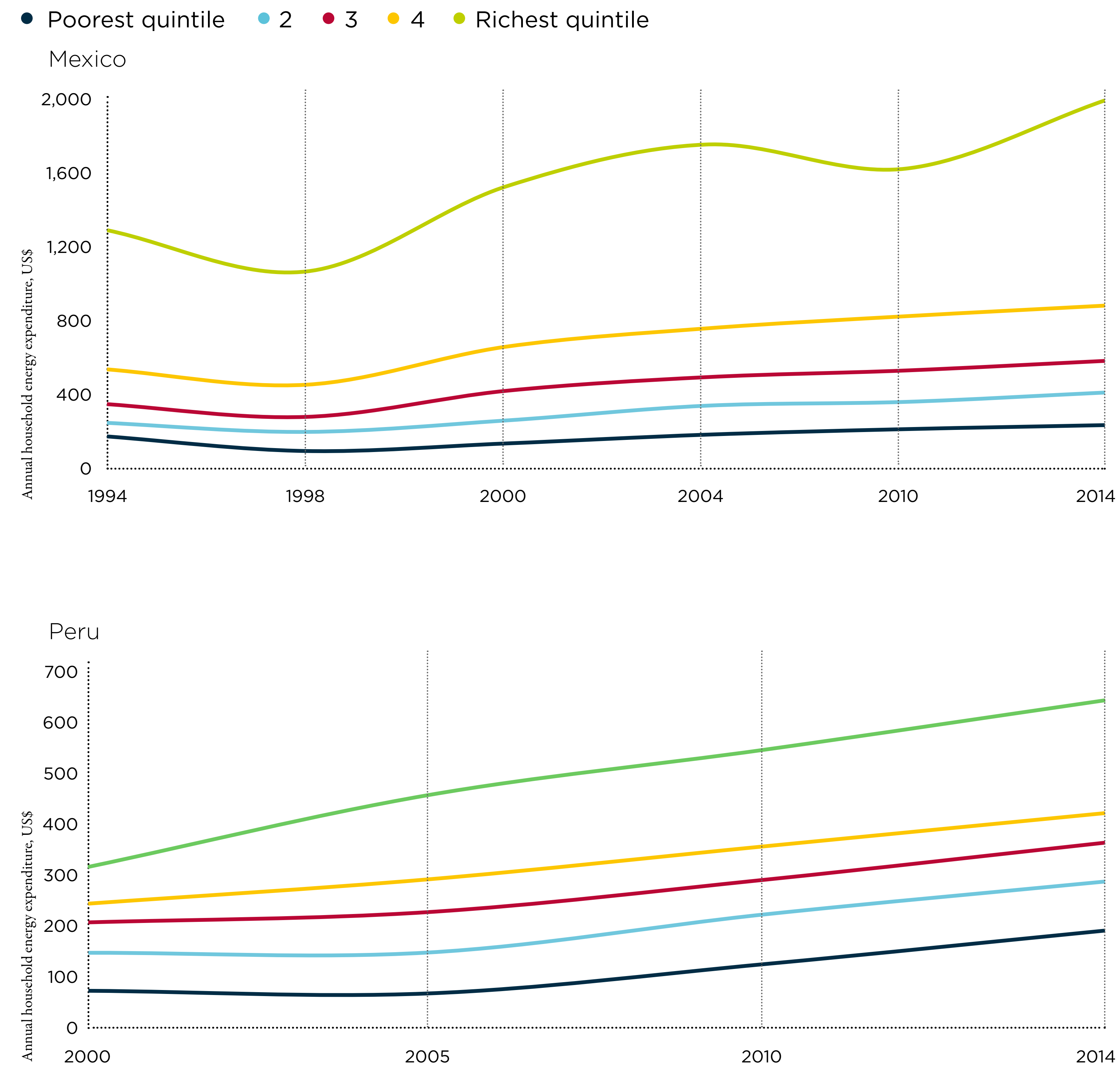
b. Share of Transport Fuel Expenditures in the Household Budget



Source: National household expenditure surveys of 12 countries.

Note: Other fuels include biofuels (specifically alcohol), mostly consumed in Brazil. CNG: compressed natural gas; LPG: liquefied natural gas.

Figure 5.10: Mexico and Peru: Trends in Household Annual Energy Expenditures by Income Quintile



Source: Prepared by the authors based on the national household surveys from several years.

Trends in Household Energy Expenditures

At the country level, Part 2 of this book documented that energy consumption patterns have changed in composition over time. This chapter has provided a detailed snapshot of the structure of household energy expenditures across income groups at a given point in time. The question remains whether this expenditure structure has changed along with the observed patterns in energy use. This section complements the previous findings by examining trends in household energy expenditures across income groups in a case study of two countries. The main questions to address are the following: How have household energy expenditures evolved over time? How has the composition of energy expenditures changed at the household level? How have aggregate energy expenditures changed? These questions provide insight into the dynamics of the distributive characteristics of energy expenditures in LAC countries.

This section focuses on case studies of Mexico and Peru, for which there is available information covering extended periods of time. Information on Mexico was gathered from six nationally representative surveys between 1994 and 2014. For Peru, information was pooled from four nationally representative surveys from 2000–2014.[7] The data sets analyzed herein are pooled cross-sections of household surveys that do not track the same households over time.

7. In Peru, the national survey from 2000 corresponds to the fourth quarter, when collection of information on energy expenditure began.

The underlying message is that as income grows the corresponding increments in household energy expenditure are generalized across all income groups, mainly suggesting higher energy consumption. In both countries, the upward trend in energy expenditures has been accompanied by a growing share of transport fuels across all income groups.

Household Energy Spending Has Increased across All Income Quintiles

Figure 5.10 shows that households in all income quintiles have increased their annual expenditures on energy. On average, the annual growth rate in energy consumption was 5 percent in Peru and 2.5 percent in Mexico, while by income quintile, the richest group had the greatest growth. Along with these trends, there are significant differences in energy expenditures between income groups. In absolute terms, a Mexican household in the fifth (wealthiest) quintile spends almost 10 times as much as a household in the first (poorest) quintile, while in Peru the equivalent factor is 5 times. This suggests a pronounced disparity in energy consumption between income groups.[8]

The trends in household average energy expenditure also show that any negative fluctuations have been mainly associated with real economic shocks. The impact of external shocks is clearer in Mexico, for which a longer data set is available. In this country, periods of economic downturns tend to coincide with reductions in absolute energy expenditures, as occurred during the Tequila Crisis of 1994–1995 and the financial crises of 2001–2002 and 2009.

8. In addition, it is important to note that these patterns remain even if we ignore 2014, when oil prices dropped, potentially leading to a reduction in internal fuel prices that may have resulted in increased demand.

Increasing Participation of Transport Fuel Expenditures

In both Mexico and Peru, expenditures on all modern fuels have increased, but growth in transport fuels has been particularly marked. As a result, Figure 5.11 shows an increasing share of transport fuels within household energy expenditures. Moreover, the increase in transport fuel expenditures has occurred among all income groups, and more profoundly in lower-income households. In Mexico, the transport fuel participation of total energy expenditures in the poorest income group grew from 4 percent in 1994 to 25 percent in 2014, while in the richest income group it grew from 53 to 66 percent over the same period. In Peru, transport fuel expenditures in the poorest group represented less than 1 percent in 2000 but 9 percent in 2014, while in the richest group, these expenditures went from 10 to 34 percent over the same period.

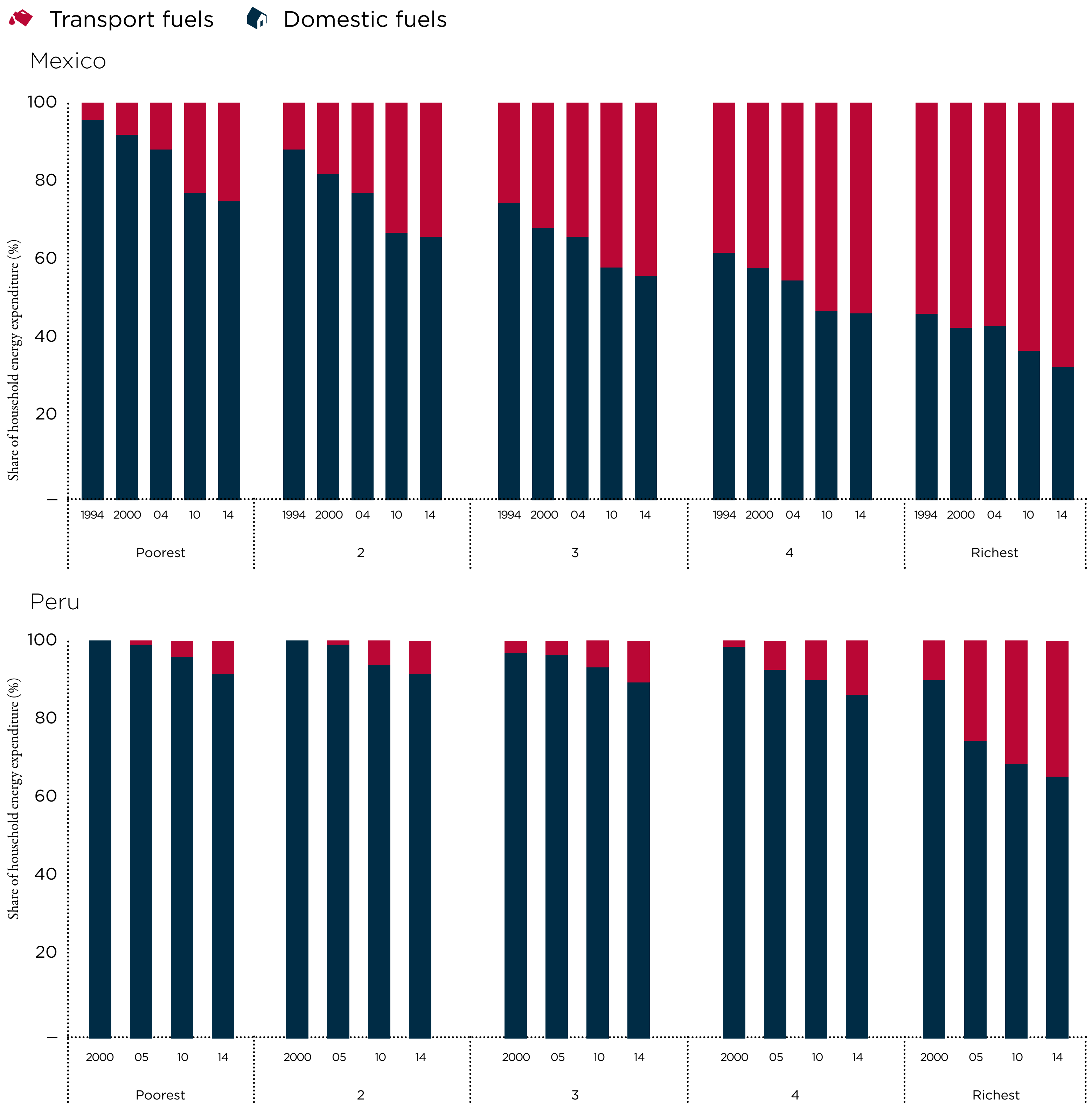
These patterns are in accordance with the observed transition from traditional to modern fuels (see Chapters 2 and 3). Given that traditional fuels are usually collected by household members, while modern fuels have established market prices, such a transition implies an increase in household energy expenditures and wealth. What is somewhat remarkable is the increasing share of transport fuel expenditures across all income groups. Along with the greater ownership of private vehicles discussed in Chapter 2, these patterns indicate a heavy motorization of Latin American and Caribbean cities.

A caveat in this assessment is that, because energy prices are not accounted for, it is not clear whether these trends are due to price increases or increased consumption. To address these points, one would need to examine either the impact of prices or the impact of consumption, but current household surveys do not provide such information. However, the trend presented in Chapter 2 – increasing per capita consumption of modern energy sources – suggests that the dominant force behind the growth in the share of energy expenditures is increased energy consumption (not prices) across all income quantiles.

Structure of Aggregate Energy Expenditures by Income Quintile

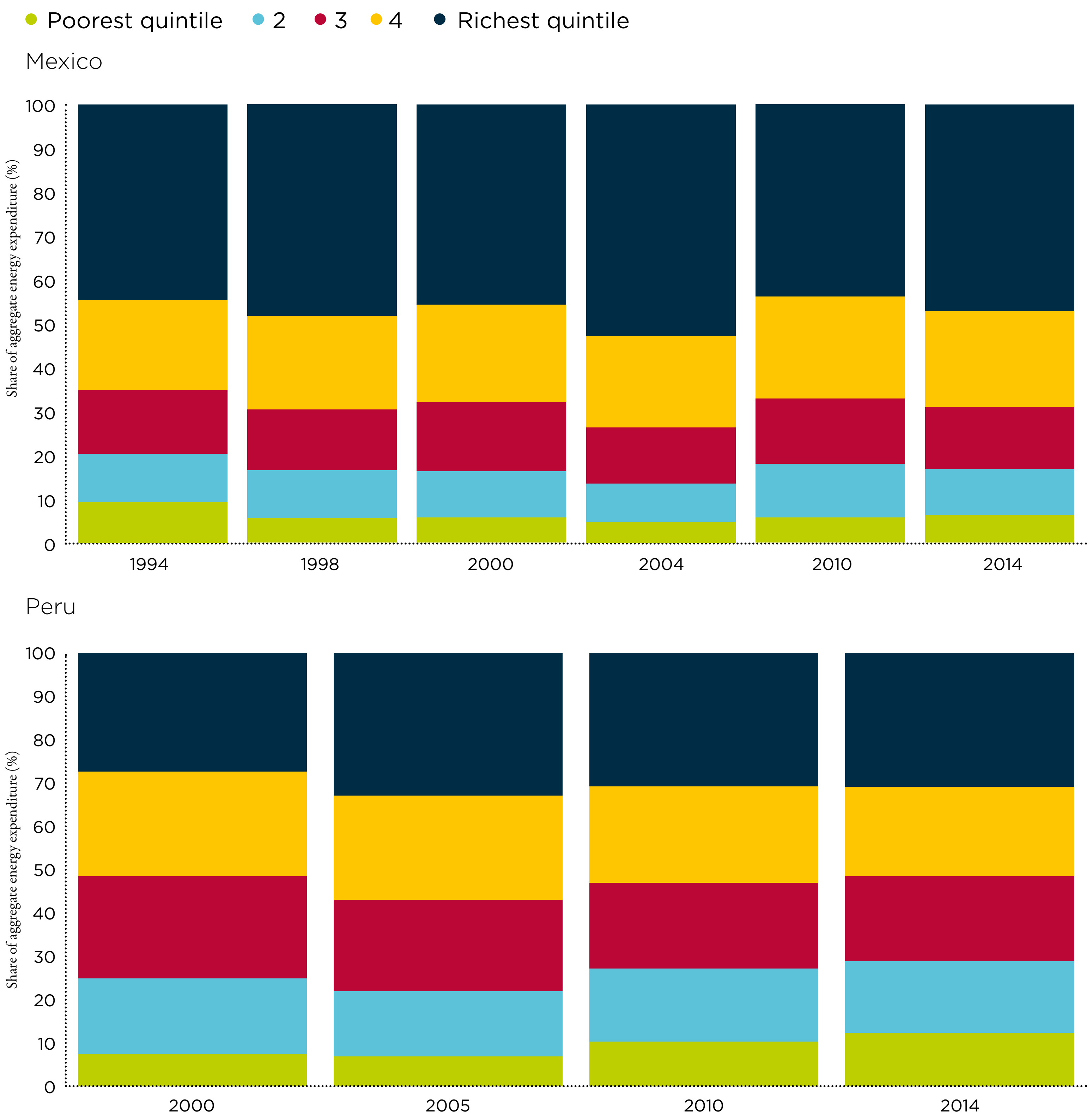
Figure 5.12 shows the breakdown of aggregate energy expenditures by income group. In Mexico, this structure has not significantly changed since 1992. The richest 20 percent of households account for around 50 percent of total national energy expenditures, while the poorest 20 percent of the population account for between 5 and 9 percent of total national energy expenditures. In contrast, in Peru, the poorest income group has significantly increased its share of total national energy expenditures since 2000. The poorest income group's share of expenditures grew from 8.2 percent in 2000 to 12.6 percent in 2014. These trends suggest that energy

Figure 5.11: Mexico and Peru: Trends in Composition of Energy Portfolio by Income Quintile



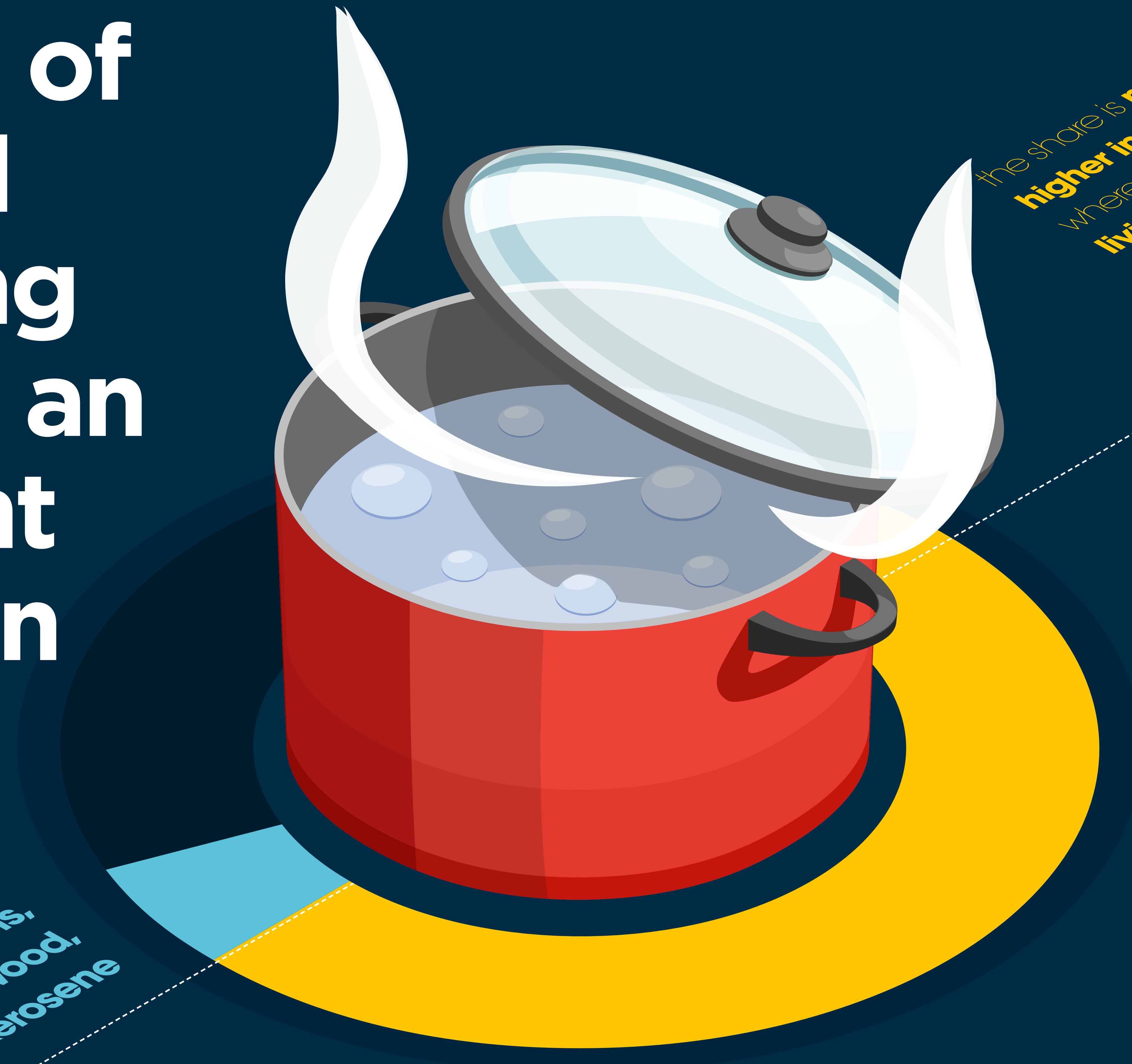
Source: National household surveys, several years.

Figure 5.12: Mexico and Peru: Cumulative Energy Expenditure Shares by Income Quintile



Source: National household surveys, several years.

The type of fuel used in cooking can have an important impact on health.



expenditures have a more neutral distribution in Peru than in Mexico. Put another way, total energy expenditures and per-household energy expenditures tend to be more similar across income groups in Peru than in Mexico.

These findings raise important questions with regard to the factors that determine trends in energy expenditures and consumption. In order to support policy evaluation and future analysis, further research on such factors ought to include the role of time, that is, the pace of development. However, the main limitation of a study on the distribution of energy consumption involves data availability, as the quantities of energy consumed and the prices paid at the household level are usually not covered by household surveys. This limits the detail in any empirical analysis necessary for policy design and evaluation.

A Key Challenge to Tackle Energy Inequality: Cleaner Cooking Fuels

Previous Chapters shows a consistently rising demand of the Latin American and Caribbean population for modern energy. A prospective view of the region energy needs certainly relies on an intensive mix of electricity and domestic gas (LPG and natural gas). By now, it is clear, however, that the household energy profile today is far from being homogenous. As previously described, differences in availability of energy sources, income, geographic location, among others, have significant implications on how families consumed energy. Maybe one of the most distressing implications is that, regardless of all the progress in terms of economic growth and general infrastructure provision; the distribution of modern energy sources has regressive characteristics that are more market severe among the most vulnerable families. While access to electricity and domestic gas–more convenient and better-quality energy sources for lighting and cooking–are more extended and affordable in urban areas and better-off population segments.

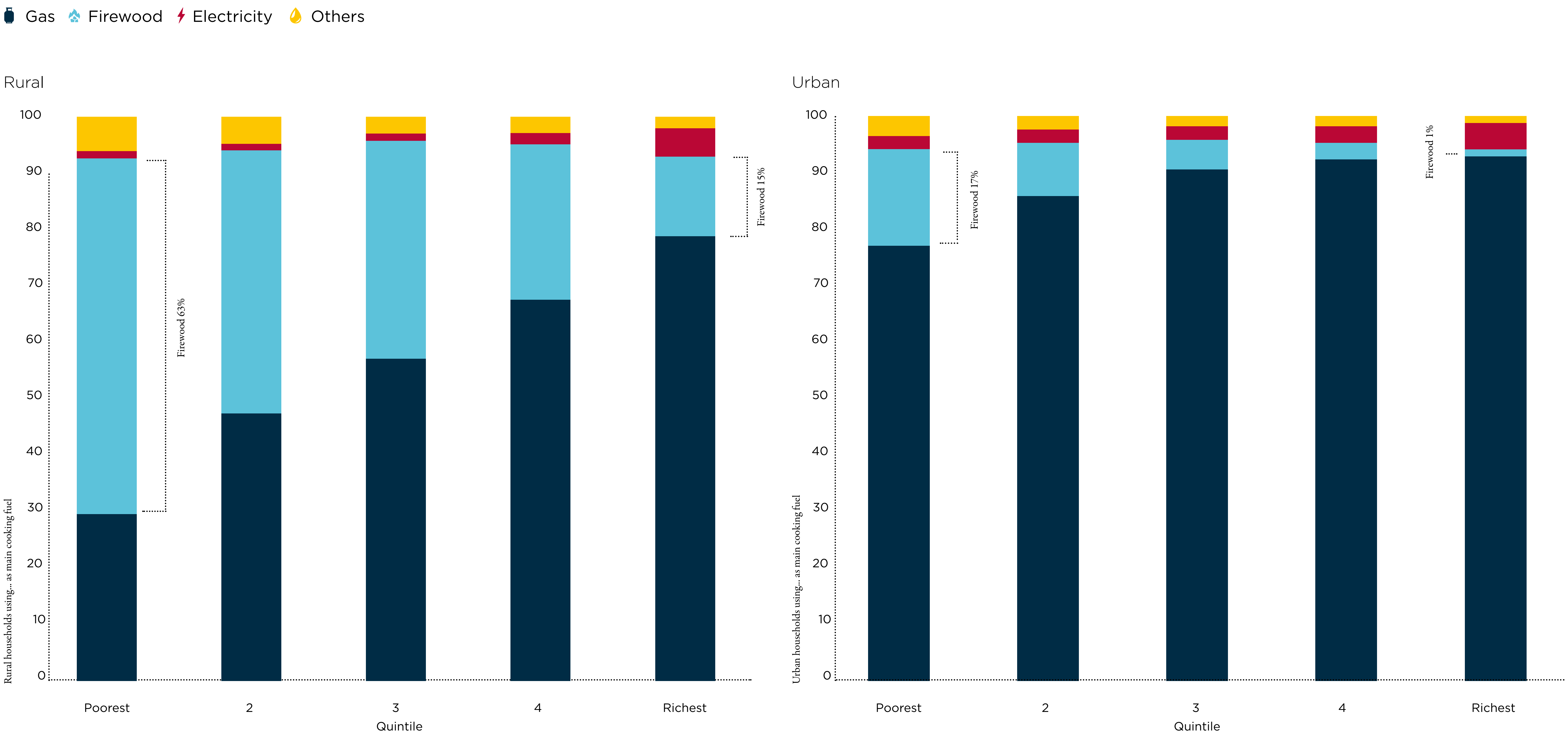
Developing countries still consume a significant amount of biomass, most of which is used for cooking, particularly by poor families in rural areas without affordable access to modern cooking fuels such as natural gas. There is much literature documenting the negative effects on health and household time of using this fuel source, in turn leading to lower educational and economic outcomes. Indeed, biomass collection has proved to be a time- and effort-consuming chore that is usually carried out by children and women, which takes time away from more productive activities, and represents an exhausting task that may translate into long-term negative health consequences. In addition, other negative health consequences, such as respiratory infections, pneumonia, cataracts, asthma, and even low birth weight and infant mortality, are associated with indoor air pollution caused by burning solid fuels in inadequately ventilated dwellings (Rehfuess 2006). Such negative effects of dirty cooking fuels also extend to the environment, as the unsustainable use of biomass may contribute to local deforestation and land degradation, particularly in rural areas. An extreme example of these effects is seen in Haiti, where the dominant energy source is charcoal made from wood.Figure 5.13 shows the use of cooking fuels by area (urban and rural) and income level in Latin America and Caribbean (LAC). Clearly, firewood is the main source of fuel used for cooking in rural areas, particularly among lower-income families. Over 63 percent of LAC's rural population in the poorest income groups depends on firewood for daily cooking, while another 6 percent depends on other dirty fuels, such as coal and kerosene. The share of households using natural gas and electricity increases with income, but this also depends on location. As can be seen, access to affordable domestic gas – the main cooking fuel after firewood – strongly depends on market accessibility and resource availability in urban versus rural areas. For example, around 15 percent of rural households in the wealthier income group use firewood as their main cooking fuel.

However, even in urban areas, around 17 percent of households in the poorest income group still use firewood as their main cooking fuel. This indicates that, regardless location, income level still plays a key role in the use of modern fuels. While other factors such as culture may also come into play, the evidence suggests that the effect of culture on fuel use is usually only marginal. For example, only 1 percent of urban households in the highest-income group rely in firewood for cooking.

As a methodological consideration, notice that this review only refers to the take-up rates of different cooking fuels. Household surveys do not usually record information on expenditure or consumption of cooking fuels. However, even if such data were recorded, there would be severe measurement problems with regard to capturing nonmarket fuels such as biomass. This is because most biomass is collected by household members, making it difficult to establish a price for any given "unit" of firewood.

Independently of those methodological considerations, previous stylized facts present us again with a complex interplay between access to better quality of energy sources and affordability. Balancing these dimensions constitute public policy priorities to tackle energy poverty and inequality and, in such context, access to cleaner cooking fuels emerges as one of the most urgent topics to address. There seem to be indications that at macro level energy inequality has reduced in the region, both in terms of access and use. For example, Box 5.1 examines the case of Mexico suggesting a reduction in the disparity of energy spending over the last 25 years. Still, at the same time, the case of Mexico also highlights the greater household dependence on modern fuels as well as the corresponding growing weight of those fuels on household budgetary decisions. That is, as documented in the case of cooking fuels, there are persistent energy puzzles requiring specific targeting and innovative energy policies.

Figure 5.13: Main Cooking Fuels Used in Latin America and the Caribbean by Income Group and Location (percent)



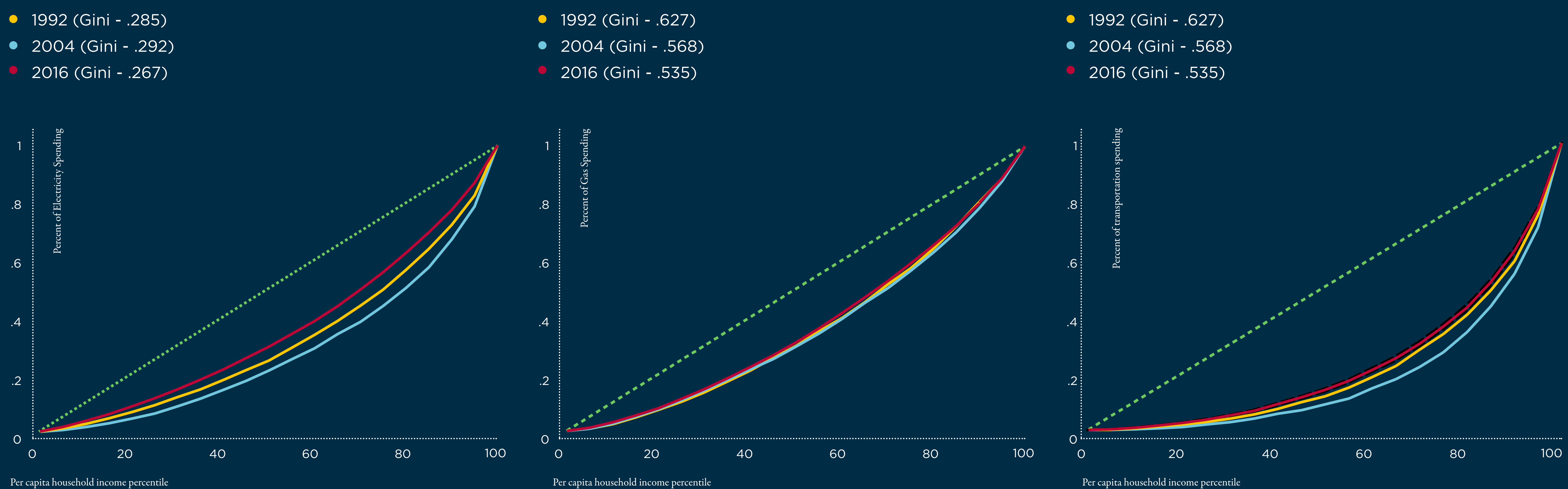
Source: Authors' calculations based on national household expenditure surveys of 17 countries.

Per capita expenditure on energy has grown at higher rates among poorer families for all energy items,

and yet more rapidly than their income.

Box 5.1: Trends in Inequality of Energy Spending in Mexico (1992-2016)

Box Figure 5.1.1: Trends in Inequality of Energy Spending in Mexico



Source: Authors elaboration.

Note: Values are weighted using the population expansion.

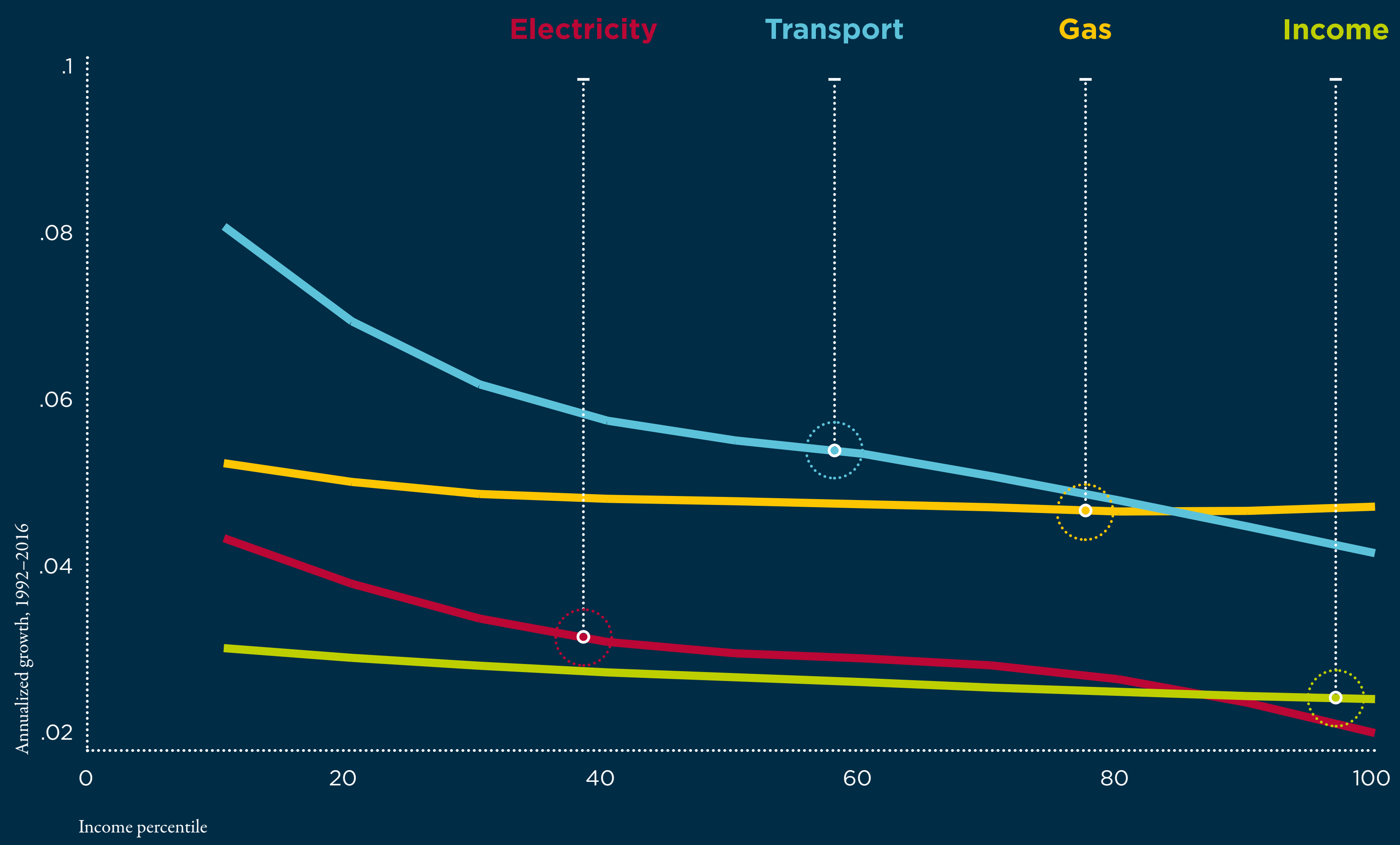
Previous trends point toward changes in the distribution of energy expenditure across income groups. To further illustrate the extent to which energy spending inequality has changed, Box Figure 5.1.1 presents concentration curves by energy category for three points in time in Mexico that show the share of total energy expenditure that corresponds to each household ranked by percentile of the income distribution. If energy expenditure is equally distributed across households with different income levels, one should observe that concentration curves approximate the 45-degree-line. The further away from this line, the more unequal is the distribution of energy spending. For example, the top panel shows that in 1992 the poorest 50 percent of the household population represented approximately 20 percent of aggregate electricity spending, a share that increased to around 28 percent in 2016. The highest reduction in spending inequality has occurred in electricity, followed by transport fuels. The levels of concentration in domestic gas have the smallest reduction (middle panel). However, notice that inequality levels for domestic gas were already low in 1992 compared to electricity and transport fuels.

The general reduction in inequality is also confirmed by the Gini index, presented in the upper left of each panel in Box Figure 5.1.1. The Gini index summarizes the degree of inequality and is given by the ratio of the area between the diagonal line and the concentration curve to the area between the diagonal line and the horizontal axis. Notice that the vertical axis is constructed based on per capita energy spending. Therefore, a population with each member having the same level of energy spending will return a Gini of zero. The greater the area between the diagonal line and the concentration curve, the greater the Gini, reflecting greater levels of inequality.

The extent of progress towards more energy equity, however, may depend on the approach. For example, in García-Ochoa and Graizbord (2016), where the analysis is more disaggregated by states, over 11 million Mexican households (36.7 percent of the total) are still classified as energy poor according to the authors' methodology. Geographical differences are substantial, with the poorest southeastern states of Oaxaca, Guerrero, and Chiapas having the highest prevalence of energy-poor households.

Nonetheless, the distributional changes in energy expenditures have been greater than those observed for household income. Per capita energy expenditure has grown at higher rates among poorer families for all energy items, and more rapidly than their corresponding income. These patterns can be appreciated in the growth incidence curves depicted in Box Figure 5.1.2. These curves show the average annual growth rate in energy spending between 1992 and 2016, by income percentile. Consistent with the literature on income inequality (Campos et al. 2014; Messina and Silva 2017), income has shown pro-poor growth since the beginning of the 1990s. By separating all energy categories, one can see that spending on transport fuels has grown significantly faster at the bottom of the income distribution.

Box Figure 5.1.2: Energy Spending Growth Incidence Curve in Mexico



Source: Authors elaboration.

Note: Values are weighted using the population expansion.

Chapter 6

Determinants of Household Energy Expenditures[1]

Uncovering the relationship between energy expenditures and their determinants as a share of total household expenditures is challenging because of the presence of many confounding and interrelated factors such as energy prices, appliance ownership, and household size, among many others. This chapter examines this relationship in further detail by conditioning a set of relevant covariates. Although this relationship has been analyzed extensively in the literature (Meier, Jamasb, and Orea 2013; Baker, Blundell, and Micklewright 1989; Advani et al. 2013; Bacon, Bhattacharya, and Kojima 2010), analyses of Latin America and the Caribbean (LAC) are still scarce and restricted to only a few countries and some specific fuels. Further, those analyses concentrate on both absolute energy expenditures and energy expenditures as a share of household income. The LAC region is facing a marked energy transition. Going forward, households will demand more electricity and liquid fuels, which will require putting in place policies based on detailed empirical data on fuel and household characteristics. Such knowledge constitutes the building blocks for policies contributing to balance the trade-offs between meeting households' basic needs and reducing the environmental impact through, for example, pricing and energy efficiency policies. This chapter distinguishes between domestic energy and transport fuels. Domestic energy includes electricity, natural gas, and other fuels (such as wood, coal, and kerosene). Transport fuels include gasoline, diesel, and, for some countries, liquefied petroleum gas. Specifically, this chapter addresses the link between energy expenditures on electricity, domestic gas, and transport, and household location, family composition, dwelling size, ownership of durable goods, and income.

Altogether, the findings highlight the relevance of these variables in shaping energy spending and affordability, but with important differences between fuels. Domestic fuel expenditures and budget shares are driven by household socioeconomic characteristics. Household location (urban/rural) and appliance ownership explain more than 50 percent of energy expenditures. At the same time, while fuel expenditure is strongly positively correlated with income, its weight in the family budget tends to decrease to the wealthier side of the income distribution, indicating that energy expenditure grows at a lower rate than income. On the other hand, the materialization of energy economies of scale of household size is clearer than for dwelling size, and further, it is more pronounced in wealthier households. These results imply that demographic and construction trends have implications for energy policy. The trend toward smaller family size may dilute the economies of scale of household size. Similarly, energy efficiency and conservation standards for household and building construction may be required to offset their observed small economies of scale.

The estimated conditional Engel curves have similar shapes between fuels, but the analysis for this chapter finds noticeable differences in the path of income elasticity by fuels. Although these elasticities are less than unity for all fuels, they tend to be higher, across all income groups, for transport fuel, followed by electricity and domestic gas. For electricity, the elasticity increases with income, but tends to stabilize starting at the 75th percentile of the income distribution. For gas, it decreases continually over the income range of the sample. For transport fuel, it increases up to the 25th percentile, and then begins to decrease. These results portray electricity, domestic gas, and even transport fuels as necessity goods. However, it is important to take into account that the richer segments of the population account for most of the residential energy expenditure, especially in the case of liquid fuels.

To the extent that the observed energy spending patterns reflect energy consumption, the findings may have implications for energy efficiency and conservation policies. The detected economies of scale suggest that energy efficiency policies for housing and buildings may have significant effects not only on energy consumption, but also on related expenditures, relieving household budgets. Similarly, given the sizable explanatory power of ownership of appliances and vehicles on energy expenditures, these implications extend to the implementation of energy efficiency standards for durable goods. These results suggest that such policies not only would save energy, but also increase affordability, which would have a greater effect on poorer segments of the population. To inform energy efficiency policies, further research may be needed to investigate, among other issues, the source of the differences in economies of scale between income groups.

Household Characteristics Matter

There are a number of factors behind how households spend on energy. Broadly, the literature groups those factors into economic and non-economic categories (Meier et al. 2013; Cayla, Maizi, and Marchand 2011; Advani et al. 2013; Baker, Blundell, and Micklewright 1989; Heltberg 2004; Fouquet 2014; Pachauri and Jiang 2008; Hanna and Oliva 2015). Economic factors – that is, income and energy prices – have received greater attention because they determine key budgetary restrictions for consumption and expenditure decisions. Accordingly, previous studies show their significant effects on household energy demand and expenditures, although with noticeable variation among income groups. For example, the income elasticity estimated by Baker, Blundell, and Micklewright (1989) shows substantial differences between income groups in the United Kingdom, from -0.172 in the top decile to 0.177 in the bottom decile.

On the other hand, energy demand actually derives from noneconomic factors – such as household size, location (urban/rural), ownership of appliances, dwelling size, and temperature – that have proven to have a sizable impact on energy spending (Poyer, Henderson, and Teotia 1997; Estiri 2015; Longhi 2015). For example, in the case of the United Kingdom, Longhi (2015) indicates that accommodation characteristics account for up to 20 percent of gas expenditures and up to 10 percent of electricity expenditures.

In light of this evidence and as a response to improvements in living standards, along with the increasing adoption of durable appliances and vehicles, it is expected that future incremental global energy demand will come mainly from the developing world, with the residential sector being

1. This Chapter is based on Jimenez and Yépez-García (2017).

a central player (BP 2016; Wolfram, Shelef, and Gertler 2012). However, relatively fewer studies have focused on the household sector in LAC, a region that has experienced dynamic economic progress in recent decades (see Navajas, 2009, for the case of gas in Argentina, and Foster, Tre, and Wodon 2000, for overall energy consumption in Guatemala). In a related multi-country study that includes Brazil, Winkler et al. (2010) discuss trends in access and affordability of electricity services, emphasizing the increasing policy relevance of the latter for tackling energy poverty.

A line of study that has received noticeably less attention focuses on economies of scale in energy consumption. Economies of scale are of interest in the broader literature studying household budget allocation (Benus, Kmenta, and Shapiro 1976; Nelson 1988; Deaton and Paxson 1998). And as an extension of this literature, the presence of economies of scale is plausible for energy consumption, with relevant policy implications. Economies of scale can appear in different ways – for example, the consumption of cooking fuels may increase less than proportionally to family size. Electricity and gas consumption for lighting and heating/cooling may increase linearly with dwelling size. To the best of our knowledge, only economies of scale from family age composition – over residential energy use and expenditure – has been studied by Ironmonger, Aitken, and Erbas (1995) for Australia, and by Underwood and Zahran (2015) for the United States. The authors find significant economies of scale, but at the same time note that the observed trends toward smaller family size would outweigh such effects, placing upward pressure on carbon dioxide emissions.

An Empirical Approach to Understanding Household Energy Spending

This section follows a standard regression analysis to study the relationship between energy expenditures and income. Closely following Meier, Jamasb, and Orea (2013), the baseline specification is:

6.1

$$lnE_h = \ln f(Y_h,\alpha) + \beta X_h + I_h + Y_c + \varepsilon_h.$$

The main dependent variables (E_h) are expenditures and share of expenditures for each specific energy source. The main independent variable is given by $f(Y_h,\alpha)$, representing a functional form of income that captures potential nonlinearities in the relationship between energy and income. Therefore, α is the vector of the parameters of interest. In the parametric setting, $f(\bullet)$ has been specified in the literature as a second- and third-order function (Banks, Blundell, and Lewbel 1997; Jamasb and Meier 2010). We follow the previous practice using cross-validation procedures to find the most suitable functional form for each energy source. This is an important distinction, as the relationship between energy expenditures and income may depend on the actual energy type. In a parametric setting, the best fit was found to be a third-degree polynomial for all energy sources, except for the transport energy share, for which the best fit was a second-degree polynomial (see Appendix 6.1 and 6.2 for details).

We also include a set of covariates (X_h) that may affect energy consumption and expenditure, including household size, urban/rural geographic distribution, number of rooms in a dwelling, appliance ownership, and vehicle ownership. The inclusion of these covariates is expected to mostly capture demand for energy. However, the inclusion of these covariates also means that some countries must be left out because of a lack of available information (see the next section on data).

An important potential drawback of the specification is that we do not have information on the energy prices paid by end users. Such information is only available at the country-aggregate level, so including those average prices would only capture cross-country variations and could be a noisy measure, as prices may differ significantly within countries. Price variation occurs because most energy pricing mechanisms take into account consumption levels and urban/rural settings, among other factors, thereby leading to heterogeneity in final prices across households. This is a context in which average national energy prices are not very informative, particularly when they deal with cross-sectional data.[2] To minimize this problem, we take advantage of the detailed geographical information provided in the data. This information is translated into fixed effects (I_h) indicating the specific location of each household in each country. A total of 10,700 locations were accounted for, representing high-dimensional fixed effects expected to capture more detailed data on the potential exposure to different energy prices and other location-specific effects, such as temperature and the quality of energy services (e.g., continuity of supply). We also include year dummies to capture the potential differential effects that may be associated with the different years in which the surveys were conducted.

The location variables, however, may not completely allow for identifying differences in energy prices paid by end users. For example, in the case of electricity, tariffs can be based on consumption bands instead of geographical location. Energy prices (such as prices of domestic gas or prices of gasoline) may depend on the choice of supplier (or brand) or payment method (for example, credit). Since those differences may be interpreted as measurement error, we follow Meier, Jamasb, and Orea (2013), who use the average annual prices and a proxy variable to control for systematic deviations using the following decomposition of the price vector:

6.2

$$lnP_h = ln\left(\frac{P_h}{P_L}\right) + ln\left(\frac{P_L}{P_t}\right) + lnP_t,$$

2. Including country-average price data here may lead to significant measurement error (*me*) and, thus, biased estimates. That is, if *me* is correlated with income or with other household characteristics, it will bias all the estimated parameters ($\hat{\alpha},\hat{\beta}$). The location parameter, among others, may capture the effect of prices, in which case we would not be able to identify the price effects.

A number of factors impact households' energy spending.

household location (urban/rural) and **appliance ownership** explain more than **50%** of energy expenditures.

where P_h is the actual price paid by the household, P_L is the price common to a location or area of a given household, and P_t is the average annual price. We can include the price vector in our previous specification and rewrite it as follows:

6.3

$$\ln E_h = \ln f(Y_h, \alpha) + \beta X_h + \gamma \ln P_t + \gamma \left[\ln\left(\frac{P_h}{P_L}\right) + \ln\left(\frac{P_L}{P_t}\right)\right] + I_h + \varepsilon_h$$

where the terms in brackets represent the measurement error. As those terms are not observed, Meier, Jamasb, and Orea (2013) use the household income per capita differences as a proxy (these differences are calculated from the surveys). Notice that the second term – in brackets – will be absorbed by our location fixed effects. Therefore, in our case, we are left to correct the income difference within each geographic location. Note that this correction term is not of primary interest in the analysis; rather, it is mainly used to attempt to clear up the omitted variable problem in the estimation of α .

While it is expected that the inclusion of the covariates and the high-dimensional fixed effects helps to clear up the relationship between energy and income, omitting the potential confounding variables means that we are not addressing other potentially important econometric problems, such as income endogeneity, measurement error (of household expenditures), and sample selection.[3] Therefore, we prefer to interpret the estimation as a conditional means of, rather than give it a causal interpretation.

Data

From the 20 countries for which we have information on energy expenditures, 13 that offer complete sets of the previously mentioned covariates (X_h). Therefore, the analysis is based on a cross-section of national household expenditure surveys that covers more than 189,000 households in those 13 countries.[4] These surveys are performed by national statistical agencies and were selected because they are specifically designed and implemented to capture household expenditures, as well as their socioeconomic characteristics. The data include only those households that reported expenditures on at least one source of energy. To reduce the presence of outliers, we trimmed the sample by dropping the 1 percent of households at the lowest and highest income and expenditure levels.

Since different products or services have a different periodicity of purchase, the data were multiplied by the corresponding factor to express expenditures in annual terms (i.e., the monthly value would be multiplied by 12). Further, given that national surveys are available for different years, all values were extrapolated to 2014 based on the change in the current household final consumption expenditure per capita (*c*). For example, in the Dominican Republic, where the last survey available is for 2007, all values were multiplied by the factor ***c,14/c,07***. This adjustment accounts for inflation and real growth in residential consumption. The data on households' final consumption were obtained from the World Bank's World Development Indicators database. Note that the extrapolation affects only the absolute expenditure amount, not the expenditure structure. All expenditures are expressed in U.S. dollars and adjusted for purchasing power parity (PPP), using official average exchange rates and PPP conversion factors for private consumption from the World Development Indicators. Similarly, the population sample weights in the surveys were updated to account for population growth in urban and rural areas. That is, for years prior to 2014, the weights were adjusted for the annual rate of growth of the urban and rural population.

Harmonization of the income and expenditure headings closely follows the International Comparison Program classification, which is broadly used in national household surveys. This classification allows for a whole picture of the household budget and income structure by relevant items/sources. However, to reduce potential measurement problems and to reflect household economic conditions, instead of income, we use total annual spending as the main dependent variable. This variable was constructed using the same expenditure headings for all countries: food, dwelling maintenance, transportation, communications, entertainment, clothing, health, education, and other monthly expenditures.[5] In the analysis, income groups (i.e., quintiles and deciles) are defined based on the distribution of per capita household expenditure within each country. In the case of energy commodities, we distinguish between domestic energy and transport fuel. Domestic energy includes electricity, natural gas, and other fuels (such as wood, coal, and kerosene). Transport fuel aggregates all fuels reported by the household, including gasoline, diesel, and liquefied petroleum gas, among others.[6]

3. Two issues may affect the reliability of the estimated parameters: the presence of zero values in the dependent variable, and measurement error in prices. The dependent variable may be zero for three possible reasons: (1) non-consumption; (2) no recall of information for the survey, known as infrequency of purchase; and (3) omitted response during the survey. The last two reasons could lead to inconsistently estimated relationships and, therefore, a lack of external validity due to the censored nature of the data. See Nicoletti and Peracchi (2005) and De Luca and Peracchi (2012) for a discussion of estimation issues for Engel expenditure curves. Under reasons (2) and (3), expenditure becomes a latent variable, and its cause is difficult to determine. Here, we assume that (2) and (3) are not systematic in our data, which is a common implicit practice in several applications (Foster, Tre, and Wodon 2000; Meier, Jamasb, and Orea 2013).

4. The countries included in this data set are Bolivia, Brazil, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Peru, Paraguay, and Uruguay. Other countries were dropped because of lack of some covariates.

5. This measure of total household expenditure includes monetary and nonmonetary reported consumption. Nonmonetary consumption includes in-kind donations, payments or subsidies, and so forth.

6. It is not possible to separate expenditures homogeneously by product or even category across all countries. Therefore, expenditures on gas and electricity include associated expenditures, such as the purchase and installation of meters, meter reading, storage containers, and outstanding charges. In the case of Bolivia, Honduras, and Nicaragua, information on transport fuel expenditures aggregates all transport fuels into one category.

Table 6.1: Summary Statistics of Households Characteristics

Variable	Obs	Mean	SD
Share of electricity expenditures	164,554	3.60	3.72
Share of household domestic gas expenditures	145,058	2.23	2.61
Share of expenditures on other domestic fuels	26,172	3.08	4.56
Share of transportation expenditures	54,518	7.42	6.67
Annual household expenditures on electricity (PPP US$)	164,554	493	571
Annual household expenditures on domestic gas (PPP US$)	145,058	237	204
Annual household expenditures on other fuels (PPP US$)	26,172	232	355
Annual household expenditures on transportation fuels (PPP US$)	54,518	1,709	2,033
Annual household total expenditures (PPP US$)	189,555	23,439	638,403
Area of habitation (rural/urban; urban=1, %)	189,555	0.72	0.45
Household size	189,555	3.80	1.96
Dwelling Size (total number of rooms)	189,555	4.03	2.50
Ownership of a refrigerator (%)	189,555	0.73	0.45
Ownership of a computer (%)	189,555	0.24	0.43
Ownership of a TV (%)	189,555	0.88	0.33
Ownership of an automobile (%)	189,555	0.20	0.41
Ownership of the dwelling (%)	189,555	0.70	0.46
Education level (from 1=incomplete primary or less to 6=university or higher)	189,555	2.85	1.32
Age of the household head	189,554	48.38	15.86
Gender of the household head (male=1, %)	189,555	0.72	0.45

Source: Adapted from Jimenez and Yépez-García (2017) with household survey data from Bolivia, Brazil, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Peru, Paraguay, and Uruguay.

Note: PPP: purchasing power parity; SD: standard deviation.

Other socioeconomic characteristics were selected based on the literature. Table 6.1 presents the descriptive statistics. The table shows that traditional energy sources have a very low representation in the family budget. Since those are mostly noncommercial energy sources, it is difficult to capture their value in expenditure surveys; therefore, we focus the regression analysis on commercial energy sources: electricity, gas, and fuels for private transportation.

With regard to domestic gas, it is important to mention that, in this sample, the reported expenditures do not distinguish between bottled versus network gas. However, network gas is only present in Brazil, Mexico, and Peru, and has a small market share. For example, in Brazil, the residential sector accounted for around 1.4 percent of consumption of natural gas in 2015 (according to the country's national energy balance). Further, less than 1 percent of households in the survey under analysis have piped connections. This implies that even if one were to distinguish the type of domestic gas, there would be a very small sample to perform the analysis.

Determinants of Household Energy Spending

Tables 6.2 and 6.3 summarize the results of regressing equation 6.3 for energy spending and energy share of total household expenditure, respectively. Conditional on the set of covariates, the relationship between energy expenditure/share and income is assumed to be linear. Then, the returned coefficient represents the average income elasticity of energy expenditure/share for the pooled sample.

Overall, the results indicate that household characteristics play a significant role and operate in an expected fashion in determining energy spending, although with relevant distinctions between fuels. With respect to energy expenditures (Table 6.2), the highest sensitivity to an income change is for transport fuels (0.67 elasticity), followed by electricity (0.39) and domestic gas (0.19). However, although spending on transport fuel increases the most with income, the energy share estimates (Table 6.3) indicate that its budget weight decreases. In other words, on average, expenditure on all fuels increases at a lower rate than income does.

The direction of the estimated coefficients for urban/rural location also depends on the specific fuel. But overall, urban households tend to spend more on and have a higher energy weight in their budgets (column 1 in Tables 6.2 and 6.3). This result seems to derive mainly from electricity expenditure, which represents an additional 0.89 percent of the budget for urban households, or 30 percent more annual expenditures (column 2 in Tables 6.2 and 6.3). Taking as a reference unconditional rural average electricity expenditures, this means additional spending of around US$100. The association with domestic gas is quite small and less clear. Families living in urban areas spend 1.5 percent less on domestic gas than families in rural areas, although the coefficient is only weakly significant (Table 6.2, column 3). In contrast, in the budget share regression, the estimated coefficient is positive and strongly significant, indicating that the share of gas is 0.2 percent higher in urban areas (Table 6.3, column 3).

With respect to transport fuels, differences by urban/rural areas are also small. Compared with rural households, urban ones tend to spend 7 percent less on transport fuels, with an associated 0.3 percent lower share of their budget. Recall that

More appliances lead to higher household electricity expenditure.

Having a refrigerator, computer and TV lead to **an increase of 30.8, 13.8 and 11.3 percent, respectively.**

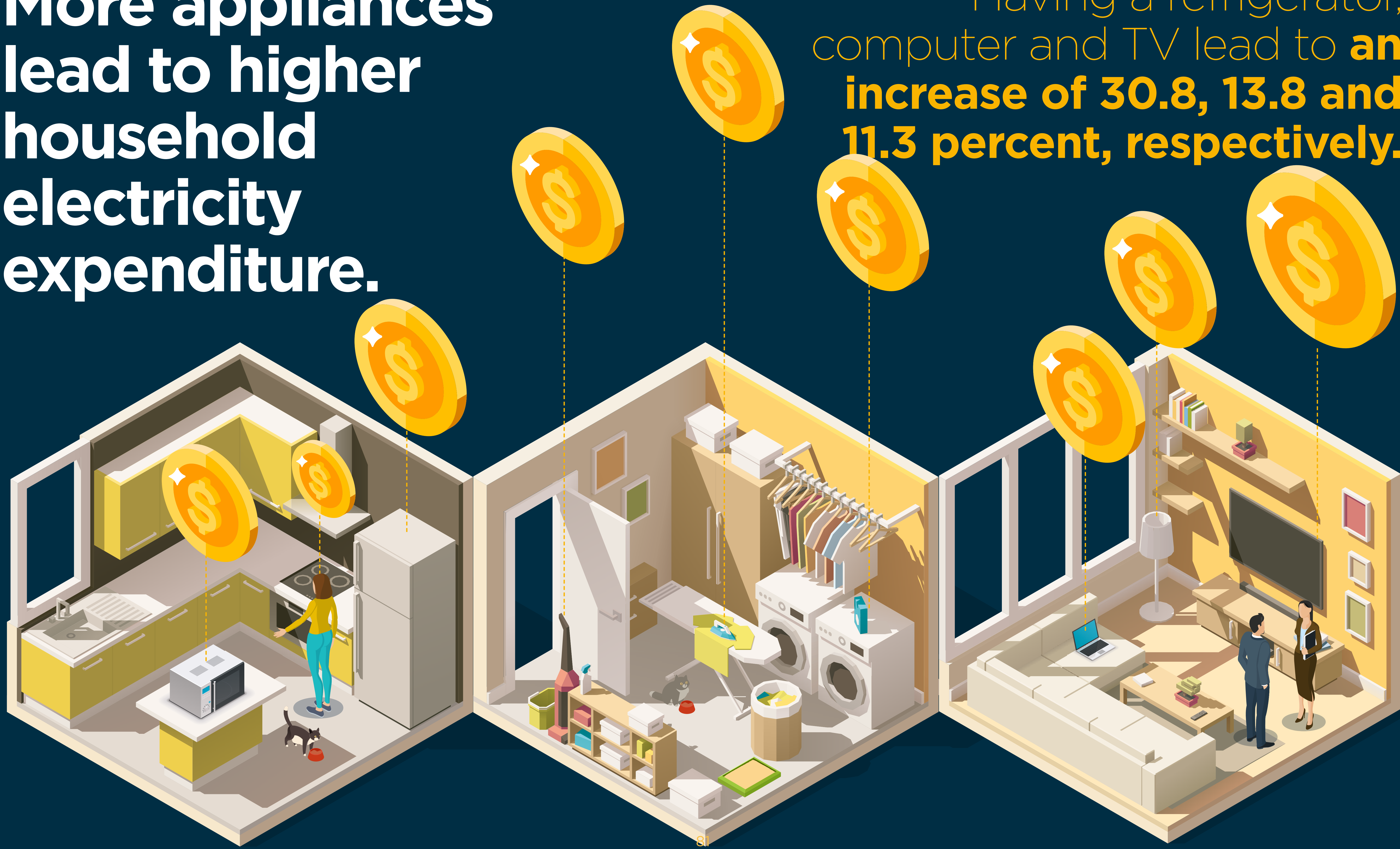


Table 6.2: Energy Expenditure Regressions, Pooled Sample

	Dependent: Ln(expenditure in..)			
	All	**Electricity**	**Gas**	**Transport Fuels**
	(1)	**(2)**	**(3)**	**(4)**
Ln(household expenditure)	0.636***	0.386***	0.192***	0.667***
	(0.019)	(0.016)	(0.014)	(0.034)
Urban=1, Rural=0	0.765***	0.297***	-0.015*	-0.055**
	(0.021)	(0.010)	(0.007)	(0.021)
Number of children	0.016	0.033***	0.032***	-0.045**
	(0.010)	(0.008)	(0.007)	(0.016)
Number of children squared	-0.010***	-0.005**	-0.002	0.005
	(0.002)	(0.002)	(0.001)	(0.003)
Number of hh members older than 12	0.086***	0.102***	0.127***	-0.032
	(0.014)	(0.012)	(0.010)	(0.025)
Number of hh members older than 12, squared	-0.010***	-0.010***	-0.011***	-0.001
	(0.001)	(0.001)	(0.001)	(0.003)
Number of rooms in the dwelling	0.108***	0.068***	0.022***	0.027***
	(0.006)	(0.004)	(0.003)	(0.008)
Number of rooms in the dwelling, squared	-0.005***	-0.001***	-0.001*	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
Ownership of a refrigerator	0.409***	0.308***	0.044***	-0.003
	(0.014)	(0.011)	(0.008)	(0.022)
Ownership of a computer	0.051***	0.138***	-0.009	0.008
	(0.010)	(0.008)	(0.007)	(0.014)
Ownership of a TV	0.546***	0.113***	0.007	0.005
	(0.020)	(0.012)	(0.010)	(0.026)
Ownership of an automobile	0.666***	0.081***	0.009	0.305***
	(0.010)	(0.009)	(0.007)	(0.014)
Ownership of the dwelling	0.065***	0.038***	0.020**	0.007
	(0.009)	(0.008)	(0.006)	(0.015)
ywithin	-0.135***	-0.261***	-0.180***	-0.025
	(0.040)	(0.033)	(0.029)	(0.063)
Education level of the hh head	0.039***	0.023***	-0.003	0.014**
	(0.003)	(0.003)	(0.002)	(0.005)
Age of the household head	0.003***	0.004***	0.004***	0.001*
	(0.000)	(0.000)	(0.000)	(0.001)
Gender of household head	0.066***	-0.018**	-0.011*	0.098***
	(0.008)	(0.007)	(0.006)	(0.015)
Observations	189554	164554	145058	54518
Adjusted R-squared	0.624	0.624	0.552	0.544

Source: Jimenez and Yépez-García (2017) with household survey data from Bolivia, Brazil, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Peru, Paraguay, and Uruguay.

Table 6.3: Energy Budget Share Regressions, Pooled Sample

	Dependent: Income Share of ...			
	All	Electricity	Gas	Transport Fuels
	(1)	(2)	(3)	(4)
Ln(household expenditure)	-3.232***	-3.256***	-2.949***	-2.478***
	(0.147)	(0.106)	(0.067)	(0.297)
Urban=1, Rural=0	1.627***	0.889***	0.244***	-0.172
	(0.071)	(0.044)	(0.029)	(0.159)
Number of children	0.140*	0.491***	0.340***	-0.399**
	(0.071)	(0.046)	(0.026)	(0.143)
Number of children squared	-0.020	-0.048***	-0.031***	0.052
	(0.014)	(0.010)	(0.005)	(0.027)
Number of hh members older than 12	0.770***	0.928***	0.670***	-0.394
	(0.098)	(0.066)	(0.040)	(0.209)
Number of hh members older than 12, squared	-0.075***	-0.068***	-0.054***	0.013
	(0.010)	(0.006)	(0.004)	(0.022)
Number of rooms in the dwelling	0.574***	0.224***	0.035*	0.187**
	(0.036)	(0.016)	(0.016)	(0.068)
Number of rooms in the dwelling, squared	-0.025***	-0.005***	0.004***	-0.006
	(0.002)	(0.001)	(0.001)	(0.004)
Ownership of a refrigerator	1.620***	0.858***	0.074*	0.086
	(0.084)	(0.055)	(0.036)	(0.197)
Ownership of a computer	0.294***	0.411***	0.164***	-0.075
	(0.081)	(0.033)	(0.022)	(0.133)
Ownership of a TV	1.177***	0.312***	-0.130*	-0.059
	(0.102)	(0.060)	(0.056)	(0.266)
Ownership of an automobile	5.389***	0.272***	0.279***	1.803***
	(0.088)	(0.035)	(0.024)	(0.129)
Ownership of the dwelling	0.409***	0.068*	0.071***	-0.078
	(0.065)	(0.031)	(0.021)	(0.130)
ywithin	0.624*	1.796***	1.680***	0.030
	(0.293)	(0.191)	(0.114)	(0.529)
Education level of the hh head	0.173***	0.079***	-0.031***	0.066
	(0.025)	(0.011)	(0.008)	(0.044)
Age of the household head	0.016***	0.011***	0.013***	0.016***
	(0.002)	(0.001)	(0.001)	(0.005)
Gender of household head	0.634***	-0.074*	-0.021	0.665***
	(0.059)	(0.030)	(0.022)	(0.129)
Observations	189554	164554	145058	54518
Adjusted R-squared	0.321	0.378	0.582	0.277

Note: Robust standard errors in parentheses. Estimations based on households with positive reported energy expenditures. ywithin captures energy prices measurement errors. Regressions are weighted by the population expansion factor. Statistical significance at *<0.1, **<0.05, and ***<0.01. All regressions contain household location dummies.

these estimations are conditional on having positive energy expenditure. Unconditional estimates usually show that in urban areas liquid fuel expenditures tend to be higher because such computations include zero expenditures, of which urban households tend to have a lower proportion.

The ownership of appliances – refrigerators, computers, and TVs – is strongly correlated with higher electricity expenditure and the share of electricity in the household budget. Consistent with the extensively documented role of these appliances in increasing energy consumption, our estimates indicate that having a refrigerator, computer, and TV lead to percentual increments in energy expenditure (and shares) by about 30.8 (0.86), 13.8 (0.41), and 11.3 (0.31), respectively. Interestingly, these estimates are greater than the marginal income effect. In the case of domestic gas or transport fuels, as would be expected, having appliances is not systematically related to the within-households energy expenditures or shares, suggesting independence between both categories of energy services and goods.

As in Meier, Jamasb, and Orea (2013), the variable that is intended to capture measurement error in individual energy prices is statically significant for all domestic fuels, with the expected negative sign. That is, *ywithin* seems to work in capturing price differentials within an area of residence, in the sense that it echoes higher prices faced by end users, having a negative effect on energy expenditures. In addition, and in a symmetric way for the case of energy budget share as the dependent variable, our estimated coefficients for *ywithin* are positive and significant for domestic fuels. That is, *ywithin* would be positively associated with the weight of energy consumption in the household budget, suggesting that electricity and gas are necessity goods. The results are not significant in the case of transport fuels, which may be explained by the fact that their prices tend to have lower spatial variability.

Economies of Scale on Household Energy Spending

For family age composition, the results strongly suggest the prevalence of economies of scale with respect to domestic energy (i.e., electricity and domestic gas). For those fuels, all first-degree terms relating to the age distribution of the family – number of children and number of household members older than 12 – are positive, indicating that greater household size tends to be associated with higher energy expenditures, as well as a higher energy share. All the quadratic terms have a negative sign, reflecting the realization of economies of scale in energy expenditures. The fact that the quadratic terms are negative and statistically significant in the energy share regression indicates that those economies of scale are quite relevant for the structure of household budgets. In contrast, expenditure on and share of transport fuels appear not to be systematically correlated with household age composition – that is, they do not exhibit economies of scale. These findings are consistent with those of Ironmonger, Aitken, and Erbas (1995) and Underwood and Zahran (2015), who suggest that the global trend toward smaller family size may offset the potential gains in energy efficiency.

Economies of scale can also be seen with respect to dwelling size for electricity spending and its budget share. As expected, there is a positive association with the number of rooms in the dwelling, while the coefficient for the squared variable, although near zero, is statically significant and has a negative sign. This suggests the presence of some energy savings with incremental dwelling size. In the case of domestic gas, the estimations are less clear, with economies of scale for expenditures but diseconomies of scale in budget share. With respect to transport fuel, as is a priori expected, the results do not show an association with number of rooms.

A related question is whether these economies of scale differ between rich and poor. We evaluate this by interacting three income groups (first income group = deciles 1 to 3 (poorest groups), second = deciles 4 to 6, and third = deciles 7 to 10 (wealthier groups)) with the variables family and dwelling size. Figure 6.1 presents the estimated marginal effects of electricity and gas expenditure. In the case of domestic gas, the intensity of economies of scale appears to be the same among the three income groups. In the case of electricity, economies of scale of dwelling size also seems to behave in a similar way, but economies of scale of family size seems to be more pronounced for the richest group, emerging for families with more than six members.

Energy Engel Curves

This section examines the shape of the relationship between energy expenditure/share and household income. For these estimations, in equation 6.3 we specify with the best fit polynomial for each fuel, controlling for the same set of covariates as in the other regressions. Figure 6.2 presents the conditional predicted energy expenditures (panel a) and energy shares (panel b) along the income distribution of the sample. These curves are typically referred to as conditional Engel curves.

The conditional predicted energy expenditure monotonically increases with income, shaping a linear relationship with a relatively tight 95 percent confidence interval. According to these estimations, greater differences are found in transport spending, as the corresponding Engel curve has a steeper slope than for electricity and gas.

Although energy expenditures increase with income, panel b shows that there is a large decrease in their budget weight as families become wealthier. As in panel a, the 95 percent confidence interval is relatively tight, suggesting low heterogeneity across households within each income group. Despite poorer households having lower energy expenditures, they comprise a larger share of household income, implying pronounced affordability problems. All else being constant, expenditure on electricity and gas at the lower income deciles tends to represent between 6 and 12 percent of household budgets.

These patterns also prevail for transport fuel. This finding is in contrast with Figure 6.1, where the share of transport fuels increases with income. However, Figure 6.1 showed unconditional averages by income group, which do not account for other covariates such as household size or ownership of vehicles, among others. The estimated curves in Figure 6.2 represent the net correlation between energy expenditures/shares and household income conditional on all the covariates, and therefore offer a better approximation of the true association between those variables.[7] We interpret the differences between the conditional and unconditional transport fuel shares as being a result of significant heterogeneity in the values of the covariates between income groups. In other words, conditional on household members being actual users of transport fuels (i.e., car owners), the share of expenditures on those fuels decreases for richer households.

7. For these predictions, all the covariates are set to their average values.

Evidence shows that LAC residential energy expenditures increase with income however, we observed a large decrease in their budget weight as families become wealthier.

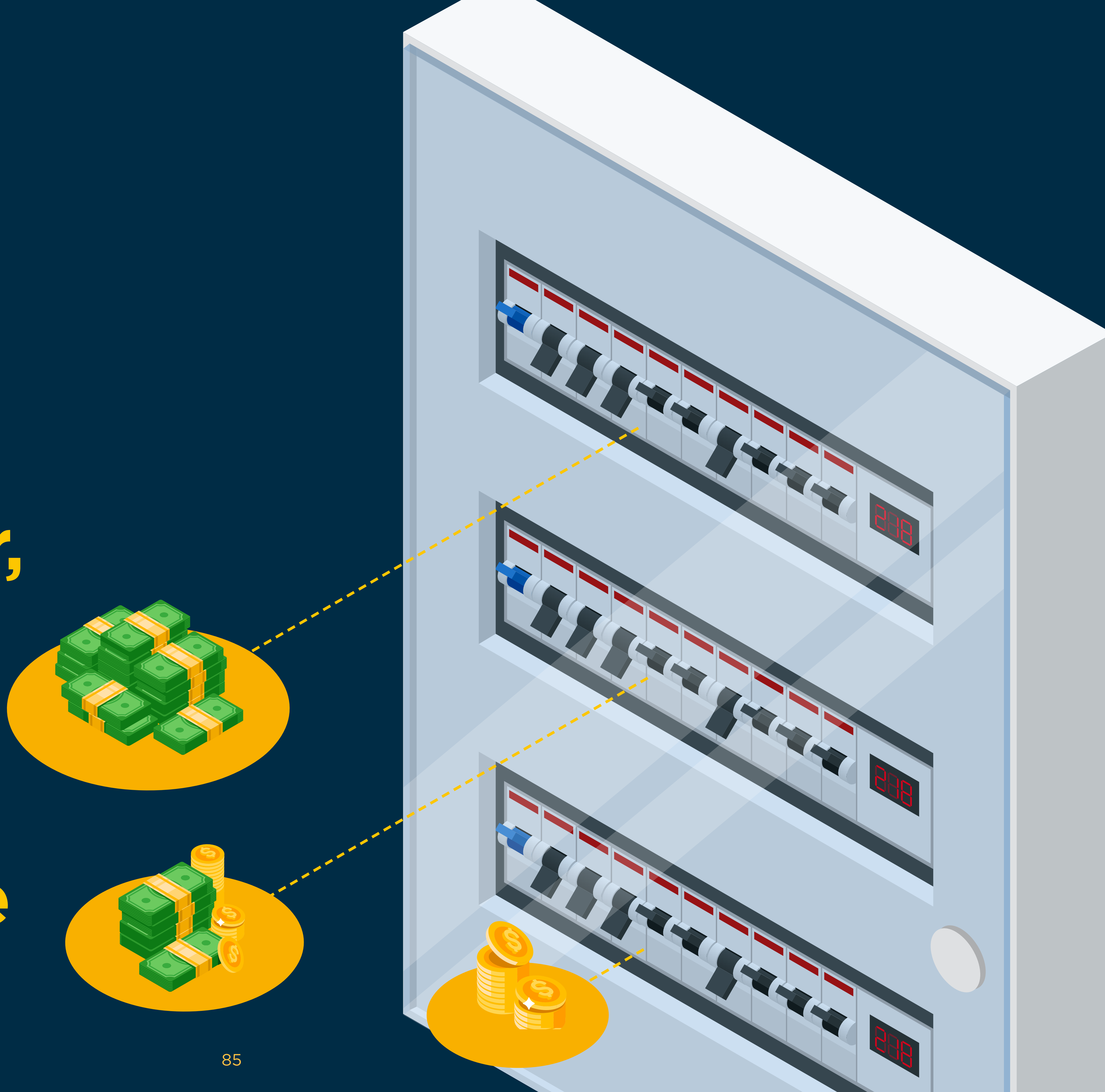


Figure 6.1: Economies of Scale of Household Size and Dwelling Size, by Income Group

Adjusted Predictions with 95% CIs ● incgroup=1 ● incgroup=2 ● incgroup=3

Source: Jimenez and Yépez-García (2017) with household survey data from Bolivia, Brazil, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Peru, Paraguay, and Uruguay.

Note: Incgroup = 1 includes income deciles 1 to 3; Incgroup = 2 includes income deciles 4 to 6; Incgroup = 3 includes income deciles 7 to 10. CIs: confidence intervals.

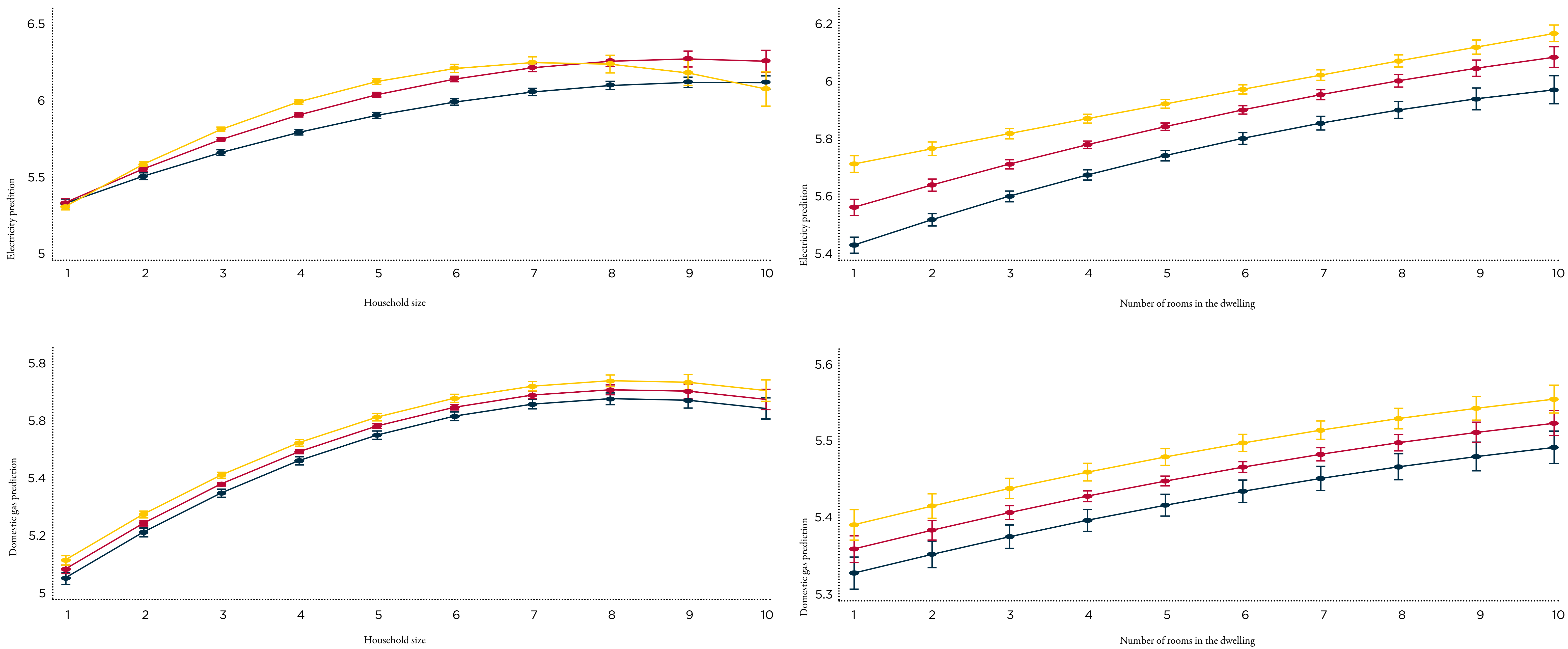
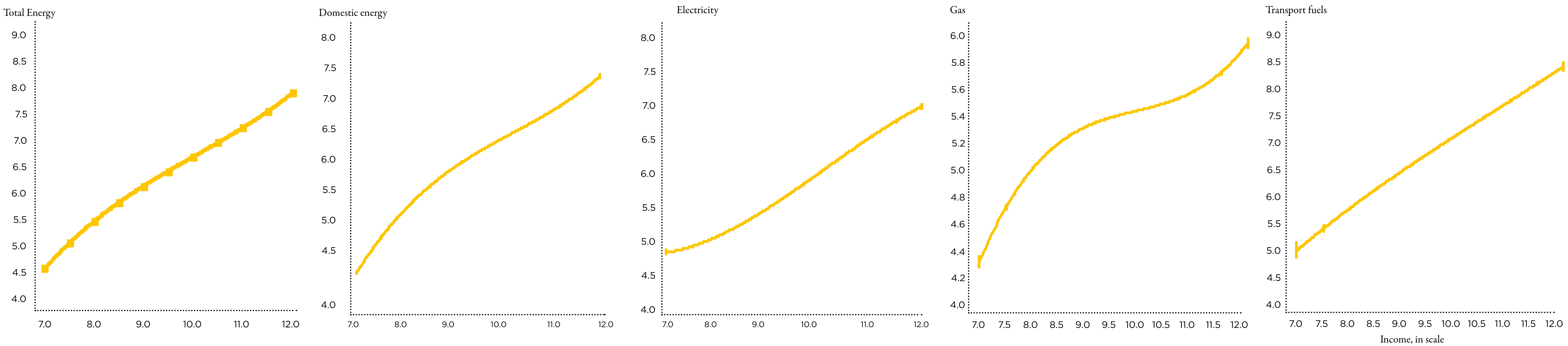
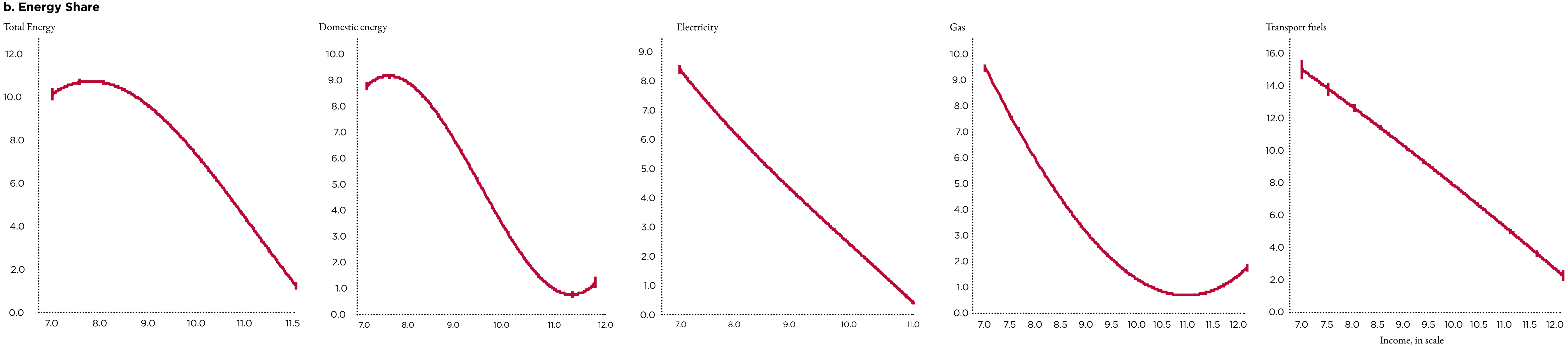


Figure 6.2: Conditional Energy Curves

a. Energy Expenditure



b. Energy Share



Source: Jimenez and Yépez-García (2017) with household survey data from Bolivia, Brazil, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Peru, Paraguay, and Uruguay.

Note: In panel a, the y axis is energy expenditures in a natural logarithm scale. In panel b, the y axis is energy expenditure as a percentage of the household budget.

Part IV

Beyond Income: Energy Prices, Subsidies, and Efficiency

Chapter 7

How Electricity Pricing and Subsidies Incentivize Consumption[1]

The role of energy prices in determining energy consumption is one of the most relevant topics in energy policy. Particularly in the case of electricity, tariffs are subject to substantial regulation directed toward multiple market and policy targets. Featured markedly among these are cost recovery of supplying electricity services, ensuring affordability for minimum levels of electricity consumption, and providing incentives for energy savings. The trade-offs are visible in, for instance, prices that ensure affordability but are too low and thus may also endanger the financial sustainability of the system and induce overconsumption. Over time such a situation could result in heavy energy dependence linked to high long-term rates of energy consumption growth, thus impacting decision-making regarding investments and the use of natural resources. Energy efficiency is indeed a delicate balance that at times has proven challenging and in many cases has required urgent interventions.

This chapter briefly presents the conceptual challenges of price formation in electricity markets and, within that framework, reviews residential electricity tariff schemes in Latin America and the Caribbean (LAC). The chapter focuses on three interrelated aspects that are central to energy tariffs in the region: (1) their levels for cost recovery, (2) their benefits in terms of facilitating service affordability, and (3) their capacity to promote sustainable energy consumption (e.g., energy saving and penetration of renewables). In this context, the chapter also discusses subsidies for electricity services that are delivered indirectly through tariffs and directly either as a discount on tariffs or as a cash transfer.

The review suggests that there is significant room to improve how electricity tariffs are determined and how subsidies are implemented. Although heterogeneous, the performance of electricity tariff schemes in the region seems to be prone to severe financial sustainability problems in several countries, while potentially inducing overconsumption. Furthermore, tariff subsidies tend to have distortionary effects on the efficient functioning of electricity markets and are expensive and suboptimal as means to ensure affordability for the poorest families. On the other hand, there are successful experiences and good practices that may serve as references for improvement.

A Conceptual Framework for Electricity Price Formation: Balancing Economic Efficiency and Equity

Electricity supply is characterized by a number of peculiarities that justify market regulation. First, providing electricity is subject to large fixed costs that mainly occur in the generation and distribution subsectors. This characteristic implies a failure to find an equilibrium between the marginal cost of providing the service and the long-run price, resulting in the presence of natural monopolies that may potentially lead to an imbalance in market power between suppliers. Second, seasonality affects the dynamics of supply and demand such that generation capacities have very different marginal costs (either on an intra-day, week-ahead, or intra-year basis). Third, supplying electricity is subject to the presence of negative externalities that need to be incorporated into electricity prices to internalize or approximate the social-environmental cost of providing the services (Borenstein 2016).

On the other hand, the establishment of tariff schemes by regulators faces the challenge of balancing these technical aspects with policy objectives such as guaranteeing the quality and affordability of electricity services and increasing the share of renewables in electricity generation. In practice, market balances may differ greatly from the textbook solution of matching the price of the electricity tariff with the marginal social cost at each kWh. Figure 7.1 illustrates the welfare losses of setting electricity prices above or below the marginal social cost. In the first case (the red area), the supplier guarantees to cover the costs of offering the service. However, losses in economic efficiency emerge due to unrealized consumption. For example, prices above the marginal social cost can lead to affordability problems in lower-income households, or they can reduce the penetration of electric vehicles. In the second case, prices below the marginal social cost potentially incentivize overconsumption and discourage the adoption of efficient equipment (gray area).

There are several tariff schemes aimed at minimizing these losses of economic efficiency that establish different incentive structures for energy consumption. Examples of such schemes include the following:[2]

- ***Price based on average cost: Under this scheme, the price is fixed and based on the average cost per kWh.*** In other words, the price includes fixed and variable costs such that the high fixed costs are distributed symmetrically by the level of electricity consumption among all end users. This setting is sufficiently straightforward for consumers to understand and simple to implement. However, it may lead to underconsumption, particularly in lower income groups facing a relatively high fixed cost component.
- ***Nonlinear block pricing: This scheme establishes rates per consumption bands.*** Currently, most electricity systems apply increasing block pricing, where electricity tariffs increase with consumption blocks. This scheme is attractive from a perspective of equity because lower-income households fall in the lower bands. Likewise, this scheme should encourage lower levels of consumption, as higher consumption will be priced correspondingly. Two approaches are usually applied to calculate the bill for total consumption: increasing block tariffs (IBT), and volumetric block tariffs (VDT). Under the IBT approach, each quantity consumed is charged at the corresponding rate, such that the final invoice represents a weighted sum. Under the VDT approach, the rate applied for all the units consumed is determined by the block corresponding to total consumption (i.e., rates corresponding to lower blocks are not taken into account as in the case of the IBT).

1. This chapter was jointly written by Raul Jimenez Mori and Jorge Mercado.

2. See Borenstein (2016) and ICF International (2015) for discussions on tariffs schemes. For a detailed discussion on the economics of electricity tariff formation, see Vogt (2017) and Harris (2011).

- ***Dynamic pricing: Under this scheme, the price is aligned with the cost of producing electricity per hour of the day, or per climate season.*** In this way, during peak consumption times, the marginal cost of providing electricity increases, providing incentives to save energy. Unlike the previous schemes, establishing hourly prices not only requires measurement infrastructure, but also smart meters.

- ***Minimum rates: This scheme establishes a minimum amount of payment for the first given amount of kWh consumed, and from this amount a specific tariff per kWh is paid.***

- ***Ramsey pricing: This scheme establishes tariffs based on the price elasticity of demand for electricity.*** Segments with greater demand elasticity pay higher rates. However, user segments with low elasticities are typically those that do not have other consumption options, and for which electricity represents a necessary good. This is typically the case of the residential sector, so this scheme raises equity concerns.

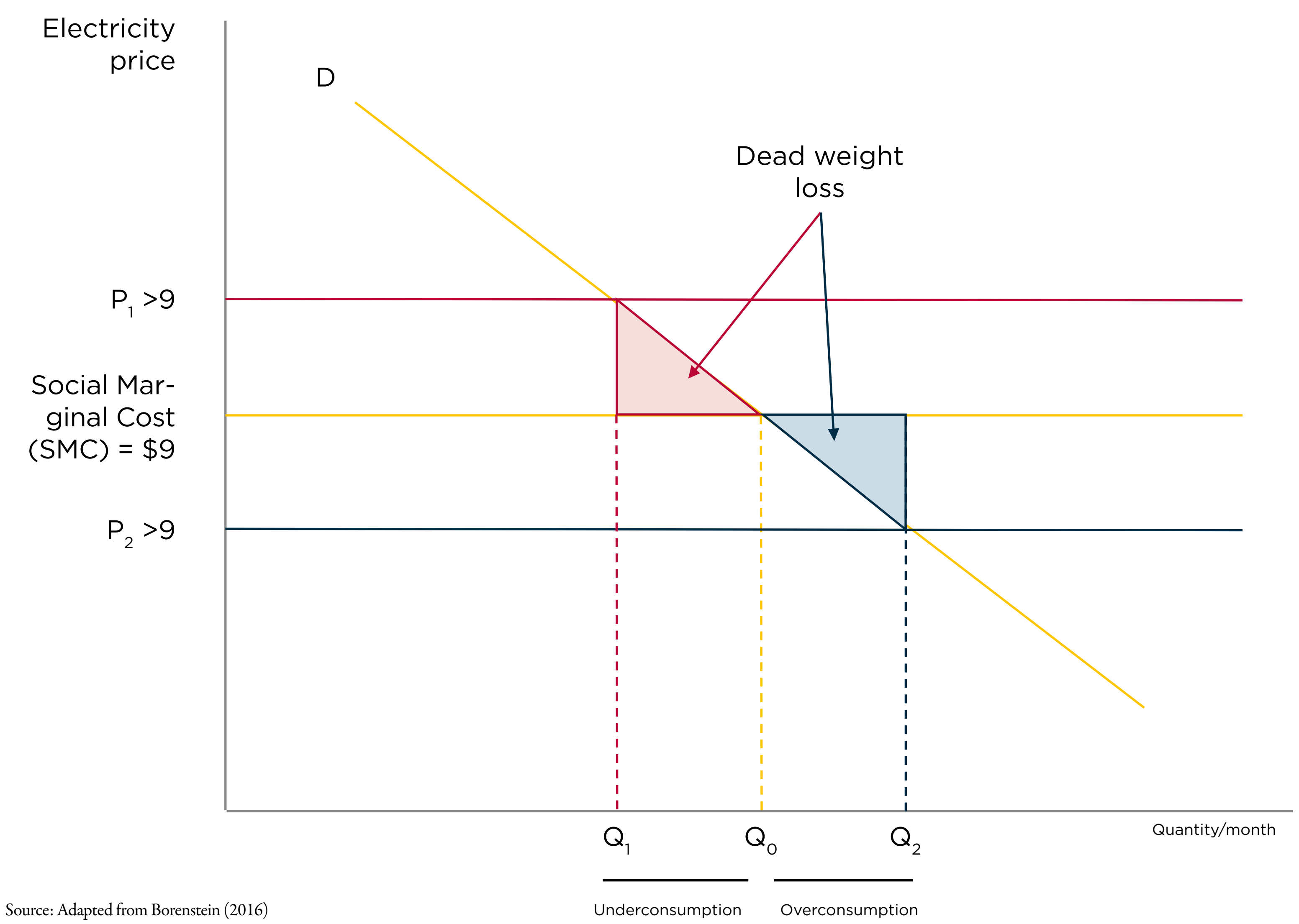
- ***Fixed charges: This refers to a scheme in which users pay a set amount regardless of the magnitude of consumption.*** This scheme can be applied by consumption bands, that is, a higher fixed charge at a higher level of consumption, encouraging users to reduce their consumption or save energy. In practice, however, in LAC countries this scheme it is mostly used among unmetered households. For example, in the Dominican Republic, informal connections are regularized by being charged fixed amounts.[3]

In general, there is no price scheme that guarantees minimizing efficiency losses or achieving complete equity. The net advantages of the different schemes depend on the specific conditions of the supply and demand side of the equation. These aspects include the generation electricity matrix, degree of market competition, household income and location, and institutional capacity for implementation, among others.

One aspect strongly related to institutional capacity is the potential bias of policymakers to disproportionally weight energy poverty concerns in the determination of tariffs. This bias of governments may give place to price distortions and leads to deficiencies in the electricity industry, without achieving egalitarian goals. Energy poverty has multiple dimensions, of which tariffs only represent one. Other dimensions include access, reliability, and quality of electricity services, as well as access to and affordability of other fuels (i.e., for heating and cooking). This points to the need for coordinated energy policies (electricity, domestic gas, and transport fuels), as well as for a clear separation between the search for energy sector efficiency and social targets.

3. The amount is calculated based on appliance ownership and socioeconomic conditions of the household. See Jimenez (2017b) for details.

Figure 7.1: Prices of Electricity and Social Welfare Losses



Source: Adapted from Borenstein (2016)

Electricity Pricing in Practice in Latin America and the Caribbean

Within the previous framework, where do the countries of LAC fall? In general, the practice of tariff formation is far more complex and involves, in several cases, a combination or simultaneous application of different schemes, even within the same sector (in this case, residential). Table 7.1 presents a broad classification of the tariff types currently applied that cover most residential customers in 18 LAC countries. Although this table represents a simplification of current electricity tariff schemes in LAC, it does show that most countries apply some type of nonlinear incremental block pricing, though with significant differences. Across countries, the tariff schemes may vary in complexity, consisting of some combination of systems (IBT and VDT), and may also depend on such factors as the geographical areas where the dwelling is located (urban/rural), or temperatures of a region, among others. For example, in the Dominican Republic, the tariff scheme is IBT, and the bands shown in Table 7.1 cover 90 percent of residential clients. In Guatemala, the tariff scheme is mixed: IBT for consumption less than 100 kWh and VDT for higher consumption. On the other hand, in Chile, electricity tariffs are based on average cost, but they are adjusted similarly to a VDT scheme according to the consumption recorded for each household during the winter season. The heterogeneity becomes much more pronounced in federated countries such as Argentina, Brazil, and Mexico. According to Hancevic and Navajas (2015), the Mexican scheme is probably the most intricate in the region. In this case, the electricity tariff does not depend only on consumption blocks, but also on their price changes depending on the season and recorded temperatures. This in essence represents a cross-subsidy scheme in consumption levels, and across seasons.

Table 7.1 also allows for noting the differences in the amplitude of the consumption bands and in the thresholds that are associated with minimum consumption levels. For example, electricity consumption bands have an amplitude of 300 and 350 kWh/month for the first two tiers, respectively, in Brazil and Panama. In contrast, in Bolivia and Guatemala, the first two consumption bands have an amplitude of 50 kWh/month. Overall, the range of consumption varies widely across countries, but one can see that in one-third of the countries reviewed, the first two tier bands are equal to or greater that 200 kWh.

Regarding thresholds that define the lowest consumption bands, one can see that in Brazil and Peru, the band with the lowest rate has as a cut-off of 30 kWh/month, while in Bolivia, Ecuador, Guatemala and Paraguay the cut-off is 50 kWh/month, and even higher in other countries, where it ranges from 100 up to 200 kWh/month. In general, within the entities in charge of setting tariffs, these minimum levels of electricity consumption are defined by estimating subsistence levels established based on consumption patterns specific to each geographical area. It is interesting to note that this heterogeneity coincides with that observed in the literature that establishes minimum levels of consumption to satisfy households' energy needs (see Table 2.1 in Chapter 2). Such heterogeneity–in the estimated minimum levels of energy consumption– speaks to the diversity of factors and assumptions that can influence energy needs.

Overall, these tariff structures reveal the weight that governments and regulators put on ensuring the affordability of electricity services. For example, in Chile, local regulations require that electricity tariff mechanisms consider the equity dimensions of providing the services, and, in practice, recognize local subsidies in areas were electricity generation takes place, as well as subsidies in the cost of services (Law No. 20,928).

However, the weight that governments put on affordability seems to be associated with excessive and distortionary intervention in electricity markets. The last column of Table 7.1 also indicates whether tariffs are established based on established regulation (nondiscretionary) or if they are subject to government intervention (discretionary). This information was collected from Marchan et al. (2017), and although it corresponds to overall electricity tariffs, it reveals the high levels of political ad hoc interference in the formation of electricity tariffs in the region. In most LAC countries, electricity tariffs are subject to ad hoc government influence at some point of the value chain of electricity services (i.e., generation, transmission, and/or distribution segments). This means that in addition to the technical challenges of setting prices correctly, there are distortions that originate from political interference in the electricity markets. Such interference can take the form of price determination, management of electricity companies, and weak independence of the regulator. For example, Marchan et al. (2017) argue that in 21 of 26 countries in the region, the determination of electricity prices is discretionary – that is, in at least some stage of price formation, there is intervention by the government to influence tariffs.

Ideally, one would expect that the current structure allows for a cross-subsidy between income groups that is progressive and sufficient for the financial sustainability of the electricity system. And to the extent that prices approximate marginal social costs, it would also be expected that they provide the incentives for promoting energy conservation. However, the evidence points in another direction. In practice, nonlinear schemes result in high levels of filtration of rich households in subsidized consumption bands. Tariffs tend to be highly subsidized, typically below cost recovery levels, affecting the financial sustainability of utilities and their investment capacity. Furthermore, electricity tariffs in LAC do not account for externalities in electricity generation, transmission, or distribution.

All in all, this review suggests that electricity prices in most LAC countries are below marginal social costs, thus resulting in a loss of economic efficiency that boosts overconsumption at the expense of reducing the financial sustainability of the sector. From the point of view of the current tariff structures, it seems reasonable to review the amplitude of the consumption bands (which in some countries seem excessively large) as well as the tariffs assigned to each of them.

Social Electricity Tariffs

Implicitly or explicitly, an instrument widely referenced in discussions of affordability is what is known as the

Table 7.1: Tariff Schedules in Latin America and the Caribbean

Source: Prepared by the authors based on information from regulators. The last column comes from Marchan et al. (2017).

Note: IBT: increasing block tariffs; VDT: volumetric block tariffs. Customer (percent of total) account for different classifications across countries. For example, in Argentina, Brazil, Chile and Uruguay, it refers to R1, RC, BT1, and TRS customer-classifications, respectively.

Country	Tariff Scheme	Consumption Blocks (kWh/month)	Customer (percent of total)	Pricing Mechanism
Argentina	IBT	<300; 301-650; 651-800; 801-900; 901-1000; 1001-1200; 1201-1400; 1401-2800; > 2800	70	Discretionary
Bolivia	IBT	<50; 51-140; 141-300; 301-500; > 500		Discretionary
Brazil	VDT (for low income)	<30; 31-100; 101-220; > 220	89.9	Discretionary
Chile	Average cost	However, tariffs are adjusted in summer based on average winter consumption.	97.5	Nondiscretionary
Colombia	IBT (low-income) VBT	<130 (173); > 130 (173). 173kWh for altitude greater than 1,000 meters above sea level. IBT applies to families in the first three socioeconomic strata.		Discretionary
Ecuador	IBT	<50; 51-100; 101-130; 131-150; 151-200; 201-250; 251-500; 501-700; 701-1000		Discretionary
El Salvador	IBT	<99; 100-199; > 200	100	Discretionary
Costa Rica	IBT	0-30 fixed charge; 31-200; 201-300 ; > 300		Nondiscretionary
Guatemala	IBT (<100kWh), VDT (>100kWh)	<50; 51-100; 101-300	89.53	Discretionary
Jamaica	IBT	<100; > 100		Discretionary
Paraguay	VDT	<50; 51-150; 151-300; 301-500; 501-1000; > 1000		Discretionary
Peru	IBT (<100kWh); VBT (> 100kWh)	<30; 31-100; > 100		Discretionary
Dominican Republic	IBT	<200; 201-300; 301-700; > 700	90	Discretionary
Panama	VBT	<300; [300-750]; > 750	98.5	Nondiscretionary
Nicaragua	VBT	<25; 25-50; 50-100; 100-150; 150-500; 500-1000; > 1000		Nondiscretionary
Mexico	IBT	<140; > 140	54.4	Discretionary
Uruguay	IBT	<100; 101-600; > 600	68	Discretionary
Venezuela	IBT	<200; 200-900; > 900		Discretionary

social electricity tariff. These subsidies seek to benefit the most vulnerable groups. Eligibility requirements to be a beneficiary include falling within a socioeconomic profile of social vulnerability. However, this stratification requires the harmonization of customer and household databases, which implies close inter-institutional communication and collaboration between, for example, statistical institutes and agencies in charge of administering the subsidy. For this reason, in several countries the subsidy via the social tariff is granted on the basis of household electricity consumption.

Table 7.2 surveys some of the basic characteristics of social electricity tariffs in LAC, including whether they are explicit (implemented under a law, regulation, or formal program) or implicit (specifically designed to help lower-income families but not enacted as social tariffs beyond IBT). In systems implementing nonlinear tariff schemes, social tariffs are often those corresponding to the lowest levels (blocks) of consumption. For example, in Guatemala, the social tariff was established by law and forms part of the tariff scheme as a block for consumption less than 50kWh. In Peru, the social tariff covers up to the first 100 kWh, including the first 30 kWh subsistence and the next 70 kWh under the IBT system that collects the subsidized rate of the preceding block. In Chile, communities located near electricity generation areas were subsidized.

In other cases, social tariffs are implemented based on socioeconomic characteristics of the families. For example, in Argentina, beneficiaries need to be registered in other social programs, and family income must be less than two minimum legal salaries. Similarly, in Ecuador, households need be identified by the National Department of Statistics as belonging to the two lowest quintiles of the income distribution.

Regarding their financing, social tariffs are financed by cross-subsidies or fiscal transfers. However, when the balance between consumption blocks is not met, the government typically transfers resources to the utilities to cover the gap. Cross-subsidies not only occur within electricity consumption groups within the same client category (e.g. residential) but also may occur across different types of clients (e.g., between residential and industrial end users). For example, in Bolivia subsidies to the lowest electricity consumption bands in the residential sector are financed by mandatory contributions of utilities that operate in the wholesale market.

Dynamic Pricing

Some argue that dynamic or time-varying pricing provides a more efficient way to match supply and demand. Given that electricity remains expensive to store in sufficient magnitudes to balance aggregate demand, hourly pricing helps equalize the marginal cost of generating electricity at different time periods with time-differentiated demand patterns. This characteristic, in turn, helps to smooth demand peaks and reduce long-run investments paths (in generation as well as operation and maintenance) (Borenstein 2016). However, its application in the residential sector is rare, particularly in LAC.

Table 7.3 shows the experience in the surveyed countries where hourly pricing schemes for households are in place. Of the 18 countries reviewed, six (Brazil, Chile, Costa Rica, Guatemala, Panama, and Uruguay) are currently implementing some type of hourly electricity pricing. The share of clients under such tariff schemes is small, less than 0.5 percent in most countries, and 4.74 percent in Uruguay, and this type of tariff structure concentrates a relatively small share of customers worldwide as well. For example, in the United States, the total share of residential customers under dynamic pricing was around 4 percent in 2017.

In general, dynamic pricing is difficult to implement because of concerns regarding exposing end users to excessive price volatility. Also, implementing such scheme implies relying on advanced metering infrastructure, as well as more complex management capacity on the utility side. With technological progress and the reduction of costs of more flexible metering technologies, these barriers are declining. However, they still may constitute a difficult and relatively expensive strategy to implement for small customers in developing countries.

Indeed, in the six cases shown in Table 7.3, the application of time-varying pricing requires that the clients have a single metering system with minimum technical requirements that allow for registering multi-tariffs, or for discerning consumption by time of day. Those technical requirements are for the basic time-of-use approach of dynamic pricing that generally splits consumption into three-time bands: base (off-peak), mid-peak, and peak demand hours within a day. Real-time pricing would require more advanced metering technology, as well as more complex information systems and management capabilities on the utilities side.

A key characteristic of these experiences is that the adoption of time-varying pricing is voluntary. This implies that the take-up of dynamic pricing will depend on incentives regarding costs of services under alternatives tariff schemes. That is, households would re-shape their load consumption profile only under sufficient economic incentives. In LAC, under subsidized and distorted electricity prices, there is no clear incentive for such behavior.

An Approximation of Cost Recovery

In the electricity sector, the price-gap methodology is the standard used to approximate cost recovery levels, as it provides a reference price that includes all costs of providing the services and measures the distance between such benchmarks and the actual price. The price gap methodology has been used in multiple studies for assessing subsidies. Marchan et al. (2017) offer the most recent and specific application to LAC. By assuming revenue neutrality, one could interpret a negative gap between the weighted average electricity price and the reference price not only as indicating the presence of subsidies, but also as a situation wherein the current tariff structure fails to cover overall costs of providing the services. If the tariff scheme allows for recovering costs, in general, one should observe that the reference price matches the weighted price of electricity applied. If not, there will be welfare losses as has been characterized in Figure 7.1.

Table 7.2: Social Electricity Tariff Rates in Latin America and the Caribbean

Country	Social Rate	Description	
Panama	**Explicit**	Covers:	Up to 100 kWh/month
		Requirements:	Clients whose consumption qualifies as basic or subsistence.
		Subsidy:	20 percent of the corresponding value
		Financing:	Cross-subsidy (percentage of monthly billing [0.6 percent] of customers with consumption above 500 kWh/month)
Argentina	**Implicit**	Covers:	Up to 300 kWh/month
		Requirements:	Beneficiaries of social programs, income <2 times the minimum legal salary, retirees, etc.
		Subsidy:	100 percent for <150kWh; 50 percent up to 300kWh
		Financing:	Fiscal transfer
Chile	**Explicit**	Covers:	Does not define a specific consumption limit to finance
		Requirements:	Generation intensity factor of electricity of each commune Percentage of contribution on total energy generated
		Subsidy:	Up to 50 percent for>2000 (kW/No regulated clients) generated, from 4.38 percent for 2.5 to 15 (kW/N)
		Financing	Cross-subsidy
Colombia	**Implicit**	Covers:	130-173 kWh according to the altitude of the city
		Requirements:	Socioeconomic strata 1, 2, or 3
		Subsidy:	20 to 60 percent progressive by stratum
		Financing	Cross-subsidy (strata 5 and 6 subsidize strata 1,2 and 3)
Ecuador	**Explicit**	Covers:	Less than 110 kWh in the Sierra and 130 kWh in the Coast, East, and Insular regions
		Requirements:	Households in income quintiles 1 and 2
		Subsidy:	Difference between the value you would pay without the subsidy (subsidized rate: tariff US$0.04 for consumption, and US$0.71 for commercialization)
		Financing:	Cross-subsidy
Bolivia	**Explicit**	Covers:	Up to 70 kWh/month to users of the interconnected system Up to 30 kWh/month for users of isolated systems
		Requirements:	Consumption less than the minimum
		Subsidy:	Discount of 25 percent average of the current rate
		Financing:	Cross-subsidy (from electricity sales in the wholesale market)
El Salvador	**Implicit**	Covers:	Up to 99 kWh/month
		Requirements:	Socioeconomic characteristics of the families and consumption below 99 kWh
		Subsidy:	For consumption of 1 to 60 kWh, a maximum of US$3; for consumption from 61 kWh to 99 kWh, a maximum of US$4
		Financing	Cross subsidy funded by pool of resources from public entities.

Costa Rica	**Implicit**	Covers:	100 kWh
		Requirements:	Living in a priority district, extreme poverty, vulnerable socioeconomic conditions
		Subsidy:	100 percent for families in extreme poverty and 50 percent for families basic poverty
		Financing:	Percentage of billing surcharge
Brazil	**Explicit**	Covers:	Up to 220 kWh/month
		Requirements:	Residential class of electric power distributors
		Subsidy:	65 percent for consumption <30 kWh; 40 percent for consumption between 30 and 100 kWh; 10 percent for consumption between 100 and 220 kWh
		Financing:	Resources of the Energy Development Account
Guatemala	**Explicit**	Financing:	Up to 50 kWh/month
		Requirements:	Consumption of less than 50 kWh/month.
		Subsidy:	Establishes a special rate for customers with residential consumption less than 50kWh/month.
		Financing:	Resources from the INDE (Instituto Nacional de Electrificacion)
Paraguay	**Explicit**	Financing:	Up to 300 kWh/month
		Requirements:	Voltage line up to 16 amp of low voltage and consumption less than 300 kWh/month.
		Subsidy:	Up to 75 percent for consumption <100kWh/month; 50 percent for consumption of 100-200 kWh/month; and 25 percent for consumption of 200-300kWh/month
		Financing:	Fiscal transfer
Peru	**Explicit**	Financing:	100kWh/month
		Requirements:	Belong to the National Integrated System; consume up to 100kWh
		Subsidy:	50 percent urban-rural and rural; 25 percent urban
		Financing:	BT5 tariff users that consume more than 100 kWh
Jamaica	**Implicit**	Covers:	Up to 100 kWh/month
		Requirements:	Consumption less than the minimum
		Subsidy:	Preferential rate for the consumption of the first 100 kWh
		Financing:	Cross-subsidy
Nicaragua	**Implicit**	Covers:	150kWh/month
		Requirements:	Consumption less than the minimum
		Subsidy:	50 percent from 0-125 kWh; 40 percent 126-150 kWh
		Financing:	Cross-subsidy
Mexico	**Implicit**	Covers:	140kWh/month
		Requirements:	Domestic use loads of low consumption and that are not connected individually
		Subsidy:	Lowers the rate for consumption less than 140 kWh; the surplus is paid approximately for double, loses the subsidy
		Financing:	Fiscal transfer

Source: Prepared by the authors based on information from regulators.

Note: In the case of Colombia, the levels of socio-economic strata–from 1 (poorest) to 6 (richest)–are defined by Governmental entities in order to apply differential tariffs for public services. In the case of El Salvador, resources financing the subsidy are the Comisión Ejecutiva Hidroeléctrica del Río Lempa (Grupo CEL) and Fondo de Inversión Social para el Desarrollo Local.

Table 7.3: Time-Varying Pricing in the Residential Sector

Country	Year of Implementation	Description	Share of Clients
Brazil	**1997**	Differentiated tariffs for the base, mid-peak, and peak hourly intra-day demand; tariffs for weekends are off-peak	0.04 percent
Chile	**1997**	Measure/contract maximum power demand during peak hours	0.05 percent
Costa Rica	**2009**	Applies three consumption blocks for base, mid-peak, and peak hourly intra-day demand	0.35 percent
Guatemala	**1998**	Differentiated tariffs for base, mid-peak, and peak hourly intra-day demand	0.00 percent
Panama	**1999**	Differentiated tariffs for peak and off-peak hourly intra-day demand	0.02 percent
Uruguay	**2000**	Differentiated tariffs for peak and off-peak hourly intra-day demand	4.74 percent

Source: Prepared by the authors based on information from regulators and utilities.

Note: Share of clients is calculated as of 2017.

In the LAC region, it seems to be a chronic mismatch between the reference price and average weighted electricity tariffs. Figure 7.2 shows the average electricity tariff (blue bars, left side) and the average electricity subsidy estimated by the price-gap methodology (orange bars, right side). High levels of electricity subsidies via tariffs are interpreted as tariff lags since the system fails to satisfy the income neutrality condition based on the current rates. This seems especially to be the case in countries with block rate schemes with discretionary rules regarding the formation of tariffs and regulatory weaknesses, such as Haiti, Trinidad and Tobago, and Venezuela. The figure shows general electricity subsidy estimates by Marchan et al. (2017) that are not specific to the residential sector. However, the figure allows for visualizing the negative association between levels of electricity prices and levels of tariff imbalance.

The negative association between tariff levels and subsidies reveals the political propensity to keep electricity costs low. In general, it also seems to be the case that where the price of electricity is higher, such prices tend to be associated with greater weight in the household budget. As discussed in Chapter 7, electricity is a necessity good and has a price elasticity of less than 1. That is, increments in electricity prices will tend to raise household expenditures on these services, mainly affecting lower income groups. However, the fact that the current structure allows for households with higher levels of income to filtrate to lower price ranges results in a negative financial balance in several electricity systems and suggests that it fails as a strategy to achieve affordability.

Several empirical studies have documented the high levels of filtration in subsidy schemes via tariffs, which also represent incentives for overconsumption and constitute a high fiscal cost with a high opportunity cost (for Mexico, see Hancevic and Lopez-Aguilar 2019; for Argentina see Marchioni et al. 2008). These are well-documented case studies indicating that subsidies through tariffs are not only costly but also fail to reach the objective of providing basic levels of services to the most vulnerable population (which generally has access to electricity services).

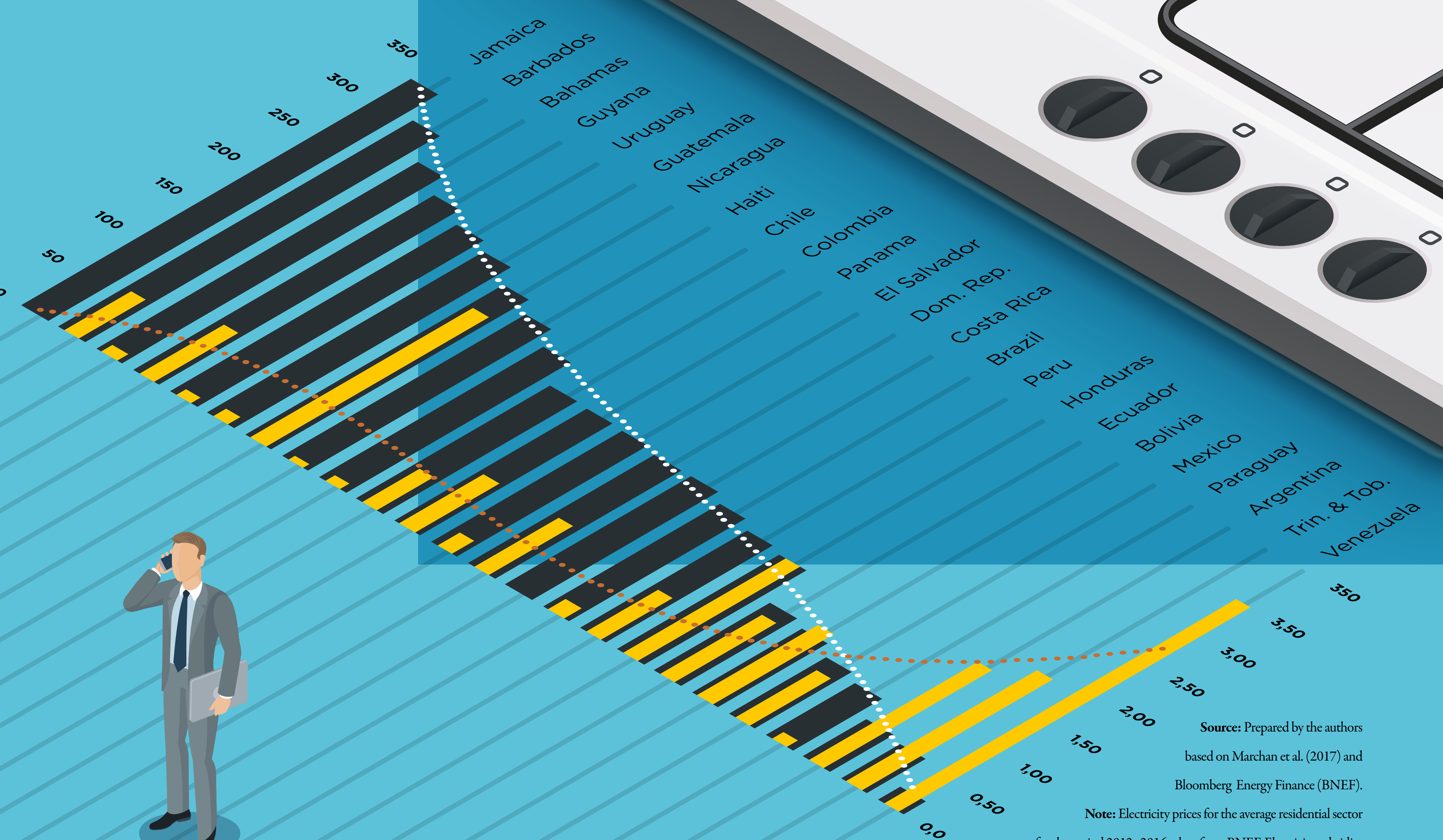
As estimated by a series of recent studies, the cost of such subsidies ranges between 0.5 and 1 percent of GDP in LAC (for Central America see Hernandez Ore et al. 2017; for LAC, see Marchan et al. 2017). These costs vary greatly by country and tend to be covered by the government, representing a significant opportunity cost, as such resources could be invested in other social programs that have proved to be better suited to reduce poverty. For example, Box 7.2 describes the case of the Dominican Republic, where electricity tariffs are estimated to be below levels of cost recovery by about 20 percent, leading to a yearly fiscal cost between 1.7 and 0.5 percent of GDP, depending on the international oil prices.

It is important to note that tariff distortions affect incentives on both the supply and demand side. On the supply side, the electricity company can lose not only the ability to finance investments to maintain an efficient and well-monitored system, but also lose the incentive to improve its corporate management system. For example, in countries where subsidies are higher, there tends to be high levels of

Electricity subsidies comprise an important component of GDP in LAC, accounting for between 0.5 to 1 percent of GDP. In many of our electric system, financial sustainability and full costs recovery remain challenging.

Figure 7.2: Average Prices of Electricity and Electricity Subsidies via Prices

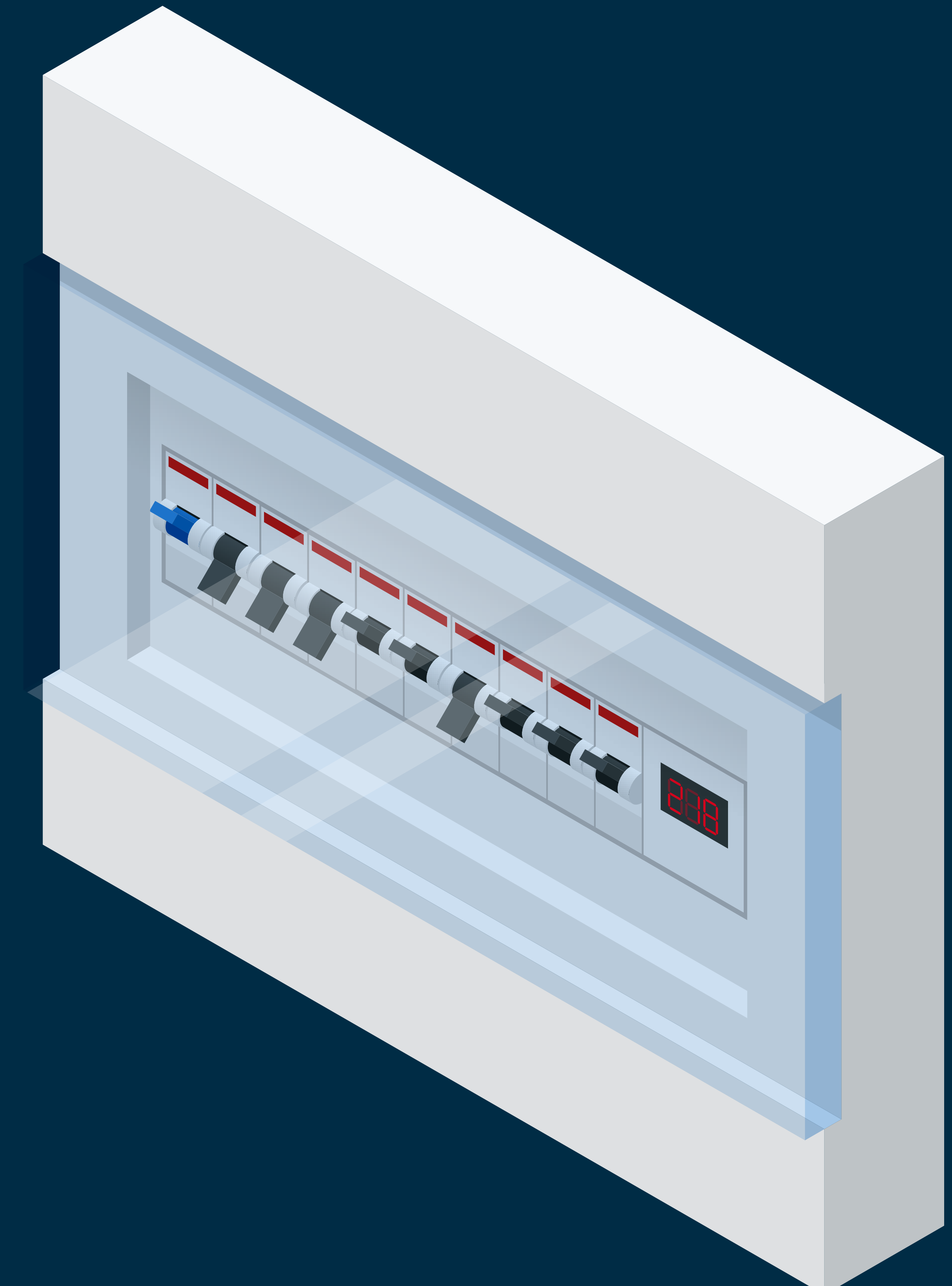
- Average Electricity Price (USD/MWh)
- Average Electricity Subsidy (%GDP)
- Poly. (average electricity price)
- Poly. (average electricity subsidy; % of GDP)



Source: Prepared by the authors based on Marchan et al. (2017) and Bloomberg Energy Finance (BNEF).

Note: Electricity prices for the average residential sector for the period 2012–2016 taken from BNEF. Electricity subsidies via tariffs estimated by Marchan et al. (2017) as a percentage of GDP. Poly: polynomial approximation.

Box 7.1: Equity Effects of Metering[4]



The implementation of electricity tariffs involves difficult trade-offs between opposing objectives. The tariffs need to recover costs for utilities, fairly allocate these costs across user types, and provide signals for efficient consumption. Metering is a basic condition for correctly charging for actual household consumption. However, a lack of metering infrastructure in Latin America and the Caribbean (LAC) remains an unresolved challenge, particularly for public utilities. For example, in Ecuador, 22 percent of dwellings connected to the electricity distribution network lacked an individual meter in 2010. This situation helps explain why a poor rate design can discourage low-valuation households from receiving the service – or make it unprofitable for firms to provide it.

In systems where electricity services are of poor quality and are highly subsidized, metering infrastructure, or the lack of it, can disenfranchise the population. For example, in Colombia, there were 624,000 complaints to the public utility regulator about metering or the estimation of unmetered consumption in 2009. Those complaints accounted for 38 percent of all complaints to the regulator. Even the Constitutional Court of Colombia has presided over legal cases against Colombian electricity retailers relating to charges for unmetered users.

So what is the efficiency and equity effect of metering? McRae (2015) addresses this question in the case of Colombia. The evidence suggests that metering leads to a large reduction in electricity consumption over the first four months following installation. This is consistent with previous overconsumption by unmetered users facing a zero marginal price. While there is also evidence of some underconsumption for some groups of households, the net associated welfare effects indicate that the efficiency effects are relatively small compared to the distributional effect of metering. That is, poor households, whose electricity consumption is low, would particularly benefit from the provision of meters.

4. The source of this box is McRae (2015).

electricity losses and low levels of service quality. On the demand side, price distortions can lead to overconsumption. Furthermore, prices below the social marginal cost represent a potential barrier to the adoption of energy efficiency practices in the region and encourage overconsumption (Hancevic and Navajas 2018). However, the more concerning aspect of price distortions is the long-term effect on the functioning of electricity markets. Precarious but lasting equilibria that mix low quality of services, high levels of electricity theft, and elevated subsidies seem to be the result of such a setting. In Colombia, McRae (2015) documents that the presence of electricity subsidies (through direct fiscal transfers to utilities) deters investments for improving the overall performance of service provision. In the Dominican Republic, Jimenez (2017b) shows that high levels of theft and extremely low quality of services have persisted for decades, regardless of the willingness of households to pay for improvements.

Facing Pricing Challenges to Ensure Affordability

Standard economic theory indicates that fiscal policies are better for generating equity or affordability gains. Pricing policies that seek to satisfy multiple objectives in addition to technical ones tend to generate significant distortions that reduce efficiency in the functioning of markets. Borenstein (2016) discusses this situation in the case of electricity markets, favoring more general fiscal policies. In this sense, the type of consumer is relevant. Tax policies can be more effective in boosting productivity and competitiveness of companies than subsidies on the price of inputs (e.g., energy). For this reason, when it comes to assisting lower-income groups, instead of tariff subsidy schemes the literature holds that programs specifically focused on these groups tend to be more effective. On the other hand, it is important to recognize the widespread policy goal of keeping energy prices at competitive and affordable levels. Through appropriate long-term planning for energy systems, this target can be achieved without relying on subsidies that represent heavy and unsustainable fiscal burdens.

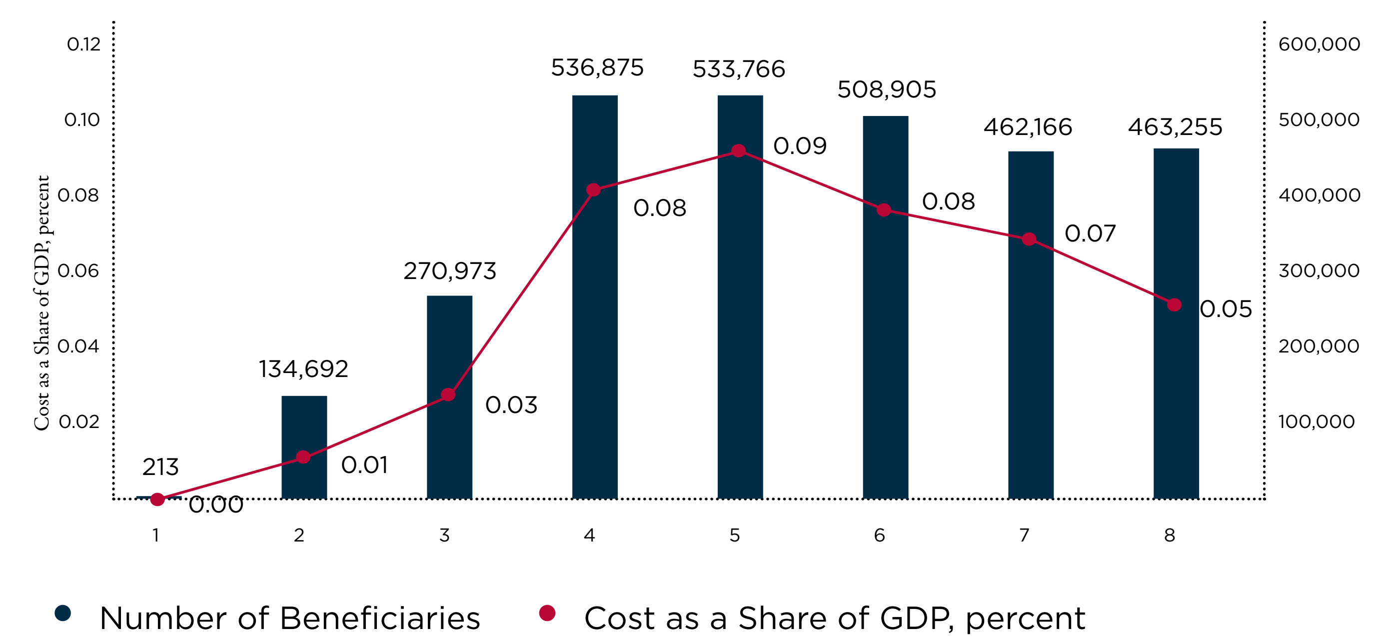
This sub-section provides two examples of experiences moving in that direction in LAC: the Dominican Republic and Chile. Both countries aim to improve the affordability of electricity services, but using very different strategies, although they have in common the intensive use of emerging technologies, including statistical information systems, online banking, and smart metering.

Direct Subsidies for Electricity Residential Consumption: Bonoluz in the Dominican Republic

In the residential sector, policies such as monetary transfers have been adopted by several countries and seem to have positive results. For example, in Ghana and Tanzania, Younger (2016) find that cash transfer programs can reduce poverty levels at a fraction of the fiscal cost of typical electricity price subsidies. In LAC, direct subsidy programs specific to the energy sector are being applied, for example, in Peru and the Dominican Republic. In Peru, the initiative is the Energy Social Inclusion Fund (*Fondo de Inclusion Social Energetica* – FISE), which is specifically destined for liquefied petroleum gas (LPG). In the Dominican Republic, a program called Bonoluz covers minimum consumption of electricity. Under different beneficiary selection strategies, both programs aim to achieve high levels of targeting.

Figure 7.3: Evolution of the Cost and Number of Beneficiaries of Bonoluz in the Dominican Republic

Source: Prepared by the authors based on information of CNE (Comision Nacional de Energia).



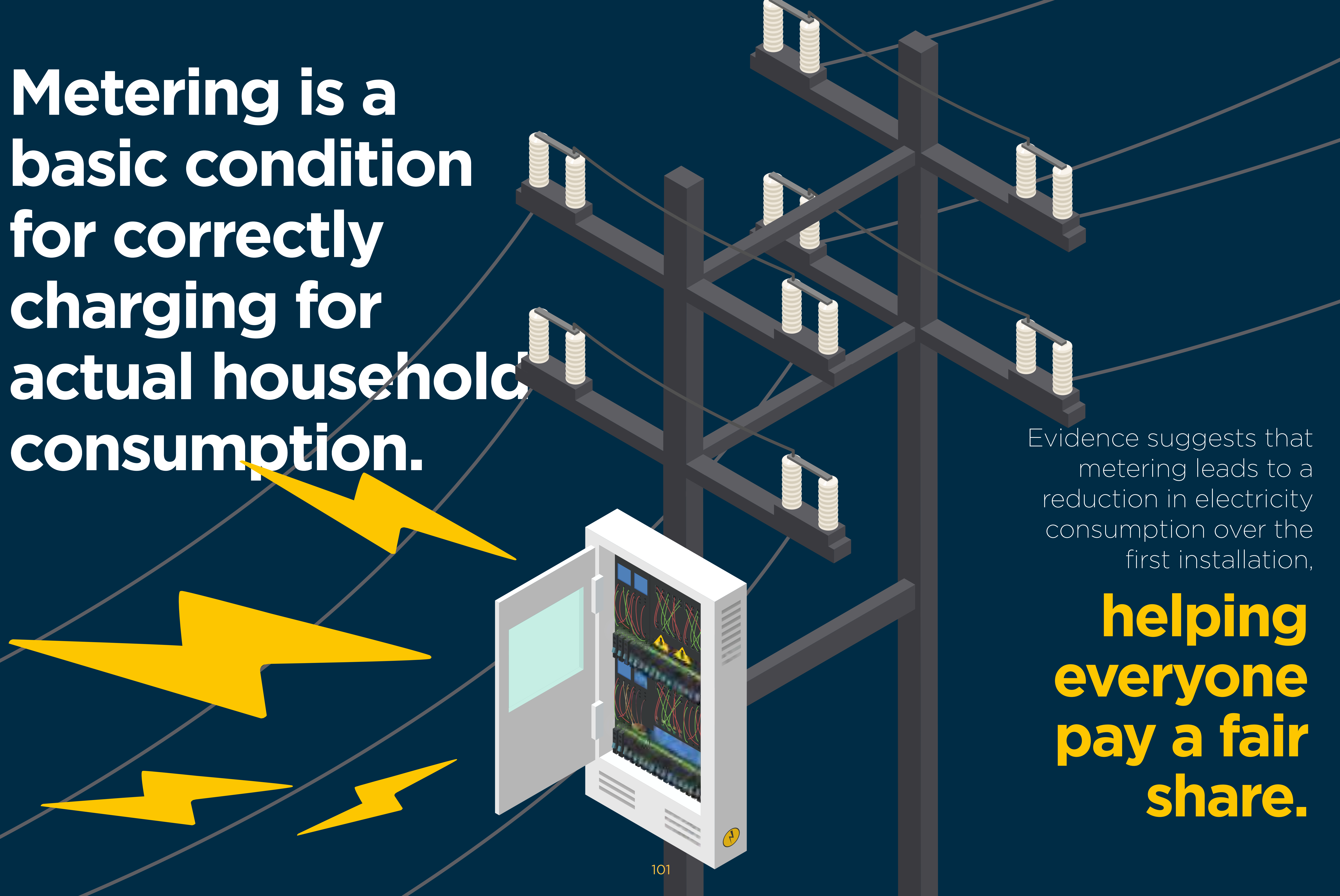
Given this chapter's focus on electricity, and to present a contrast with subsidies via tariffs shown in Box 7.2, this section reviews the case of the Dominican Republic, including the distributive and cost effectiveness of Bonoluz. The program was launched in 2009 to improve the targeting of subsidies to the most vulnerable families.[5] It is a direct subsidy in the form of a cash transfer delivered through bank accounts. Currently, it is not a conditional cash transfer; rather, beneficiaries are selected based on their socioeconomic conditions. The amount of the subsidy is in the range of DR$ 4.44 (US$0.1) to DR$ 444 (US$10), which represent up to around 100 kWh.

Better off users benefit more from universal blanket subsidies for electricity than less well-off users,

as the former **gains 2.5 dollars**

and the latter **1.2 dollars from every 10 dollars,** respectively.

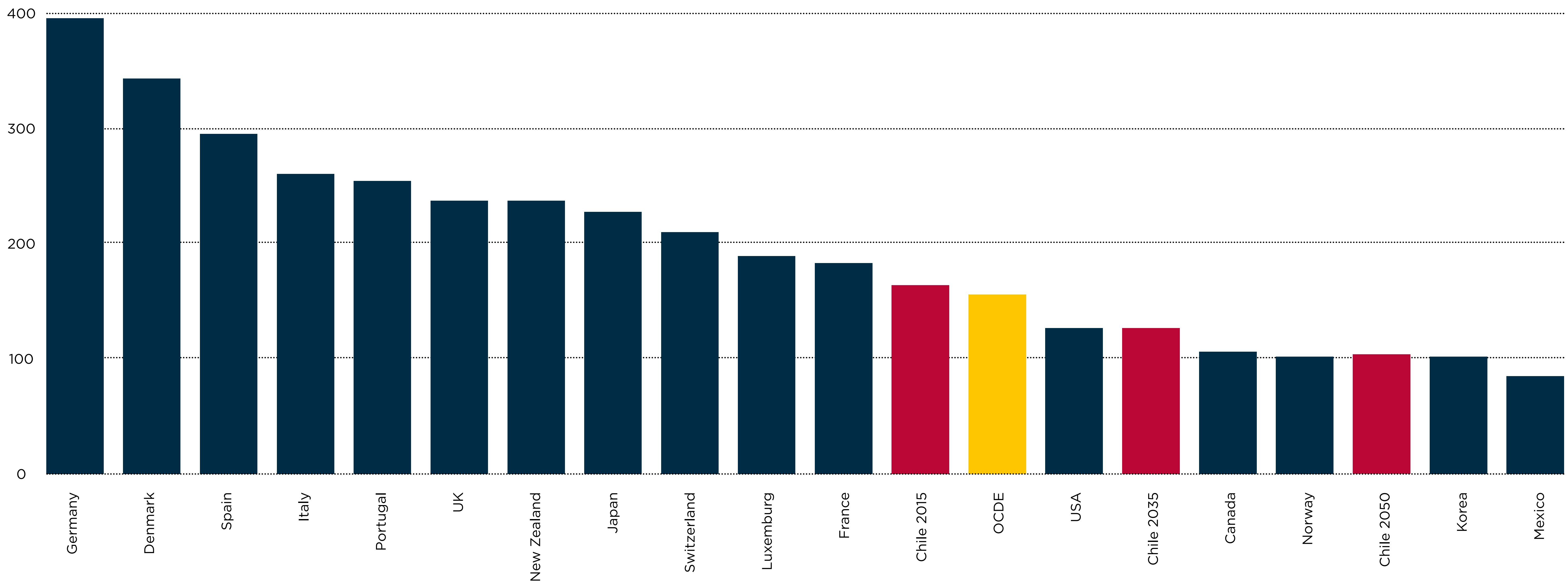
Metering is a basic condition for correctly charging for actual household consumption.



Evidence suggests that metering leads to a reduction in electricity consumption over the first installation,

helping everyone pay a fair share.

Figure 7.4: Targets for Generation Costs in Chile Compared with Other Countries (in U.S. dollars/MWh)



Source: Ministry of Energy of Chile, Division of Renewable Energy, 2017.

In terms of effectiveness, Bonoluz seems to have achieved the desired targeting properties at a relatively low cost. At the end of 2016, the number of beneficiaries reached 463,255 families, approximately 25 percent of the residential client base in the Dominican Republic. Since the program started it has delivered approximately US$245 million, which is equivalent to half the annual fiscal transfer made to the country's utilities services. Figure 7.2 details the evolution of the number of beneficiaries per year, as well as the amounts granted as a share of GDP. As a result of statistical efforts to identify the socioeconomic characteristics of households, the program has made progressive improvements in better targeting beneficiaries and in calculating the subsidy amount per each household. Figure 7.2 shows that since 2012 (after the implementation of the national survey of basic needs), the number and aggregate amount delivered through the program annually tended to decline. As a percentage of GDP, the amounts granted represented 0.05 percent of GDP in 2016.

Increasing Renewables and Affordability in Chile

As part of its long-term strategy in the energy sector, Chile has taken on the challenge of achieving a high share of renewables to be compatible with reducing the cost of generating electricity. In 2016, renewables in Chile represented around 40 percent of power generation. By 2035 and 2050, Chile intends

to achieve 60 percent and 70 percent of renewable-based electricity generation, respectively. This goal is part of a strategy to consistently provide competitive electricity prices, reach environmental targets, improve energy security, and position the country among the member countries of the Organisation for Economic Co-operation and Development with the lowest prices of electricity.

Reaching these objectives involves substantial regulatory changes that have direct effects on final consumers. One concrete aspect is the expansion of individual electric generation systems, or distributed generation. This expansion is based on the observed downward trend in costs of such systems, which is expected to continue into the future. In this sense, the changes in the regulation aim to facilitate the penetration of this new technology with a focus on residential users. One measure in that regard is the definition of the size of the project that is suitable for this type of consumer. Between 2014 and 2016, the government defined small projects (less than 100kW) and medium-sized projects (greater than 100kW), granting the right to customers to generate energy, consume it, and inject surpluses into the network. It also simplified the process and reduced the costs required for starting projects.

One of the most salient drivers of these measures is that distributed generation has the potential to reduce the cost of electricity for consumers with surpluses and, at the same time, promote energy savings. For example, Chile applies a net billing scheme in which the value corresponding to the electricity injections is deducted from the electricity bill corresponding to the month in which those injections were made. If there is a balance in favor of the client, it will be considered for a discount on the following bill and readjusted for inflation.

In this way, the decentralization of electricity generation offers the opportunity not only to expand the penetration of renewable energy, diversify the energy matrix, and reduce the cost of the service, but also provides incentives for households to save energy and respond more dynamically to incentives via rates.

Final Remarks

Pricing mechanisms are at the core of well-functioning markets and constitute a key driver of energy consumption. The nature of electricity services today poses several challenges that preclude achieving first-best solutions of equating marginal social cost to price. However, the deviations from the preferred solution seem to be not as related to technical aspects as it is to political considerations. Ensuring affordability is an important policy objective but influencing prices to that end may have boomerang effects (e.g., reducing the incentive to improve quality, fostering overconsumption, and presenting a high fiscal burden). This situation is particularly detrimental when public services are used to seek political objectives.

This chapter has shown that although widely heterogeneous, pricing schemes in LAC have a significant effect on affordability issues. Through incremental block pricing, social tariffs, or even by maintaining tariff lags, LAC countries aim to ensure minimum levels of household energy consumption. However, the financial balance in several countries seems to result in the need for subsidies and transfers to keep the system operating. This chapter suggests this should not be the case, and that affordability and financial sustainability are compatible policy targets.

Updating regulations to align with emerging new technologies such as distributed generation can make a substantial impact on upstream electricity-generation costs. Turning towards direct subsidy programs can also be more cost-effective, better targeting the poor at a fraction of the fiscal cost of tariff subsidies. Initiatives to implement such approaches have taken advantage of new technologies and introduced them to population segments that would otherwise not have significant take-up. In this sense, interventions aimed at relief-pricing mechanisms to ensure affordability have the potential to be replicated in LAC.

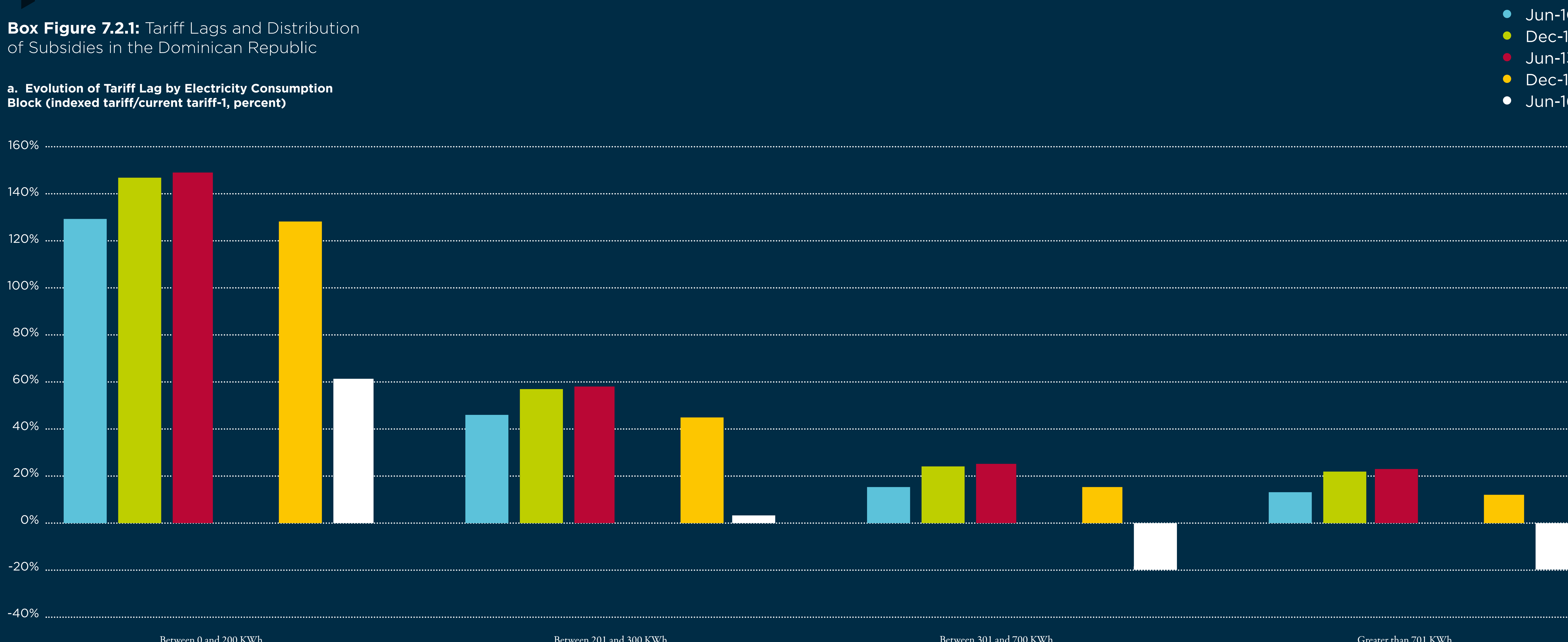
The right pricing scheme will set the right incentives for adoption of new technologies and for long-term investments to improve the performance of the electricity sector. Setting the appropriate pricing mechanism will be increasingly important as household income grows and households become more dependent on energy-intensive assets. For this reason, the right economic incentives (i.e., prices) are essential to deter overconsumption of electricity and to incentivize energy efficiency. Two open related questions in this regard are how the expansion of smart metering and time-varying electricity pricing will impact residential energy consumption patterns. Today, both are still at very low levels of implementation. However, both would be expected to play an increasingly relevant role if distributed generation and energy storage were to expand in a substantial way, as it is usually argued. Smart metering and time-varying pricing requires both substantial investment in updating the network and improvements in the technical and managerial capabilities of utilities. To that end, it is necessary to improve transparency in price formation. This includes improving the mechanisms to determine blocks of electricity consumption and their associated tariffs, which need to be established based on technical considerations.

More research is necessary to guide the design and improvement of direct subsidy programs. Most of the literature has been oriented to general monetary transfer programs, and less towards evaluating and comparing programs in the energy sector. Since price mechanisms have proven to be complex and inefficient to achieve affordability goals, alternative mechanisms – such as direct subsidies or the unification of direct transfers that account for subsidies for electricity, food, education, water, and sanitation, among others – have to be further evaluated.

Box 7.2: The Distributive Cost of Electricity Tariff Lags in the Dominican Republic[6]

Box Figure 7.2.1: Tariff Lags and Distribution of Subsidies in the Dominican Republic

a. Evolution of Tariff Lag by Electricity Consumption Block (indexed tariff/current tariff-1, percent)



6. The source of this box is Jimenez (2019).

Source: Prepared by the authors based on information from the Corporación Dominicana de Empresas Eléctricas Estatales.

b. Distribution of Consumption and Electricity Subsidy

Income Quintile	Electricity Consumption (KWh/ month/household)	Subsidy Distribution (%)	
		June 2014	June 2016
Poorest	128	12,09	81,33
2	168	17,14	18,67
3	187	21,28	(28,8)
4	216	24,05	(130,7)
Richest	253	25,44	(308,6)
Total	**192**	**100,00**	
Subsidy Balance:		**Deficit**	**Surplus**

The Dominican Republic uses a system of incremental block pricing. On a regulatory basis, end-user tariffs are established with respect to reference prices, which must adequately reflect the costs of providing the service. This reference price is called the indexed tariff and is established based on the consumer price index, fuel prices for generation, and electricity distribution costs. Given that 60 percent of electricity generation comes from fossil fuels, international prices of those fuels have a significant impact on the formation of reference prices.

However, in practice, tariffs applied to final users have barely responded to the cost of providing the services. Panel a in Box Figure 7.2.1 shows the evolution of the tariff structure by consumption bands from 2010 until the end of 2016. In this period, the tariff structure changed only three times, and in general, was not adjusted in accordance with the reference prices. What is more, panel a shows the presence of pronounced mismatches in all consumption bands, although the mismatches declined after late 2014 as a result of the exogenous fall in international oil prices. Only after oil prices dropped below US$60 (West Texas Intermediate [WTI] per barrel) can it be seen that the segments with the highest consumption paid more than the reference price. That is, as a result of the fall in oil prices, the indexed tariff was reduced enough so that, under the current rate structure, the system observes a cross-subsidy scheme. This situation had a direct fiscal impact that is reflected in the transfers that the government made annually to electricity distribution companies. These transfers fluctuated between 0.51 and 1.79 percent of GDP over 2010–2016.

Panel b in Figure 7.2.1 summarizes how this exogenous fall in oil prices has affected the distribution of subsidies across income groups. In mid-2014, at the beginning of the drop in oil prices, all income groups received subsidies (a product of the lagged tariff for all consumption blocks). This coincides with what is observed in panel a, and also shows that the three richest quintiles benefited more from the tariff structure than the lower income groups. The richest quintile received 25 percent of the aggregate subsidy, while the poorest quintile received 12 percent. Towards mid-2016, with the adjustment in the indexed tariff stemming from the fall in oil prices, the distribution of subsidies acquired a cross-subsidy structure in which lower-income households received subsidies that were financed by the richest quintiles. In 2016, the first and second quintiles received 80 percent and 19 percent of total subsidies, respectively. In contrast, the upper quintiles paid a “tax” (rates higher than the indexed rates) that exceeded even the subsidies implicitly delivered to those income groups. The aggregation of taxes paid by the three richest quintiles represented 4.7 times the aggregation of the subsidies received by the two poorest quintiles. That is, at between US$50 and US$6 per WTI barrel, the tariff structure reached progressive properties and achieved a net positive net balance for the distribution electric system in the residential sector.

Chapter 8

Prices and Subsidies for Liquid Fuels

Pricing of fossil fuels is among the most debated policy issues in both developing and developed countries. On the one hand, governments tend to favor subsidies, implicitly or explicitly, in order to achieve energy affordability and promote competitiveness of local industries. However, both theoretical and empirical evidence indicate that price subsidies constitute an inefficient way to deliver on such targets. Further, such approaches lead to overconsumption and negative externalities, such as greater greenhouse emissions and traffic congestion, while being regressive.

Strikingly, pricing distortions remain in most countries. According to the International Energy Agency (IEA), the global amount of subsidies in 2014 was around US$455 billion. Even with the decline of more than 50 percent in international oil prices over 2014–2016, subsidies still totaled US$261 billion in 2016. It is worth noting that these amounts only account for the price gap between what would be market prices and current subsidized prices. That is, while such subsidies may represent a substantial fiscal cost for governments, they do not account for all economic and environmental costs of maintaining price distortions.

This chapter addresses subsidies for transport fuels and domestic gas, focusing on the overall economic cost of such subsidies and its distributive properties. Throughout this chapter, it is clear that subsidy programs could become more efficient by rigorously answering which fuels to subsidize and how to better implement those subsidies. In the residential sector, generalized price subsidies for fuels for private transportation are expensive for fiscal budgets and mainly benefit rich households that do not need the benefit. In sum, there is no reason to maintain such subsidies.

This chapter shows that there may be better ways to reduce energy poverty – specifically, by supporting access of poor households to cleaner cooking fuels through more targeted approaches. The case for expanding the use of liquefied petroleum gas is seen as a feasible, medium-term strategy to reduce or eliminate the consumption of traditional, more contaminant cooking fuels. Experience shows that generalized price subsidies tend to present high levels of filtration that lead to substantia pitfalls of fiscal resources. More targeted approaches, such as, cash transfers, seem to be substantially less costly and better focused.

Pricing Fuels for Private Transportation

In the countries of Latin America and the Caribbean (LAC), the establishment of fuel prices has a discretionary component. That is, fuel prices do not necessarily respond to market drivers or essential, ex ante, cost-recovery rules, but rather are influenced by arbitrary decisions. Certainly, other than on strictly technical grounds, there may be good grounds for influencing the establishment of fuel prices. However, lack of transparency and basic "rules of the game" may negatively affect the performance of the industry and the stream-down market (Marchan et al. 2017; Balza and Espinasa 2017).

As a result, fuel price distortions are one of the most notable and persistent problems in the region. Subsidies are typically implemented based on affordability and competitive reasons. Liquid fuel prices are seen as key elements for boosting competitiveness of the economy, as well as reducing energy poverty. It is important to mention that liquid fuel prices are also strategic components for managing inflation and maintaining the purchasing power of households during economic slowdowns. This last argument is the main reason why governments have stabilization funds to smooth price fluctuations derived from international price volatility. However, there is strong evidence suggesting that discretion in establishing pricing for transport fuels opens the way for significant political intervention all around the world (Coady et al. 2010). As in the case of electricity, this means that governments tend to intervene at some point of the pricing chain in an arbitrary manner, resulting in market distortions and fiscal pitfalls. For example, as of 2014, 22 of 26 LAC countries used discretionary mechanisms to set gasoline and diesel prices, a practice that is associated with high levels of subsidies. In LAC, fossil fuel subsidies are around 0.97 percent of GDP, representing a direct fiscal burden with sizable opportunity costs.

The severity of the subsidy problem, as well as price distortions, is more pronounced in fossil-resource-abundant countries. Certainly, prices and pricing mechanisms are endogenous to the natural endowment of those nations, but this does not necessarily have to lead to negative outcomes. Institutions play a key role in transforming what could be a curse into a blessing, and LAC can and must do better. Indeed, Table 8.1 shows that lower transport fuel prices tend to be associated with higher levels of subsidies, which are more significant in resource-abundant countries.

Table 8.1 also shows that while the type of pricing mechanism is discretionary in most cases, there is an enormous amount of variation in fuel prices, as well as subsidies. Gasoline prices in the region average US$1.04 per liter, but range from US$0.01 in Venezuela to above US$1.6 in Uruguay and Barbados. Diesel prices tend to be a bit lower, averaging US$0.88 per liter. This wide variation in prices is somewhat surprising because crude oil and refined products are widely traded internationally, so the opportunity cost of fuels is similar in different locations. Although there are differences in transportation, refining, and distribution costs, they can explain only a small part of the observed variation in average prices. Instead, the more important explanation for such variation is that taxes and subsidies differ widely. This means that while most countries may have discretionary pricing approaches, such approaches are substantially different.[1]

On the other hand, it is important to note that the amounts of subsidies across countries and over time can substantially change with international oil prices. This means that independently of the different pricing approaches among countries, the actual levels of subsidies seem to be driven by

1. See Beylis and Cunha (2017) for an extended discussion on LAC government strategies for setting energy prices.

Table 8.1: Diesel and Gasoline End-User Prices (Subsidies as of 2014; fuel prices as of June 2018)

Source: Pricing mechanism and subsidy from Marchan et al. (2017).

Note: Diesel and gasoline prices are from regulators, ministers, and Bloomberg. Subsidy account for post-tax subsidies for fossil fuels estimated for 2014 as a percentage of GDP.

Country name	Pricing Mechanism	Fuel	Subsidy (% of GDP)	Diesel Prices (per liter in U.S. dollars)	Gasoline Prices (per liter in U.S. dollars)
Barbados	Discretionary	Diesel	0,07	1,30	1,70
Uruguay	Discretionary	Diesel	0,01	1,29	1,61
Belize	Discretionary	Diesel	0,00	1,39	1,49
Chile	Nondiscretionary	Diesel	0,02	0,93	1,31
Dominican Republic	Discretionary	Diesel	0,08	1,01	1,30
Jamaica	Discretionary	Diesel	0,13	1,24	1,29
The Bahamas	Discretionary	Diesel	0,00	1,14	1,26
Brazil	Discretionary	Diesel	0,00	1,02	1,23
Costa Rica	Nondiscretionary	Diesel	0,00	0,99	1,20
Argentina	Discretionary	Diesel	1,40	0,96	1,12
Peru	Discretionary	Diesel	0,14	0,94	1,11
Honduras	Discretionary	Diesel	0,29	0,95	1,11
Nicaragua	Nondiscretionary	Diesel	0,00	0,91	1,06
Guyana	Discretionary	Diesel	0,60	1,00	1,05
LAC Average			***0,97***	0,88	1,04
Paraguay	Discretionary	Diesel	0,04	0,94	1,03
El Salvador	Discretionary	Diesel	0,63	0,87	1,02
Guatemala	Discretionary	Diesel	0,00	0,84	1,01
Mexico	Discretionary	Diesel	1,64	0,96	1,01
Suriname	Discretionary	Diesel	0,01	0,87	0,92
Haiti	Discretionary	Diesel	1,49	0,73	0,91
Panama	Nondiscretionary	Diesel	0,16	0,80	0,90
Colombia	Discretionary	Diesel	0,13	0,75	0,81
Trinidad and Tobago	Discretionary	Diesel	3,38	0,36	0,59
Bolivia	Discretionary	Diesel	9,40	0,54	0,54
Ecuador	Discretionary	Diesel	6,36	0,27	0,39
Venezuela, RB	Discretionary	Diesel	9,19	0,00	0,01

external factors instead of consistent policies to reduce or eliminate those subsidies. In turns, this indicates stagnation in terms of pricing energy according to the market principles and externalities such as environmental considerations. Along these lines, a strong body of evidence shows that, in LAC, resource abundance has been disconnected from overall productivity, and the efficiency of the energy industry lags behind other regions with comparable resource endowment.

In such a context, establishing strong institutions represents a "can't-do-without" condition for a more efficient allocation of natural and fiscal resources. Setting independent, nonarbitrary and transparent pricing rules in a transparent way constitutes a specific way that LAC countries can contribute to better performance of energy markets. This step should not be seen as apart from goals boosting competitiveness and increasing affordability, but rather as complementary and synergetic. That is, consumption of liquid fuels, in the household sector, tend to have a strong pro-rich distribution such that subsidies have historically resulted in high levels of regressivity with minimal impact of relieving energy poverty issues. On the contrary, adequately pricing liquid fuels have shown to be a substantial source of income for governments, resources that can be more effectively distributed to better-targeted social programs.

Economic Cost of Fuel Subsidies

What effects do fuel price distortions and subsidies have on social welfare? The standard wisdom is that subsidies create deadweight loss by enabling transactions for which the consumer's willingness to pay is below the opportunity cost – that is, transactions that would have not happened in the absence of price distortions (Davis 2014, 2016). As is clear from Figure 8.1, the size of the welfare losses depends on the elasticities of demand and supply, which may vary substantially across countries and fuels. Chapter 2 presented a summary of estimations of income and price demand elasticity from the existing literature, providing some guidance on the adequate selection of such parameters. Along these lines, Davis (2014) estimates that the size of the welfare losses is around US$92 billion globally, and in the case of LAC, it reaches around US$17 billion (grey area), including deadweight loss as well as external costs (e.g., environmental costs).[2]

The fuel overconsumption generated by price subsidies can easily be displayed empirically. Figure 8.2 shows gasoline prices and gasoline per capita consumption, distinguishing between countries with low, medium, and high levels of subsidies. Although these prices are not directly comparable (for example, due to transactional costs), they still provide an informative indication of the cost of transport fuels to the household and their effect on consumption. Consistently, and as expected, gasoline consumption tends to be high in countries with lower fuel prices. For example, per capita, gasoline consumption in Trinidad and Tobago and Venezuela is almost three times the average consumption in LAC. It is also important to consider that in taking into account the persistence of fuel subsidies, they can have more intricate dynamic effects. On the one hand, liquid fuel consumption can have an idiosyncratic component, and be perceived (as in the case of electricity) as a commodity that should have a low cost. Persistent subsidies can also affect long-run growth of motor vehicles ownership, and therefore increase operation, maintenance, and investment costs of roads.

What is the average effect of subsidies on fuel consumption? According to calculations based on the dataset from Davis (2014), low prices in LAC lead to overconsumption of around 44 percent for gasoline and 23 percent for diesel (Figure 8.3). In this calculation, the level of overconsumption was calculated as the difference between fuel demand at domestic consumer prices and international spot prices.

Distribution of Subsidies for Transport Fuels for Private Transportation

How are subsidies distributed between household income groups? Characterizing energy expenditures and consumption patterns is a key element in evaluating the potential distributional effects of policy reforms. An evaluation of the distributional effects refers to a comparison between richer and poorer households, with particular attention to whether a given reform would be "progressive" or "regressive." The policy objective is to design interventions or reforms that are progressive, meaning that they have a larger proportional positive effect on poorer households than on richer ones (Gasparini, Cicowicz, and Escudeo 2012). In this context, the design of subsidy schemes and energy price policies is key to determining who gets the most benefit.

In particular, subsidies that focus on goods and services are more likely to have a progressive impact if lower-income groups consume those goods or services at a proportionally higher rate than higher-income groups. Previous descriptive findings indicate that this may be the case for electricity and domestic gas, as the share of expenditures on those fuels tends to be high among lower income groups, particularly in rural areas. However, recent studies have found significant filtration of the benefits of those subsidies towards richer households (Davis 2014; Clements et al. 2013; McRae 2014), indicating that besides consumption patterns, the allocation mechanisms of subsidy schemes also play a critical role in effectively increasing equity in energy consumption.

Previous descriptive evidence also indicates that consumption of and expenditures on transport fuels are concentrated among higher income groups; that is, the intrinsic patterns of household consumption and expenditure do not present suitable conditions for progressive subsidy programs.

Still, energy subsidies exist in most LAC countries. Di Bella et al. (2015) quantify energy subsidies in the region and find that 28 of 31 countries have subsidies for electricity, liquid fuels (e.g., gasoline and diesel), or both. In general, the literature shows that such subsidies are poorly targeted and mainly benefit higher-income groups. Table 8.2 presents the share of total subsidy benefits per income group based on estimations by Arze del Granado, Coady, and Gillingham (2012) for a set of countries in South and Central America. The authors distinguish between direct impacts (through fuels) and indirect impacts (through

2. Total welfare losses for LAC region is calculated by the authors based on the dataset of Davis (2014).

Experiences from El Salvador and the Dominican Republic are good examples of the benefits of social tariffs applied to electricity prices that are distributed to the final consumer, relative to her or his income;

thereby helping those who can't afford energy.

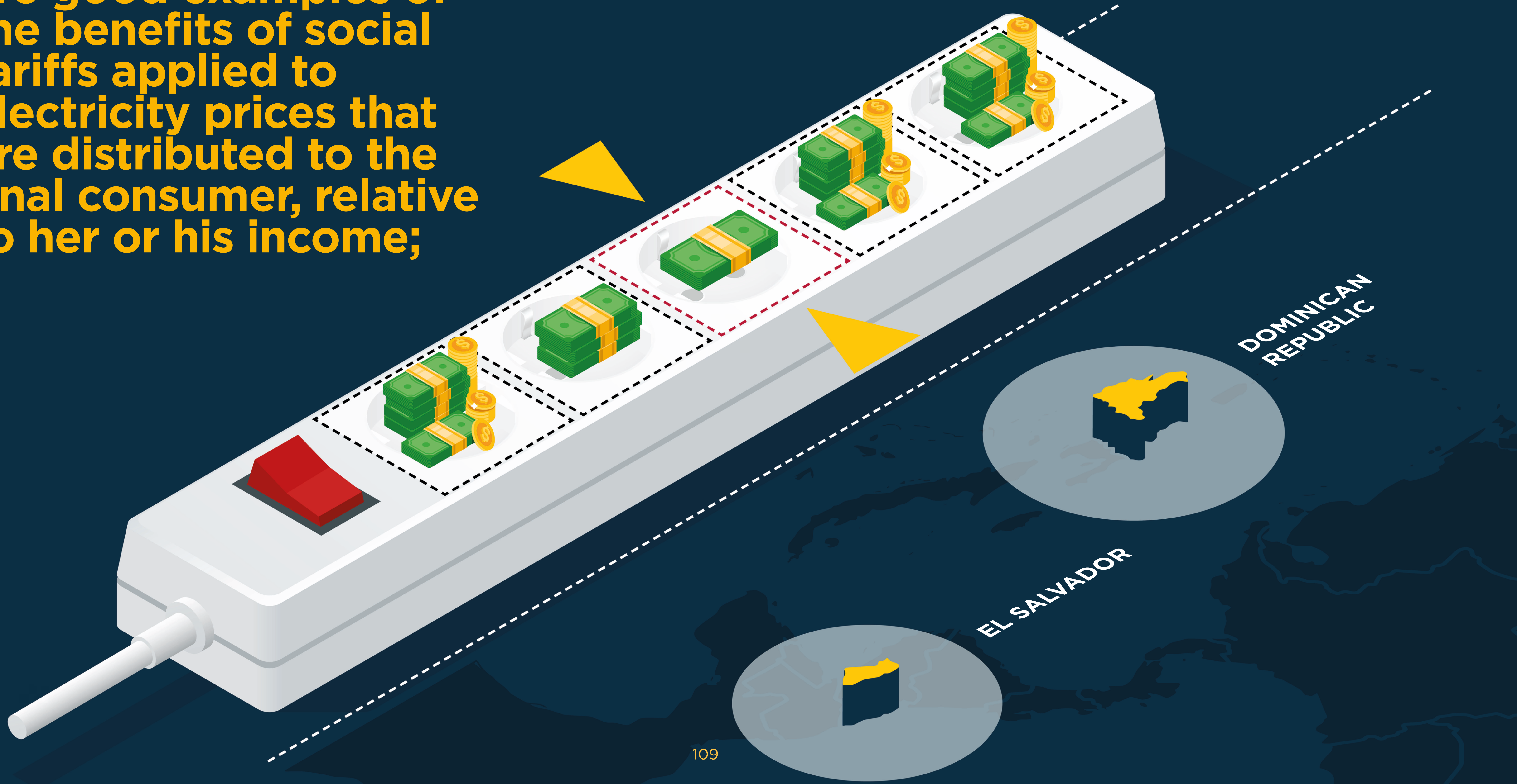


Figure 8.1: Transport Fuel Prices and Social Welfare Losses

Source: Davis (2014).

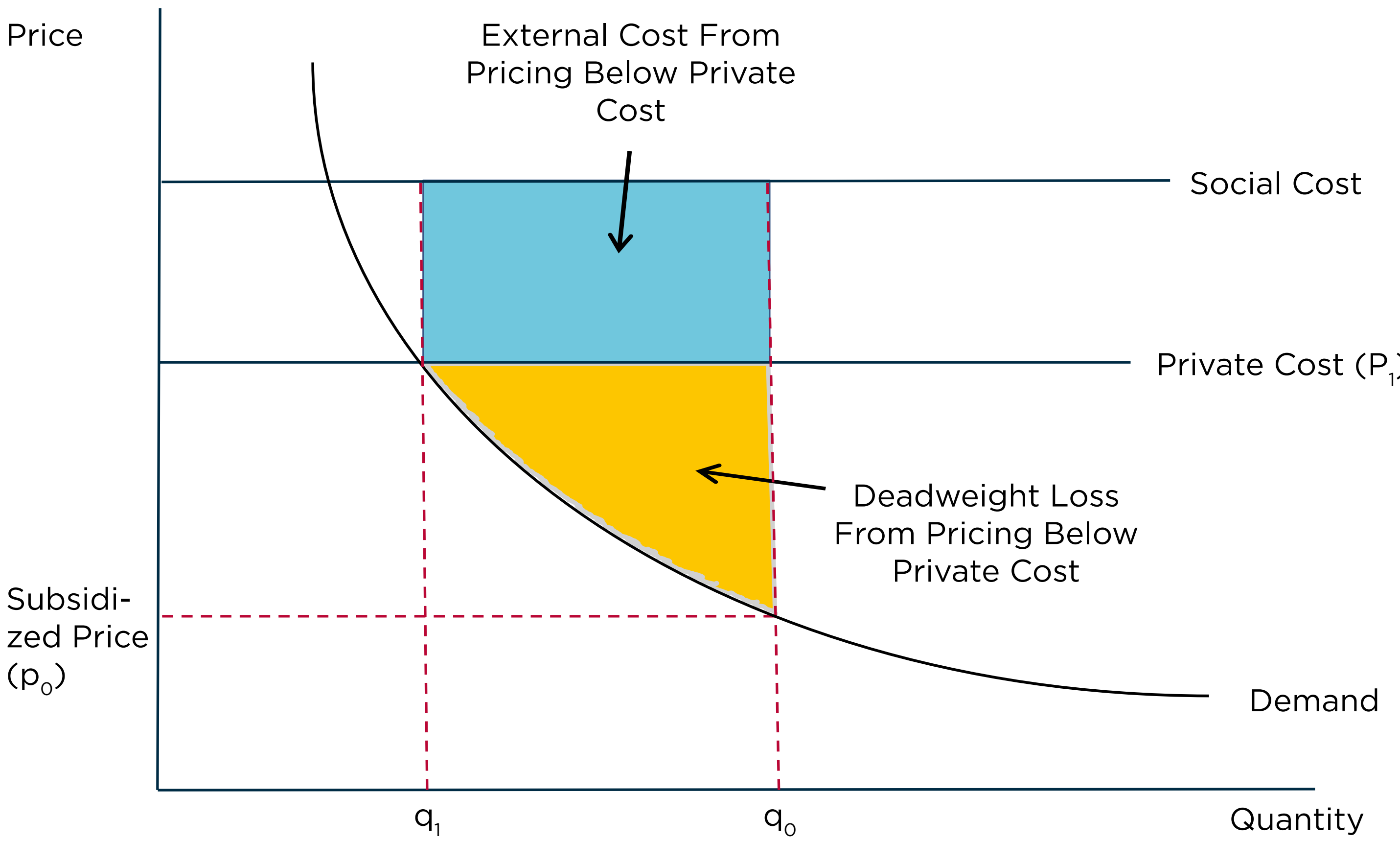


Figure 8.2: Gasoline Consumption and Prices in Latin America and the Caribbean

Source: Prepared by the authors based on information from the International Energy Agency and GIZ.

Note: Green: low subsidy level; Yellow: medium subsidy level; Red: high subsidy level. Data as of 2016.

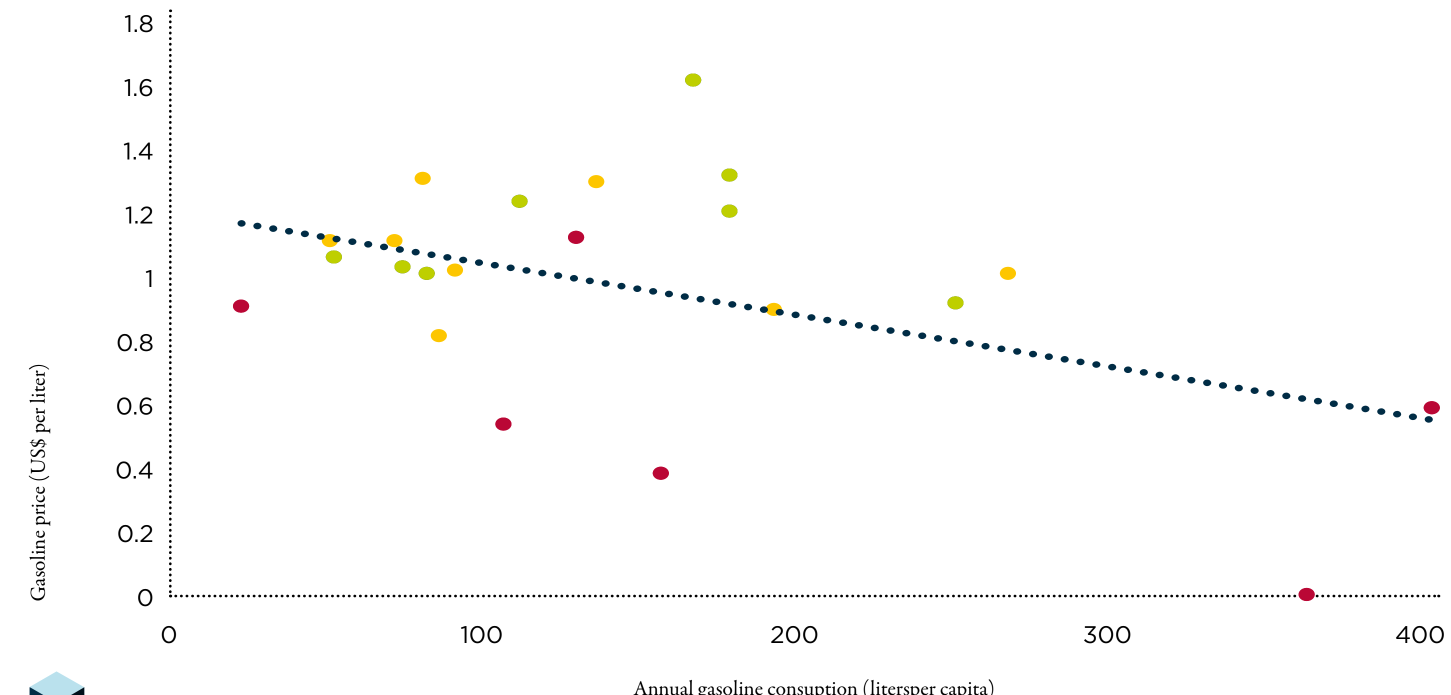
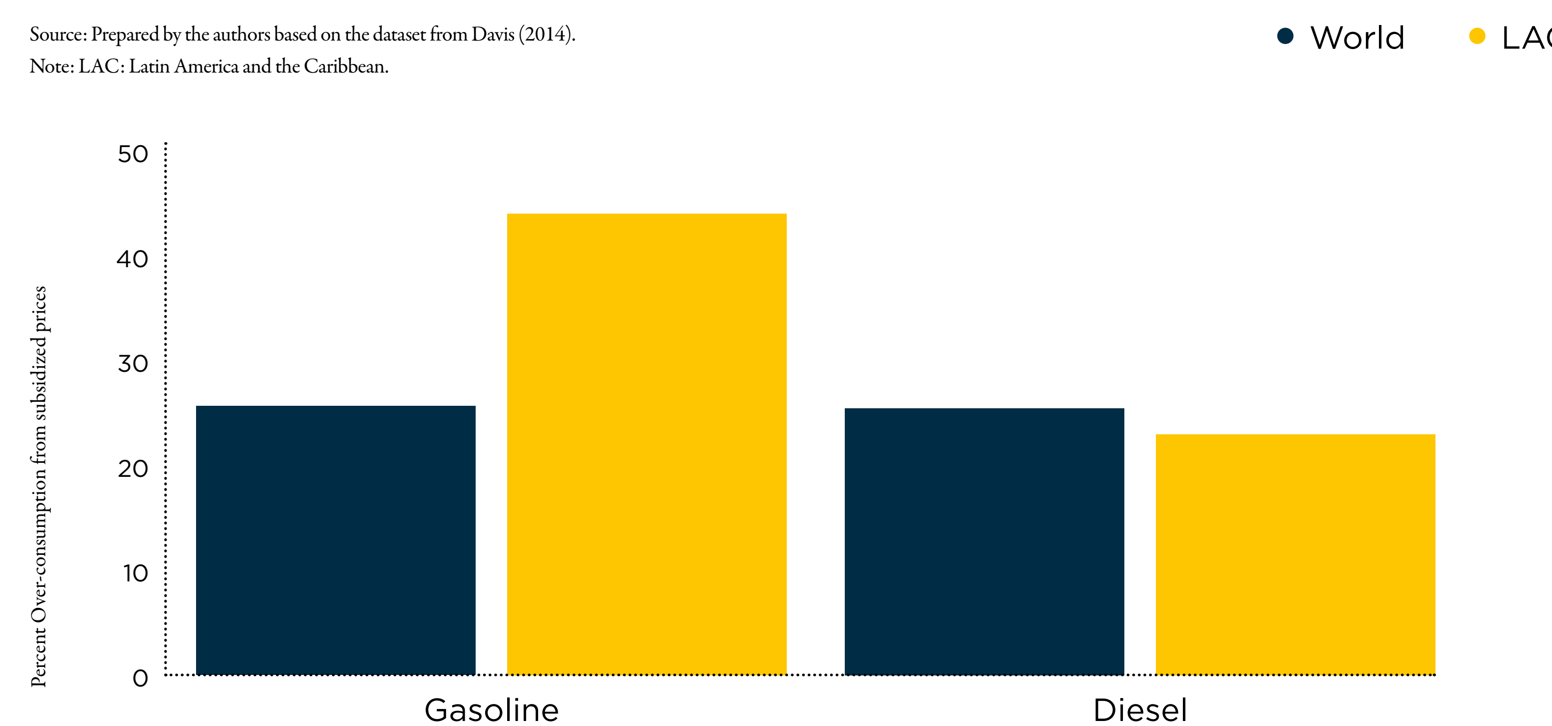


Figure 8.3: Transport Fuel Prices and Social Welfare Losses

Source: Prepared by the authors based on the dataset from Davis (2014).
Note: LAC: Latin America and the Caribbean.



other goods consumed by households), showing that, on average, households in the richest quintile receive six times more subsidies than those in the poorest quintile. This asymmetry holds across different fuels: gasoline, liquefied petroleum gas (LPG), and to a lesser extent, kerosene (where the subsidy benefits tend to decrease among higher-income groups but are still substantial).Table 8.2: Subsidy Benefits by Consumption Quintile in South and Central America (percent)

In addition to poor targeting of beneficiaries, concerns over subsidies and price distortions also include the financial harm that they may pose to the energy industry, reducing its investment capacity and leading in the long term to inefficient and underdeveloped energy systems that lack the capacity to supply quality energy services.

A Simulation of Universal Price Subsidies to Transport Fuels

In the case of transport fuels, an examination of the potential distributional effects of subsidies is less complex, particularly in the case of the residential sector, which tends to face common nationwide fuel pricing.[3] Taking this into account, we simulate the potential distributive effects of flat universal subsidies on transport fuels. We extend the exercise of Bacon, Bhattacharya, and Kojima (2010) for our sample of 17 LAC countries with information on transport-fuel expenditures. The authors apply the benefit-targeting indicator (BTI), defined as the ratio of the share of total benefits received by poor households to the proportion of households that are poor. If the indicator takes a value of one, then the scheme is neutral, and the poor

El Salvador moved from a general LPG subsidy to a specific stipend targeted one directed at end-users by focusing on households with lower electricity consumption, therefore reducing the cost of the general subsidy.

receive benefits in proportion to their numbers. A subsidy is progressive if the BTI (Ω) is greater than 1, and regressive if it is less than 1, with non-poor households receiving a larger share of the total subsidy pool than their proportion of the population. The BTI can be expressed as:

$$\Omega = \left(\frac{M_p}{P_H}\right) \bullet \left(\frac{T_p}{T_H}\right) \bullet \left(\frac{R_p}{R_H}\right) \bullet \left(\frac{Q_p}{Q_H}\right),$$

where ***M*** is the percentage of households that consume the energy source; ***T*** is the share of households that is connected to the energy source and eligible for the subsidy; ***R*** is the average rate of subsidization for eligible households; ***Q*** is the average quantity consumed by subsidy recipients; ***p*** is poor households; and ***H*** is all households.

Following Bacon, Bhattacharya, and Kojima (2010), the assumptions are that households face similar fuel prices and that the hypothetical subsidy is universal and constant. In the context of a simulated universal flat subsidy, the proportion of households receiving subsidies (T_p/T_H) and the average subsidization rate for eligible households (R_p/R_H) are both equal to 1. The ratio of expenditures is used as a proxy for the ratio of quantities consumed (R_p / R_H). Then the BTI is approximated by multiplying the percentage of poor households consuming a specific fuel by the average consumption of all households. Poor households are defined as those in the four bottom income deciles.

Figure 8.4 summarizes the results, suggesting that subsidies on transport fuels, gasoline, and diesel are likely to be strongly regressive. In the case of gasoline, the BTI (*Ω*) is low, ranging from 0.3 to 0.5, which is fairly similar across countries and indicates high regressivity. As would be expected, the values of ***Ω*** tend to be higher for diesel, ranging from 0.5 to 1.0. As diesel is a lower quality and less expensive transport fuel, its use is higher among lower-income groups. These results are aligned with the patterns observed in previous sections, where consumption and expenditures on transport fuels (especially gasoline) are highly concentrated among higher-income groups.

It is important to recall that these results are simulations and not empirical patterns. For example, in certain countries, the subsidy on transport fuels may tend toward neutrality for reasons other than its benefit to poorer households, such as generalized low fuel prices that broaden fuel consumption. This may be the case for Argentina and Mexico, where the BTI tends to be closer to 1. On the other hand, it is important to note that reforms that make everyone better off can still be regressive if the gains are proportionally smaller among poorer households than among richer households. This may be the case for transport fuels given their concentration among the higher income groups in national energy expenditures observed in Chapter 5.

Table 8.2: Subsidy Benefits by Consumption Quintile in South and Central America (percent)

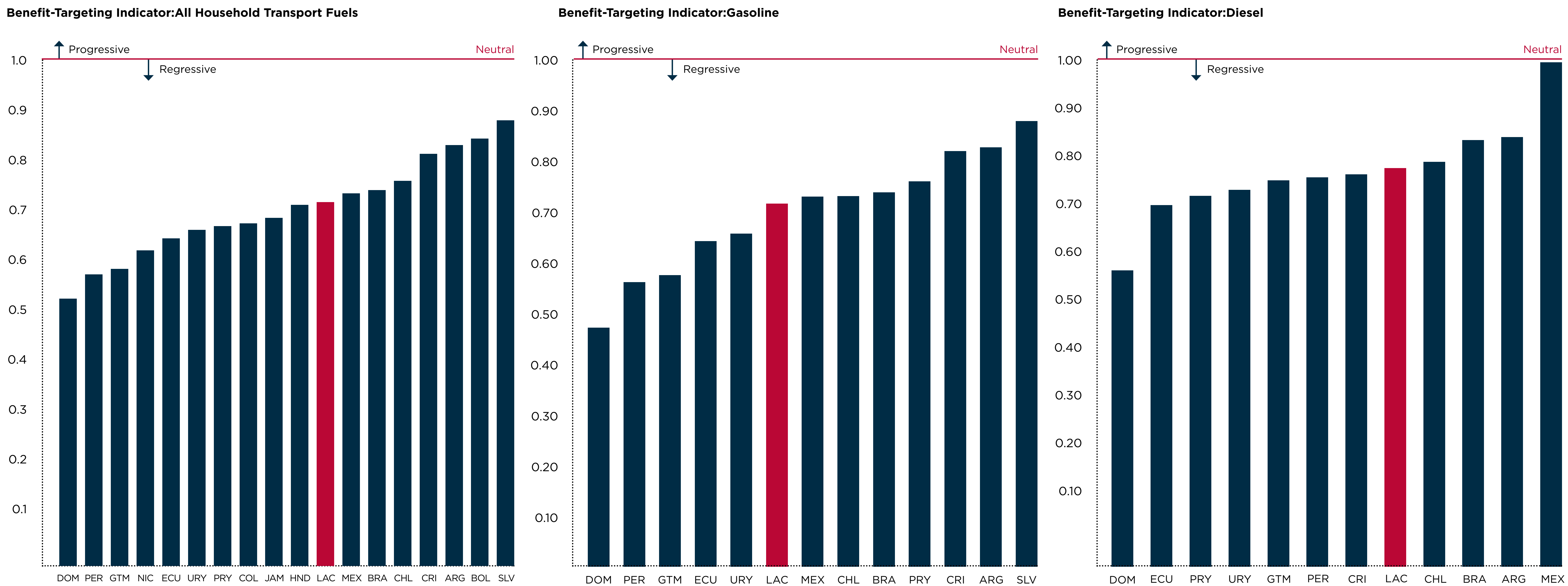
Source: Arze del Granado, Coady, and Gillingham (2012).
Note: Direct impact refers to the short-run effect through households' direct fuel consumption. Indirect effects refer to changes in the prices and consumption of nonenergy goods and services caused by variation in energy prices.

	Consumption Quintile				
	Poorest	**2**	**3**	**4**	**Richest**
Total impact	5.2	10.8	17.3	24.8	41.8
Total direct impact	4.2	9.4	15.2	22.1	44.9
Gasoline	4.2	8.6	14.8	22.2	50.2
Kerosene	31.7	24.7	19.8	16.2	7.6
Liquefied petroleum gas	3.2	8.4	15.4	23.3	46
Indirect impact	5.9	11.1	16.5	23.2	42.3

Figure 8.4: Universal Flat Subsidies on Transport Fuels Are Regressive

Source: National household expenditure surveys of 17 countries.

Note: In 11 national surveys, gasoline and diesel appear separately.



What Would Be the Effect of Reducing Fuel Subsidies?

As mentioned earlier, subsidies are implemented based on social concerns or political motives, and once they are implemented it becomes politically challenging to eliminate them. For example, in 2018, there were civil protests related to increased transport-fuel and domestic gas prices in Argentina and Brazil.[4] Surprisingly, less attention is given to the actual specific impact of those subsidies on the household budget and how those subsidies are distributed. The previous section showed that fuel subsidies are in fact regressive, as they benefit the rich far much than the poor. This section provides a closer look at the actual effects of reducing fuel subsidies on the household budget, taking into account different income levels.

4. During the same year, notable protests related to increased fuel prices also took place in France.

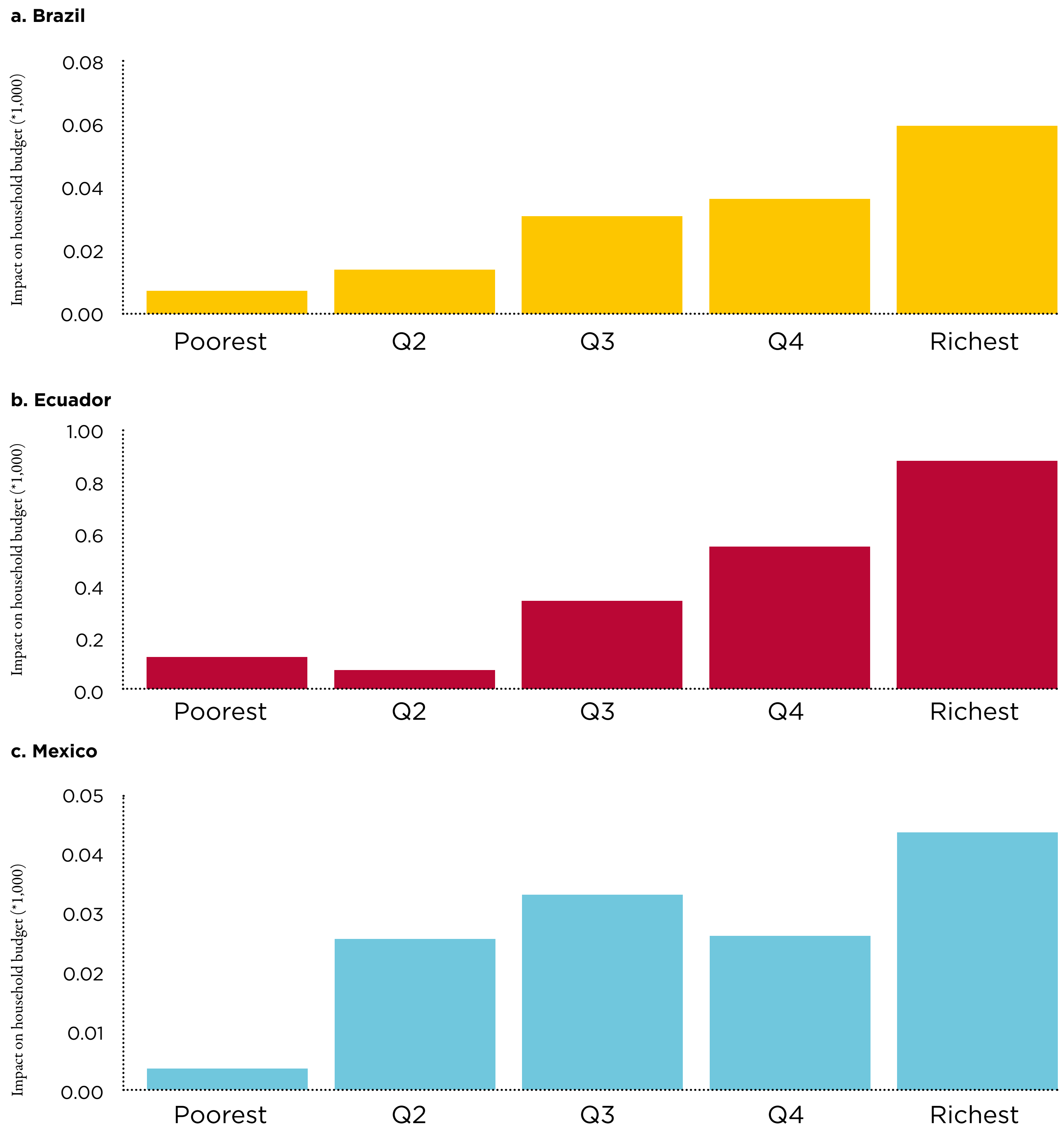
Closing the Gap of Subsidies on Diesel Prices: Impact on Household Budgets

The price gap estimations of the World Bank and Inter-American Development Bank are used to estimate the impact of eliminating such gaps (subsidy) on the household budget. The focus is on diesel because the gap estimation refers to diesel for private transportation, and its consumption can be identified in the household surveys.[5] It is assumed that eliminating the subsidy will increase the final price of diesel for all households in the same proportion, which is a realistic assumption for transport fuels because they typically fluctuate on the basis of their anchor components, independent of retail location/geography. Also, this analysis is of a static nature, that is, it is assumed that households do not adjust consumption in response to price changes.

5. In contrast, in the case of gasoline the price varies substantially by type of gasoline, and specific consumption by each type cannot be identified in household surveys.

In the Dominican Republic, the benefits from switching to a targeted LPG subsidy program were twofold. First, 38% of those in the two lowest quintiles become included in the program. Second, the subsidy cost was reduced by 0.07% of GDP.

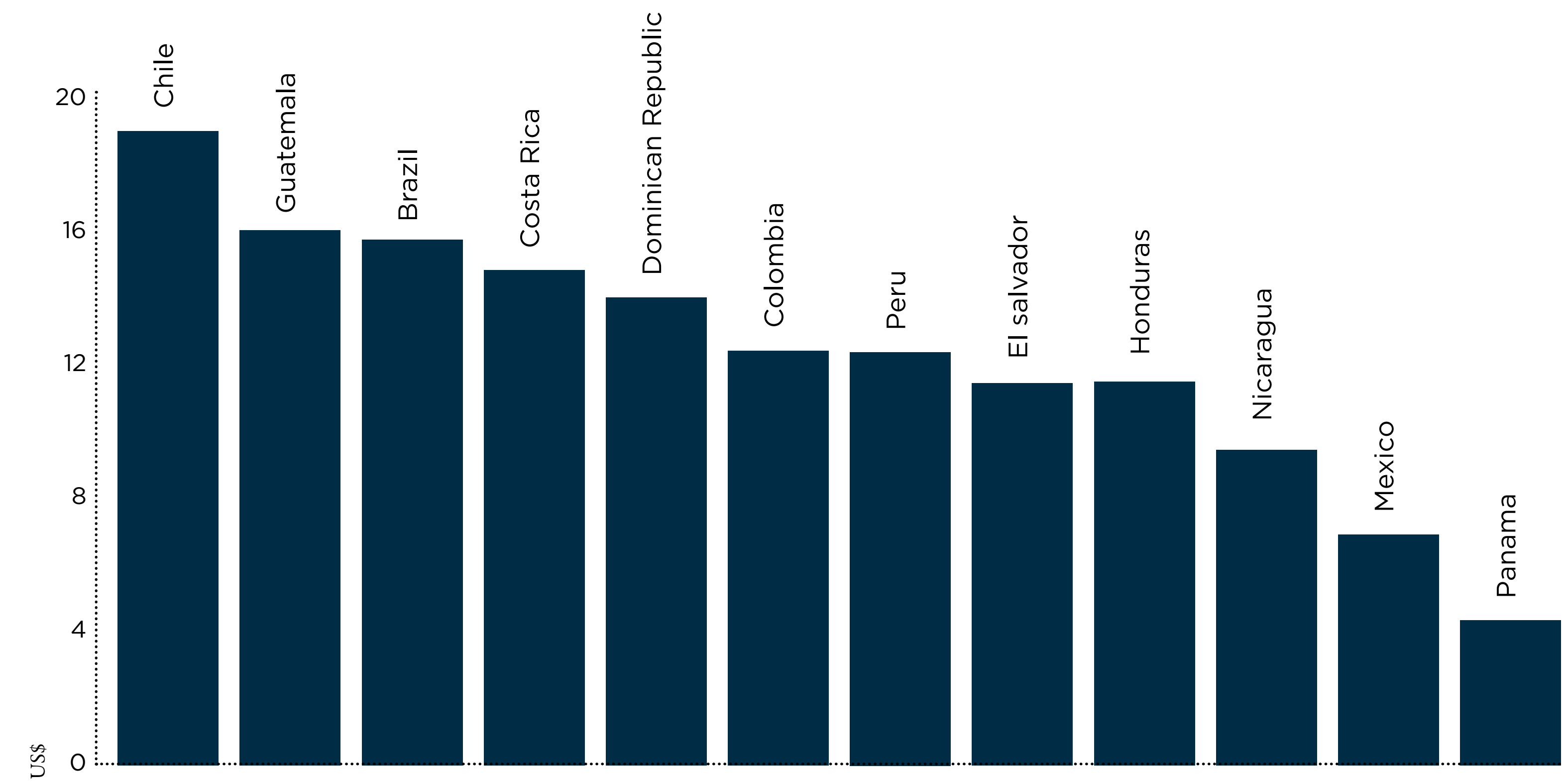
Figure 8.5: Brazil, Ecuador, and Mexico: Impact on Household Budgets of Eliminating Diesel Subsidies



Source: Prepared by the authors based on household surveys (Brazil 2009; Ecuador 2012; and Mexico 2014); and on price gap estimations by the Inter-American Development Bank and World Bank. Y-axis is expressed as in 1,000. For example, eliminating diesel subsidies in Brazil would represent an average impact on the household budget of around 0.006 percent in the richest income quintile and close to cero in the poorest income groups.

Figure 8.6: Price of a 25-Pound Liquefied Petroleum Gas Cylinder for Domestic Use

Sources: Government websites.
Note: Prices to end users reported between December 2017 and May 2018.



The analysis in this section focuses on Brazil, Ecuador, and Mexico. These are oil-producer countries with some common features in their history of fuel subsidies. Further, these cases are relevant because the countries have recently undertaken significant energy reforms. Equally important for this exercise is that these countries have available microdata to perform a distributive analysis.

The gap (subsidy) of diesel as a percentage of the price in 2014 was equivalent to 5 percent in Brazil, 230 percent in Ecuador, and 14 percent in Mexico. This section simulates eliminating that subsidy – which is equivalent to increasing end-user prices in the same proportions – in order to evaluate the marginal effects on household budgets. Figure 8.5 summarizes the results of the calculation. In Ecuador, increasing diesel prices by 230 percent means that the richest households would spend 0.09 percent more on diesel consumption. The impact is smaller on other income groups and in the other countries. Generally, the impact is small because there are few households in each quintile using diesel, implying that eliminating diesel (a highly contaminant fuel) subsidies, would affect relatively fewer families. Further, eliminating subsidies on diesel has an even smaller budgetary impact on the poorest income groups.

Better Ways of Subsidizing: The Case of Domestic Gas

The case of domestic gas – that is, gas for cooking such as LPG and natural gas – provides a policy-relevant area around which to center the discussion. Regarding liquid fuels, there seems to be no grounds for subsidizing fuel for private transportation. However, in the case of domestic gas, there is significant debate regarding how to eliminate or at least reduce the share of households cooking with traditional fuels. Price has emerged as a potential barrier, though mostly in terms of perception due to elements such as the frequency of purchase and required appliances and equipment. Firewood is

usually accessible in small and cheaper amounts, while switching from traditional cooking methods to gas-based or electricity-based methods implies initial investments in kitchens and gas connections.

As a reference point for how costly it may be to access modern cooking fuels in LAC, Figure 8.6 presents the price of a typical 25-pound cylinder of LPG. Buying such a cylinder is equivalent to around 6 percent and 4 percent of the minimum legal monthly salary in Brazil and Guatemala, respectively (as of 2018). However, it is important to note that, as in the case of fuels for private transport, subsidies of LPG prices are subject to sizable filtrations and regressivity. This is because retail LPG markets are decentralized such that arbitrage makes it difficult to differentiate consumers.

For this reason, recent schemes are based on systems that directly transfer the subsidy to previously identified beneficiaries. In those efforts, the use of information technologies and appropriate statistical systems seem to be key to increasing efficiency and effectiveness. Information technologies help reduce the costs of delivering the subsidy, while adequate statistical identification and monitoring help reduce filtration and increase targeting. However, attaining appropriate targeting under a generalized subsidy system represents a gradual process that requires political commitment.

Experience of El Salvador

El Salvador has made important efforts to correctly identify beneficiaries and reduce the costs of delivering subsidies, though only employing marginal changes. The government of El Salvador has subsidized LPG for residential use since the mid-1980s. This subsidy took the form of a generalized price subsidy delivery to the suppliers. The first reform took place in 2011, when delivery of the subsidy was changed so that it was delivered directly to final users. Targeting mechanisms have been gradually implemented since early 2013, including targeting households with monthly electricity consumption less than 200 KWh.[6]

Since 2014, the government has implemented a mechanism based on verification of household socioeconomic conditions under which households must apply for the subsidy (providing a copy of their electricity bill) and are subject to field verifications to determine if the households correspond to the target population. A household classified within the target population receives a unique ID number and electronic card (tarjeta solidaria), which is then used for the transfer of the subsidy. The subsidy is approximately half the price of a 25-pound cylinder (between US$4 and US$5), and it can be used once a month. The subsidy is directly paid to the supplier up to authorization of the beneficiary.

Figure 8.7 shows the share of households by income quintile that received the LPG subsidy in 2013 (before implementation of the targeting mechanisms) and in 2016. The share of beneficiaries has declined among all income groups, and more pronouncedly among the richest group, where it went from around 59 to 50 percent. However, that means that half of the richest income group still receives public fiscal resources that the government is aiming to provide to more vulnerable households. As a percentage of GDP, the fiscal budget allocated to the LPG subsidy declined over the last decade to represent between 0.3 and 0.4 percent in 2015/2016. However, given the still high levels of filtration, it is probable that this decline is moderating, at least in part, the observed reduction in the price of international fossil fuels since mid-2014.

The experience of El Salvador shows the difficulty of going from a generalized price subsidy to a more targeted scheme. Improving targeting tends to be a gradual and slow process that requires finding a feasible mix of conditions to identify the right beneficiaries. It is a learning-by-doing process that faces, at least, two main challenges. First, governments that start by implementing a generalized price subsidy lack the technical capacity and necessary technological infrastructure to properly gather, monitor, and analyze information on the target population. Second, the design of more efficient subsidy schemes may face substantial bias that could slow the learning-by-doing process. For example, governments may be prone to err on the side of caution and include citizens that would not adjust to the requirements of the subsidy than to exclude some who indeed qualify making the cost of the subsidy ore expensive.

Experience of the Dominican Republic

Another case of an LPG subsidy based on direct, unconditional cash transfers is the BonoGas Hogar program (known as BonoGas) in the Dominican Republic. This program also made reforms during 2008–2010, moving from a generalized subsidy to a targeted approach (Inchauste and Victor 2017). Households have to apply for the subsidy, and their socioeconomic characteristics are verified by field visits and monitored through the Sistema Unico de Beneficiarios (SIUBEN) implemented in 2010. The allocation of subsidies among households is based on a national poverty map constructed using a 2011 household survey and specifically designed to identify potential beneficiaries.[7] The amount of the subsidy was R$228 (approximately US$5) in 2016, or one-third the cost of a 25 pound-cylinder.

The program reached more than 926,000 beneficiaries in 2016 (around 35 percent of households in the country). Although not perfect, the distribution of beneficiaries by income group shows less filtration than is typical of generalized price subsidies. Between 37 and 39 percent of the two poorest quintiles receive the LPG subsidy. From there, the levels of filtration decline to 12.6 percent for the richest quintile (panel a in Figure 8.8).

Panel b of Figure 8.8 shows the evolution of the aggregate subsidy amount as a percentage of GDP. Notice that targeting efforts improved in 2012/2013 following the SIUBEN survey in 2011. The reduction in the fiscal weight of LPG subsidies was gradual, reaching approximately 0.07 percent of GDP in 2016. The improvement in targeting was mainly attributed to continued efforts to verify the beneficiaries' dataset.

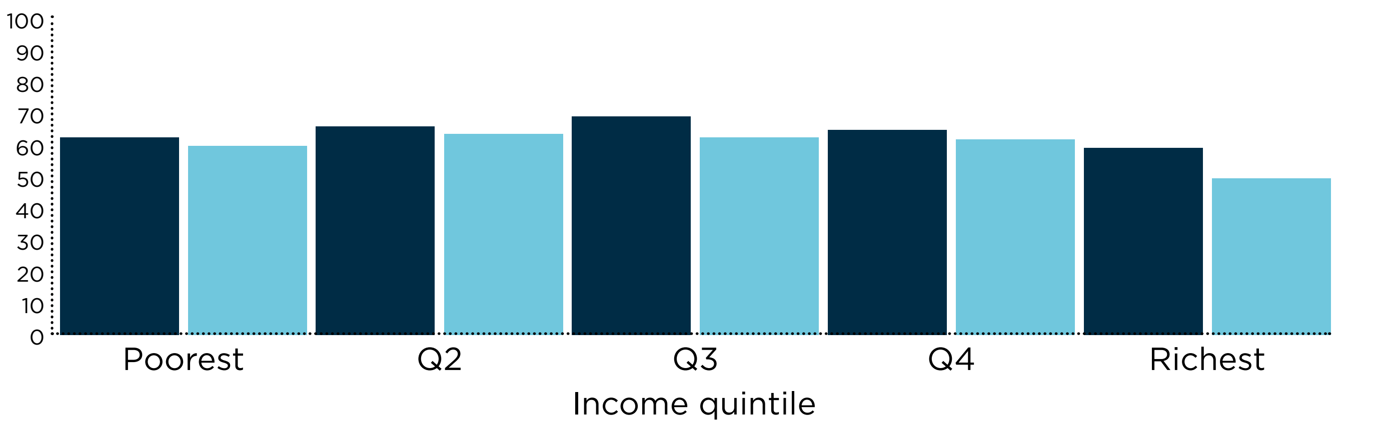
6. The program also includes low-income households with microenterprises (negocios de subsistencia).

7. The first survey took place in 2011. The dataset of beneficiaries has since been updated again following another survey in 2018.

Figure 8.7: Liquefied Petroleum Gas (LPG) Subsidy in El Salvador

Source: Prepared by the authors based on household surveys in El Salvador and on information from the Ministry of Economy.
Note: Income quintiles are based on household per capita levels.

a. Percent Distribution of Households Receiving the LPG Subsidy by Income Quintile



b. Cost of Subsidy as a Percentage of GDP

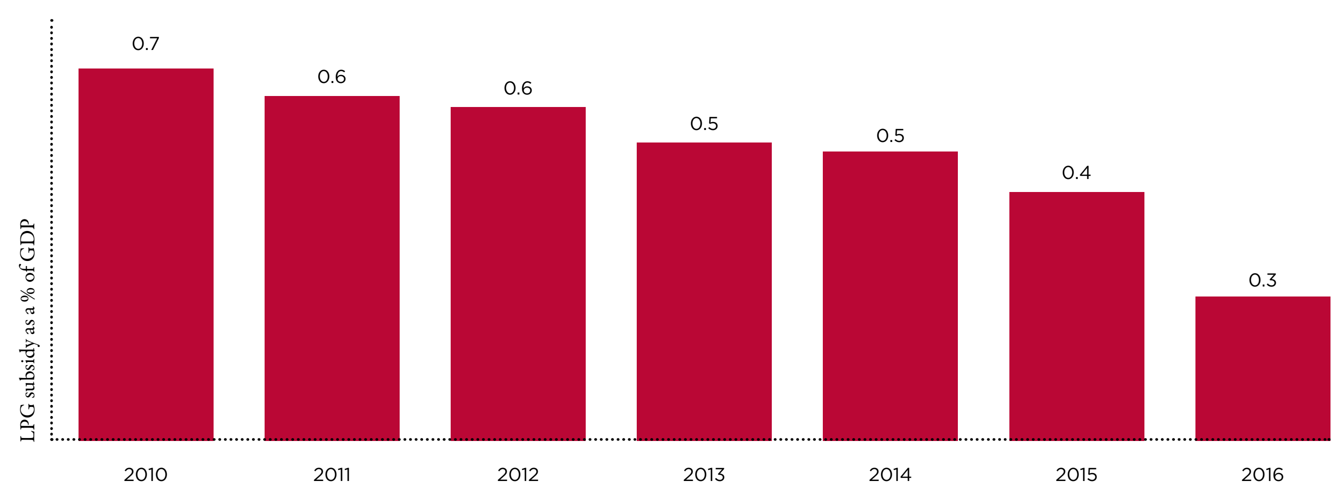
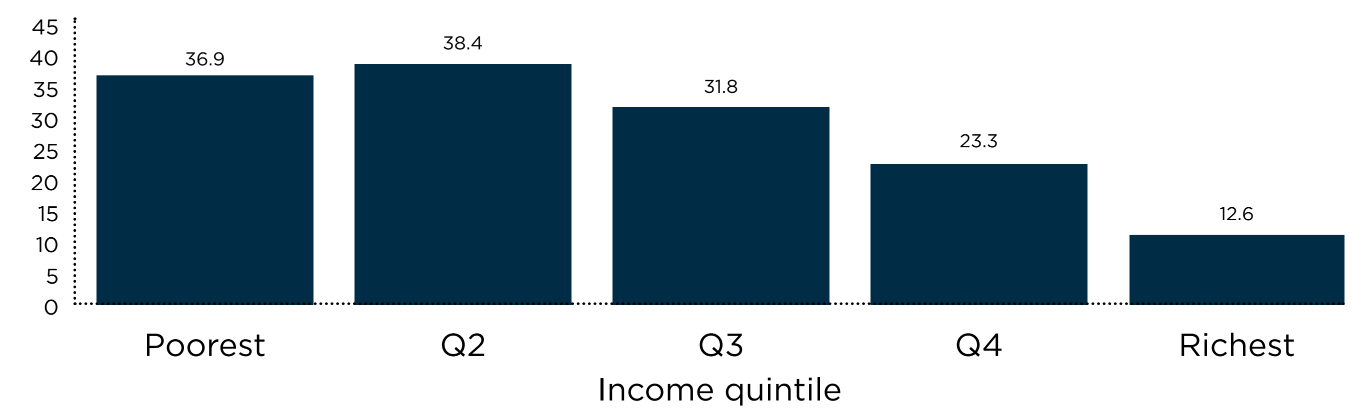


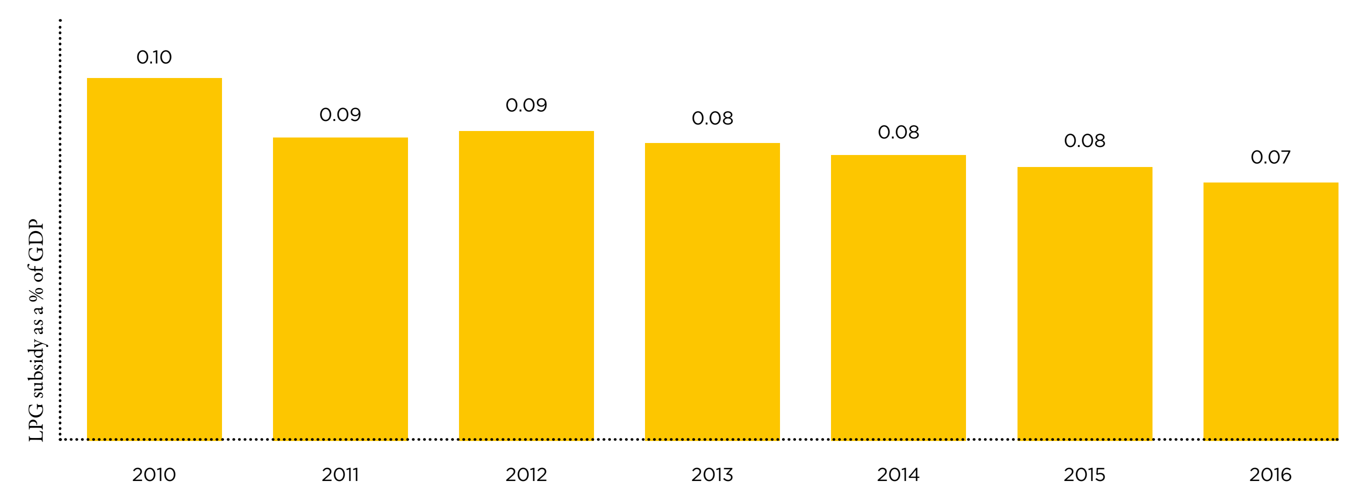
Figure 8.8: Liquefied Petroleum Gas (LPG) Subsidy in the Dominican Republic

Source: Prepared by the authors based on information from the labor force survey and the Administradora de Subsidios Sociales (ADESS).
Note: Income quintiles are based on household per capita levels.

a. Share of BonoGas Beneficiaries by Income Quintile (percent)



b. Evolution of LPG Subsidy as a Share of GDP (percent)



Final Remarks

Evidence from countries in LAC shows that those households with high income spend more in fuel than low income households. Poorly targeted subsidies may have a regressive impact by subsidizing high income households, more prone to consume fuel for transport compared to low income households who spend more in domestic cooking fuels. As it would be expected lower prices tend to induce higher consumption. Additionally, subsidies increase demand. The impact of fuel subsidies reductions is limited for low income households as a result of their lower participation on fuels consumption.

Additionally, poorly targeted subsidies over the price of fuels can, in the long terms, create financial harm to the industry reducing its investment capacity maintaining endogenous energy system inefficiencies that result in poor quality of service. Hence the reduction of the burden of subsidies over the system is a priority to make the operation of the energy system better. Experiences with the design of more efficient and better targeted subsidies has been shown to help the progressive effect of the subsidies while reducing its fiscal impact.

Chapter 9

Energy Efficiency and Household Energy Consumption

Energy efficiency is regarded as the less costly way to meet energy demand, basically by reducing energy consumption. Indeed, energy efficiency refers to using technology that requires less energy to perform the same function or service. For example, residential light-emitting diode (LED) light bulbs use around 75 percent less energy and last 25 times longer than incandescent lighting. Along with this example, the International Energy Agency (IEA) reports substantial historical and potential future savings from more energy efficiency equipment. According to the agency, the effect of energy efficiency gains between 2000 and 2016 was strongest in the residential sector, reaching savings of around 22 percent. Over the next three decades, the agency estimates an energy efficiency potential of around 30 percent of what could be global energy demand (IEA 2017).

Certainly to the extent that energy efficiency reduces household energy consumption, it will in turn impact energy spending, increasing the affordability of energy services. At the same time, energy efficiency may affect the configuration of the energy portfolio as households switch to more efficient energy carriers, such as electricity instead of firewood. Furthermore, energy efficiency policies can affect energy consumption behavior by improving the energy conservation habits of the public.

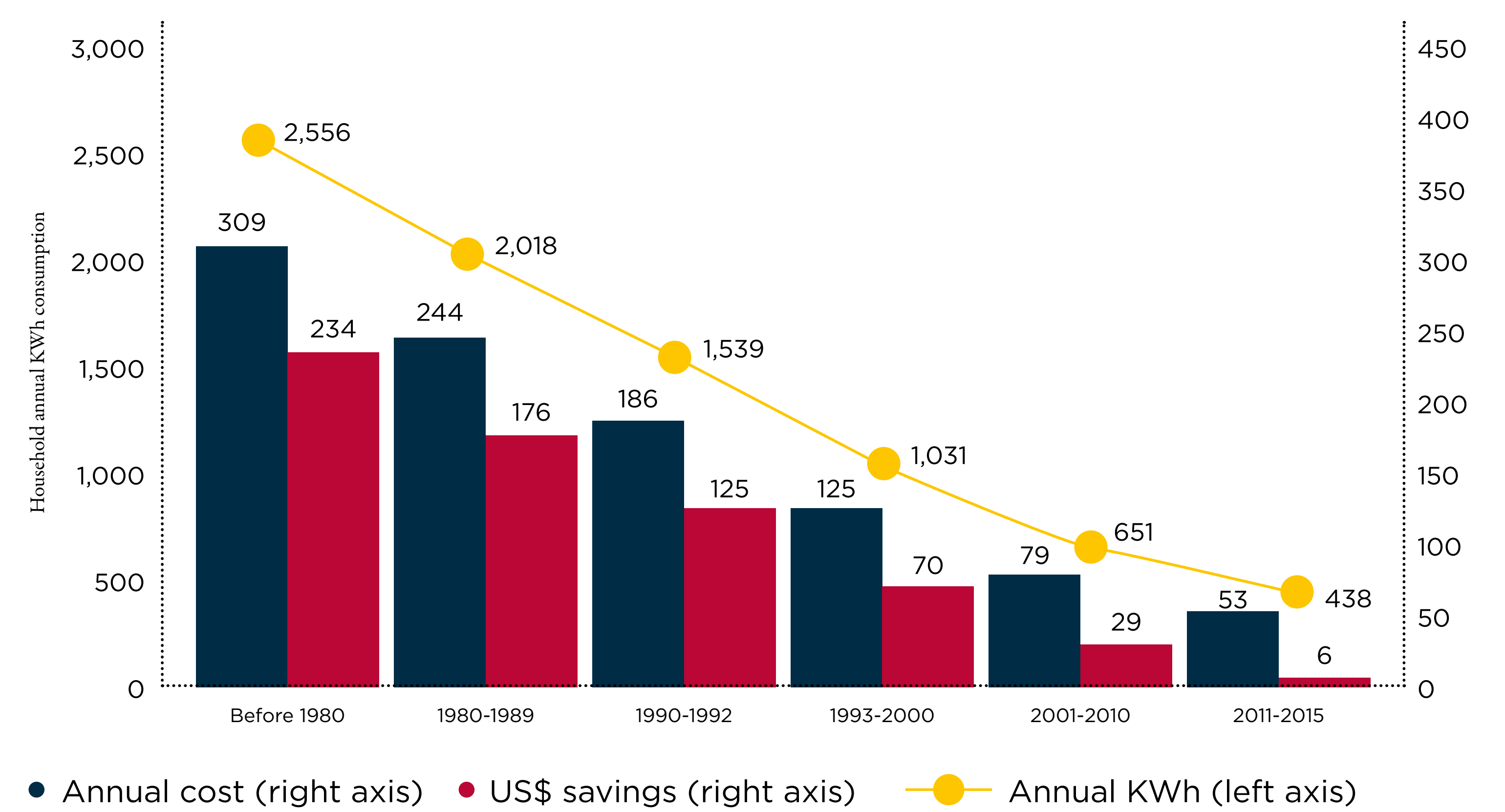
While energy efficiency can play a role in how households in Latin America and the Caribbean (LAC) consume energy, it is not clear how and to what extent. As documented in previous chapters, LAC will reach higher levels of energy that are commeasured with its stage of economic development, even using more energy-efficient equipment. Greater access to modern fuels and a growing middle class are expected to raise per capita energy consumption of electricity, gas, and transport fuels.

This chapter takes a look at these issues and reviews energy efficiency policies and programs in the region, including their limitations. It shows that diffusion of energy efficiency equipment and appliances remains a challenge regardless of the potential gains such diffusion may bring. Besides engineering considerations, energy efficiency programs and policies need to take into account behavioral considerations, such as lower-than-expected gains and potential rebound effects. Based on our exploration, currently, energy efficiency policies and programs–design and expected gains–have been largely based on simulation-based ex-ante research. These studies typically use strong behavioral assumptions to simulate changes and then extrapolate the resulting effect of these changes on total energy usage. This charter presents a growing body of rigorous empirical evidence showing that those expected gains can suffer substantial reductions due to behavioral factors.

The Potential of Energy Efficiency

Technological progress is having a huge impact on the energy efficiency of everyday equipment. Real prices of household equipment have declined substantially, as has the cost of using them, thanks to greater energy efficiency (Roberts 2017). For the case of a typical refrigerator, one of the most energy-consuming appliances in a household, Figure 9.1 compares refrigerator models produced in different time

Figure 9.1: Historical Power Consumption of a Typical Refrigerator and Potential Energy Efficiency Savings



Source: Prepared by the authors based on information from EnergyStar.gov.

Note: Assumptions: 19 to 21.4 cubic feet top freezer, electricity rate: US$0.121.

periods with and without energy saving standards (i.e., EnergyStar in the United States). The figure shows the evolution of power consumption, its associated energy cost, and the energy savings derived from technological progress. With and without energy standards, the energy consumption of this basic appliance has declined considerably. Replacing a refrigerator produced in 1980 with one produced under 2015 energy-saving standards reduces power consumption and energy spending by more than 80 percent (under constant power prices).[1] This represents a long-term trend that is expected to continue in the future. For example, as documented by Fouquet and Pearson (2006), the price of lighting is less than one three thousandth of the estimated value for the year 1,800.

Following this trend, as prices of modern and more efficient appliances go down in cost, the adoption of more modern and efficient appliances is expected. This trend will be reinforced by growing household income in the region. However, the net effect on energy consumption is not at all clear. Growing income and the expansion of the LAC middle class will also increase residential energy consumption. Moreover, the changing demographics of the population will surely impact energy consumption patterns in different ways. Where there is less discussion is that energy consumption, per capita and in aggregate terms, will increase in all countries.

1. Another example is the case of television. As of 2015, a 30-inch TV consumed 25 percent less power than a 2008 model (Urban and Roth 2017).

That is, even if LAC replicates the rates of energy efficiency adoption observed in high-income Organisation for Economic Co-operation and Development (OECD) countries, the average LAC household in the years ahead will still consume 50 percent more than in 2016 for comparable income levels. These considerations need to be realistically taken into account when evaluating national energy efficiency programs.

Despite the important challenges ahead, there is a strong case for pursuing effective energy efficiency policies. Energy efficiency offers the opportunity to reduce energy demand while reducing energy expenditures. International organizations have emphasized this approach as one of the lowest-cost ways to meet energy demand, in the sense that avoiding a kilowatt-hour of demand is typically cheaper than investing in additional generation or transmission and distribution to guarantee reliable supply. The IEA estimates that every dollar spent on energy efficiency avoids more than US$2 in supply investments.[2]

Is There an Energy Efficiency Gap in the Latin American and Caribbean Household Sector? Diffusion Is Key[3]

Do LAC households consume energy efficiently? As discussed in Chapter 3, per capita energy consumption in LAC is lower than in OECD countries. However, it does not mean that LAC is more energy efficient than the OECD. Instead, it is income that explains why per capita energy consumption is higher in the latter. Most LAC countries are at or below middle-income levels and, as they climb the development ladder, they will also increase their energy consumption. This wealth effect works through the ownership and use of energy-dependent equipment, such as the number of cars, heating, air conditioning, laptops, TV, and other aspects such as bigger dwellings and/or less sensibility to variation in energy prices. These trends are latent in the region, where the composition of household energy consumption and intensity is notably increasing (see Chapter 3 for an overview).

2. Assuming an average price between US$.02 and US$.03 per kWh. See Astarios et al. (2017).

3. This section is based on Jimenez (2018).

In this context, it is relevant to ask if technological progress in energy efficiency has been absorbed by LAC households? This is a hard question because while households may have been increasing their ownership of appliances, they may not be acquiring the more efficient models. Initial investments in energy-efficient equipment can be high, and energy savings might not be fully captured for consumers, thus deterring its adoption. Furthermore, as discussed in Chapter 7, there is evidence that current electricity prices schemes in several countries may be fostering overconsumption.

To take a glance at the existence (or not) of an energy efficiency gap, we perform a simple exercise that compares the average LAC household to a synthetic LAC household constructed with information from other regions. The average LAC household and its synthetic are equivalent in terms of per capita income, average GDP growth, highest and lowest annual temperatures, endowment of natural resources, and electricity prices. Figure 9.2 shows the levels and composition of energy consumption in LAC and OECD high-income countries. As can be observed, on average, LAC seems not to consume more than other countries at an equivalent stage of economic development (its synthetic).[4] However, there is substantial cross-country variability that can be traced, in part, to economic factors. In the case of low-income countries, they tend to consume more energy because of high consumption of biomass. That is, in these countries, households perform basic activities such as cooking, lighting, and heating using technologies and fuels that are highly inefficient and pollutant. As countries move toward higher income levels, energy consumption growth is almost

4. This seems to be also consistent with the findings by Jimenez and Mercado (2014) for the overall energy consumption of the average LAC country.

5. This picture assumes OECD high-income countries as an energy efficiency benchmark. These countries have seen reductions in their energy consumption that have been attributed to energy efficiency gains. On the other hand, these countries have stringent energy efficiency policies, and in general, their relatively higher purchasing power capacity would allow for greater penetration of newer appliances. However, it may be case that energy efficiency is not as great in these countries as one may want, and there is still important potential to be realized. To examine that potential, we would need to undertake more of an engineering-like exercise to compare the average household to the ideal energy-efficiency/energy-consumption profile. Such comparison would in turn be flawed for socioeconomic and behavioral reasons. Pricing and incomes that allow for adopting and using energy efficiency equipment are key determinants. On the other hand, behavior has been shown to play a role in explaining actual gains in energy efficiency, as will be discussed later in this chapter.

entirely driven by electricity and gas, such that total energy consumption converges toward the levels observed in OECD countries.[5]

Figure 9.2 does not assess the extent to which the potential of energy efficiency technologies has been fully or appropriately exploited in LAC. To address this topic, Figure 9.3 draws on specialized urban household surveys showing the vintage of refrigerators and the penetration of compact fluorescent lamp (CFL) bulbs. These two appliances are central in household electricity consumption nowadays comprising both the extensive and intensive margins of use. According with this figure, the penetration of relatively new technologies seems to be aligned with the international experience. Around 50 percent of refrigerators are less than 10 years old in Ecuador and the Dominican Republic, which represents a similar ratio to that reported for the United States. Interestingly, the percentage is higher in Ecuador (over 60 percent) due to a Governmental replacement program carried out in 2012 (Figure 9.3). Regarding the penetration of CFL, in Peru the share of households with at least one CFL bulb is high, around 95 percent on average, which can also be associated with that country's national program to replace incandescent bulbs in 2009 and 2010.

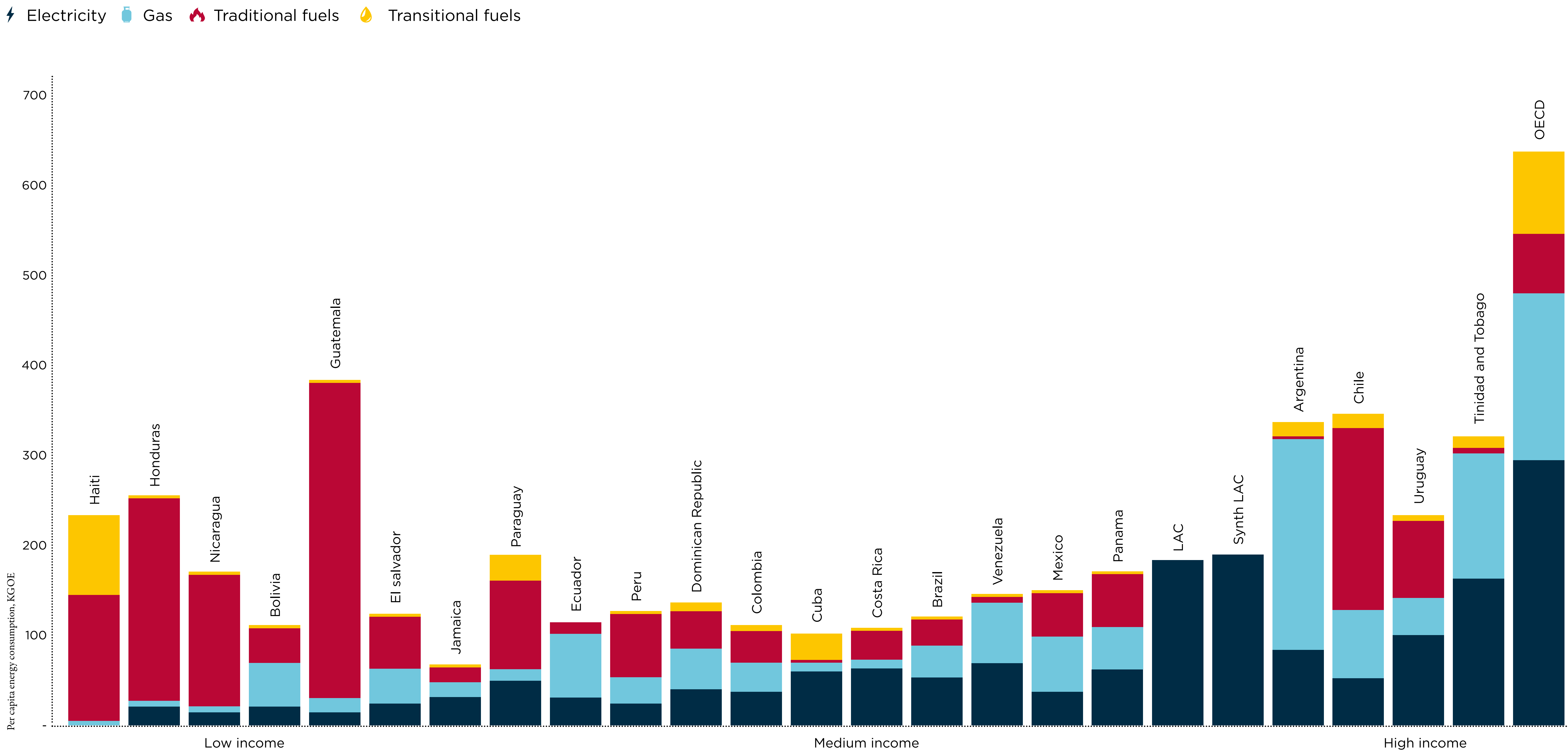
The relatively high ownership rate of refrigerators over the last five years is consistent with observed economic growth in LAC countries. At the same time, it is important to notice that this trend in growing appliance ownership has occurred at all income levels, documented by Straub and Fay (2019) and Wolfram, Shelef, and Gertler (2012). However, we should be careful in drawing conclusions from Figure 9.3 as it does not imply that households are acquiring the most efficient equipment. These figures do not account for energy efficiency standards, so the actual situation is probably less optimistic than it appears. For example, refrigerators may have been recently acquired but are not necessarily the most energy-efficient model. This is the case, for example, in Brazil where only 43 percent of the purchases made during the last 10 years were models with the national energy efficiency labeling.[6] In contrast, using the United States as a mild benchmark, products with the U.S. Environmental Protection Agency's Energy Star label (which certifies their energy-efficiency level) make up 46 percent of all new refrigerators, 84 percent of new dishwashers, 93 percent of new LCD monitors, 53 percent of new computers, and 67 percent of new compact fluorescent lamps (WEF 2017). That benchmark signals that there is substantial room for improvement in LAC countries regarding application of energy-efficiency standards and their adoption.

The figure also confirms a relevant characteristic of adopting energy efficiency: poorer households tend to have less energy-efficient equipment. This raises equity concerns about energy efficiency measures that may translate into political or public opinion barriers against, for example, minimum requirements for energy efficiency of new appliances. A popular belief is that energy efficiency policies impose higher costs on equipment and appliances, which affects more low-income households. However, empirical evidence suggests that in fact energy efficiency standards lead to net gains for consumer and social welfare. For example, in the United States, Brucal and Roberts (2017) show that after the imposition of energy efficiency standards for appliances, their prices declined while quality and consumer welfare increased, especially when more stringent energy efficiency standards were enforced in 2012. Similar evidence is scarce for LAC countries, but experiences and cost-benefit analysis (discussed below) do indicate that labeling programs have resulted in sizable energy and monetary savings.

These brief comparisons emphasize that leapfrogging will be challenging and that public policy will have a significant role to play. Energy efficiency policies will have to be reinforced to increase their effectiveness and make them more comprehensive. Part of these efforts includes communicating the progressive-distributive effects of energy efficiency policies – that is, that energy efficiency not only will save energy and reduce contaminant emissions, but will also bring monetary savings that benefit the most low-income families. It is also important to take into account that the current trend of high adoption of appliances in LAC implies that in the coming decades households will need to gradually replace such appliances. In other words, the high take-up of appliances today will become an issue to be addressed over the next decades in terms of replacing them for more energy-efficient models.

6. PROCEL (2007). The base year for this reference is 2005.

Figure 9.2: Is There an Energy Efficiency Gap in Latin America and the Caribbean?



Source: Prepared by the authors based on information from the International Energy Agency and the World Bank's World Development Indicators.

Note: KGOE: kilograms of oil equivalent; LAC: Latin America and the Caribbean; OECD: Organisation for Economic Co-operation and Development.

Boosting energy efficiency continues to be challenging in LAC, and evidence reveals that the application of energy efficiency standards in a field in which there is still room for improvement.

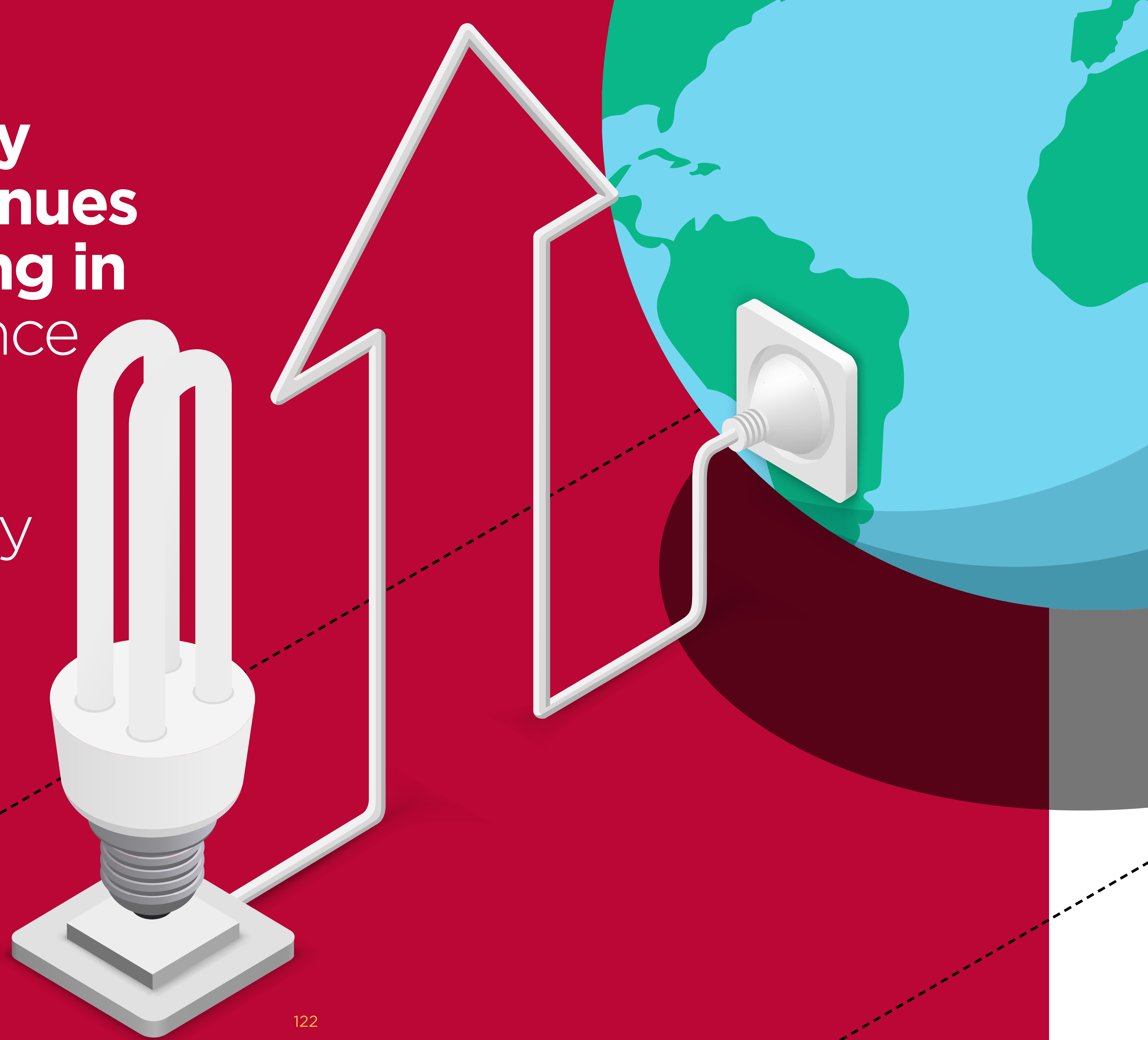
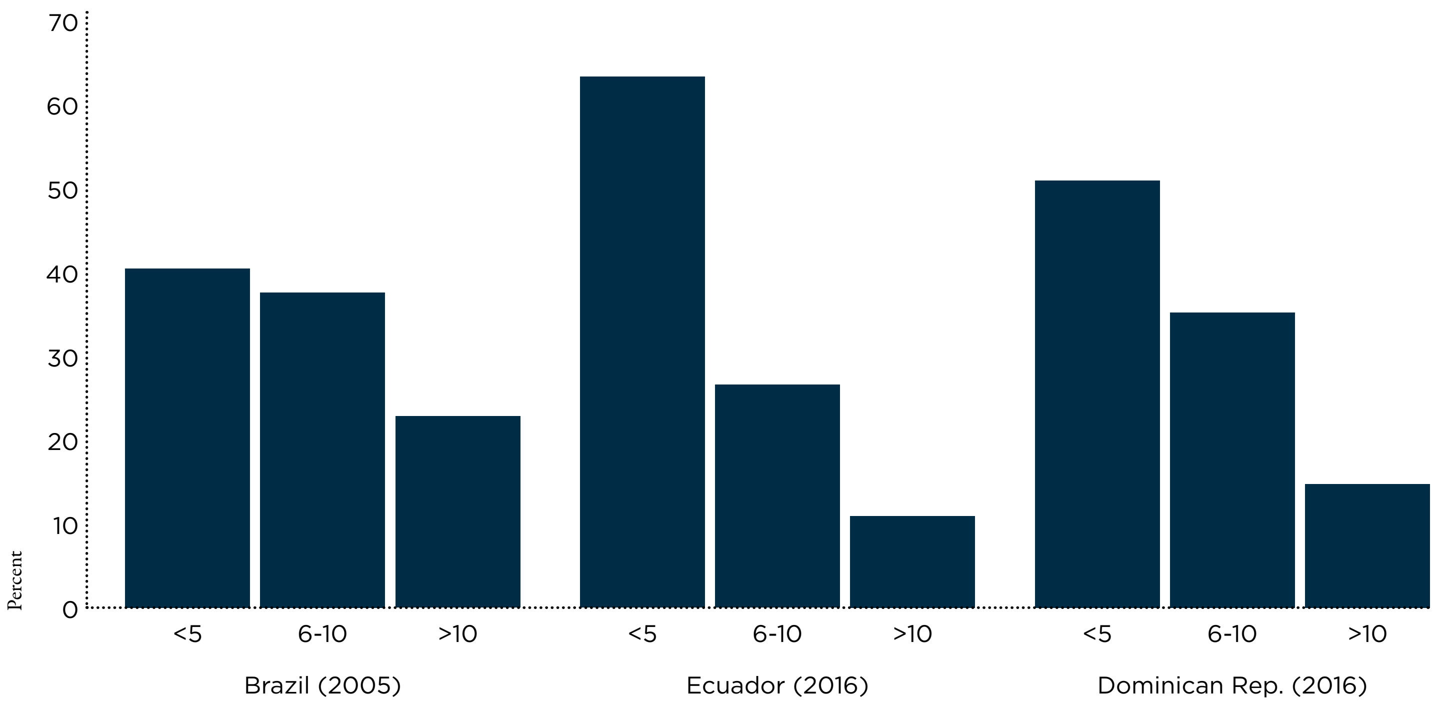
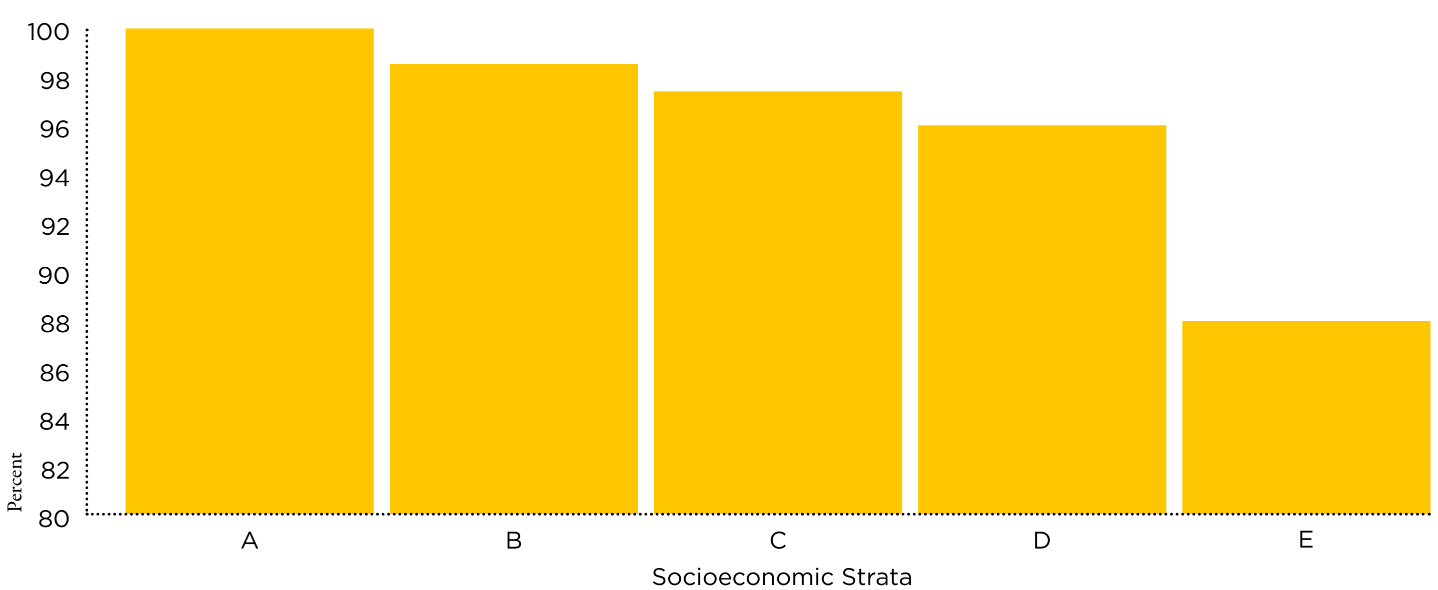


Figure 9.3: Diffusion of Energy Efficiency in Selected Latin American and Caribbean Countries

a. Vintage of Refrigerators in Brazil, Ecuador, and the Dominican Republic, 2016



b. Compact Fluorescent Lamp Penetration by Socioeconomic Strata in Peru, 2015



Source: Prepared by the authors based on urban household surveys in Ecuador, Peru and the Dominican Republic. Data for Brazil coms from Appliances and Habits of Use Surveys carried out under the Brazilian government's Electrical Energy Saving Program (known as PROCEL).

Note: Categories on the x axis of panel A indicate years (e.g., <5 less than 5 years old).

Why Is Boosting Energy Efficiency So Challenging?

Despite the sizable potential of energy efficiency, and the visible room for improvements in that area, effective policies are difficult to implement, particularly, in developing countries. There are technical, economic, political, behavioral, and natural endowment dimensions that may interact in different ways that affect the formation of institutional frameworks to support the diffusion of energy efficiency.

Regarding the technical dimension, adoption of more efficient technologies remains challenging because of four interrelated factors: household income, energy prices, cost of the equipment, and equipment replacement cycles. This section outlines some of the reasons, which often cut across these four-interrelated factors, why improving energy efficiency is so challenging in LAC.

Earlier chapters noted, 7 and 8, that energy prices in many LAC countries might not be providing the right signal for economically efficient energy consumption. The cost of energy efficiency equipment is declining, but so is the cost of less efficient equipment, and not necessarily at the same rate. Older equipment tends to depreciate quickly and may have a broad secondary market that is preferred by many segments of the population. Thus, it is perfectly comprehensible that low-income households in countries with higher subsidized energy prices choose energy inefficient equipment. On the other hand, appliances and equipment have long-term replacement cycles of 10 or more years, which, in turn, explains the slow penetration of energy efficiency technologies regardless of their financial and environmental attractiveness. For example, in the United States, it is estimated that 50 percent of households already have new refrigerators, and replacing the remaining universe of refrigerators will take more than 25 years.[7]

A country's stage of development matters because it may result in different policy priorities. With growing energy demand and still substantial infrastructure inefficiencies and insufficiencies, planners face the task of allocating their limited financial resources, as well as their scarce technical and institutional capacity to attend to other pressing demands, such as limited generation, transmission, or distribution infrastructure. In the short run, these demands may have more political and social weight, leading to weak systematic efforts to develop energy efficiency policies.

As an important aside, the quality and reliability of electricity services seem to be a basic condition for the widespread adoption of energy efficiency. From a qualitative viewpoint, in the Dominican Republic, Jimenez (2015) documents the low quality of electricity voltage and high frequency of outages as a key public concern regarding the longevity of electric assets. For Colombia, McRae (2015) provides quantitative evidence that unreliable electricity service affects the portfolio of appliances owned by households. In other words, there is some strong evidence that the probability of ownership of energy efficiency appliances decreases in relation to the average number of power outages.

7. Assuming replacement cycles of about 13 years (WEF 2017).

Table 9.1: Institutional Frameworks for Energy Efficiency, 2017

Country	Energy Efficiency Law
Uruguay	Law 18597 (2009)
Chile	Expected in 2018
Peru	Law 27345 (2000)
Guatemala	Expected in 2018

Historically, energy efficiency measures have been motivated by energy scarcity, but LAC is different from other regions because it has a substantial endowment of natural resources related to energy generation. Hydropower, the main source for electricity generation in LAC, is estimated to have around 50 percent additional potential (Andres, Johnson, and Yépez-Garcia 2011). This is also the case for nonconventional renewables. Other countries like Brazil, Bolivia, Venezuela, and Trinidad and Tobago have substantial reserves of fossil fuels. This abundance correlates with lower energy costs and may explain to a certain degree why energy efficiency does not appear as a structural goal in many countries in the region. Thus, resource abundance – either renewable or fossil – seems to have posed a different political economy setting that may have led to technically inappropriate energy pricing.

There may also be meaningful differences in terms of the sense of urgency to boost energy efficiency that are driven by environmental concerns. Developed countries, which concentrate more than 60 percent of total energy consumption, are active in energy efficiency and renewable policies as part of ensuring their energy security. Consistently in those countries, environmental awareness seems to be a relevant public concern. However, in LAC the setting seems to be different in two aspects. On the aggregate, the region has the cleanest electricity matrix in the world, mainly due to hydropower generation, and, what is more, the overall renewable share is increasing in many countries due to growing and economically viable exploitation of nonconventional resources such as solar, wind, and geothermal.

Environmental preferences may be heterogeneous. From the economic viewpoint of households, individual sensibility to environmental factors seems to be far less relevant in LAC countries than in rich countries, maybe due to the region's more urgent economic needs. The population in LAC, and in general populations from emerging economies worldwide, tends to be less concerned about environmental issues.

Taking advantage of the rebound effect of energy efficiency will require the re-optimization of the regulatory and business model of energy markets. Technological progress related to decentralization of energy production may relax the price and availability restrictions of clean energy, reducing the financial and environmental cost of using more energy. This, again, will constitute another dimension of the challenge for establishing adequate pricing mechanisms, because incorporating the so-called "pro-sumer" approach will require the re-optimization of the regulatory and business model of energy markets. However, these challenges also represent an opportunity, since most of the region's energy markets today are dysfunctional, with many regulatory deficiencies.

Energy efficiency policies in the residential sector may be more difficult than in other sectors. The industrial and commercial sectors, and even the transport sector, have a clear incentive and decision-making mechanisms to reduce energy inputs to maximize net revenues. In the household sector, factors such as credit constraints and information asymmetries may be more pronounced, reducing take-up rates of energy efficiency programs or the adoption of new energy-efficient equipment. Further, individuals are susceptible to behavioral bias (e.g., information and price perception, risk aversion) that may reduce the adoption of energy efficiency assets.

Energy Efficiency Policies in Latin America and the Caribbean

Regardless of the potential gains from energy efficiency, general normative and institutional frameworks are still more the exception than the rule in LAC (Table 9.1). According to the previous discussion, the complexity in developing energy efficiency policies and programs, and the specific circumstances of different countries in the region, may explain to a certain degree this situation. There is indeed great interest among policymakers in working on conservation and efficiency. However, it seems apparent that the countries of LAC could stand to work harder in developing adequate institutional frameworks as a cornerstone to increase the effectiveness of specific energy efficiency policies and programs.

As of 2017, according to information from Bloomberg Energy Finance (BNEF), only three of 26 LAC countries had specific laws on energy efficiency, and only six countries had institutions with ad hoc responsibilities. In a 2009 report, the Economic Commission on Latin America and the Caribbean (ECLAC) emphasized these limitations along with many others, such as insufficient financing and technical capabilities for effective program implementation. Currently, the general perspective is that, with the exception of a few

countries, energy efficiency initiatives seem to be isolated and not fully integrated with energy planning and institutional mechanisms in the sector. In other words, progress in institutionalizing energy efficiency seems to have been slow in the region over the last decade.

This situation tends to negatively affect the sustainability and replicability of good practices and experiences, wasting valuable lessons learned and the capacity generated during the implementation of those isolated initiatives. For example, Bolivia has a National Program of Energy Efficiency implemented during 2008 and 2011 to replace incandescent light with by fluorescent light (CFL) bulbs.[8] The program achieved energy savings by reducing peak demand, but due to the absence of overall regulation and technical standards on energy efficiency standards, the program was not scaled up (IDB 2018).

As a means of tracking and disseminating experiences and progress in energy efficiency planning, policies, and regulations, international institutions such as the Energy Sector Management Assistance Program (ESMAP) and the IEA have developed a platform to monitor the different initiatives. Through its SEforAll initiative, ESMAP has developed the Regulatory Indicators for Sustainable Energy (RISE) index (Figure 9.4), which includes an energy efficiency score composed of the following 12 dimensions: (1) existence of national energy efficiency planning, (2) energy efficiency entities, (3) information provided to consumers about electricity usage, (4) energy efficiency incentives from electricity rate structures, (5) incentives and mandates for large consumers, (6) incentives and mandates in the public sector, (7) incentives and mandates for utilities, (8) financing mechanisms for energy efficiency, (9) minimum energy efficiency standards, (10) energy labeling systems, (11) building energy codes, and (12) carbon pricing. The score is based on a simple average of these dimensions, and in its last version covers 111 countries, including 13 from LAC.

In terms of these indicators, among the 13 LAC countries examined Mexico is the top performer, with scores above even the average OECD high-income countries. It is also interesting that in 2015, Mexico was the only country in the region with a carbon tax.[9] However, this version of the RISE index does not include Chile and Uruguay, which in recent years have undertaken important steps to build an institutional framework and financing platform to boost energy efficiency in the residential sector.

In contrast to the RISE index, the IEA focuses on mandatory codes and standards. These represent minimum technical energy efficiency requirements that apply to specific products such as lighting and appliances, motor vehicles, buildings, or sectors (industry). The IEA's Efficiency Policy Progress Index evaluates coverage and strength of these codes and standards. "Coverage" refers to energy use by applicable equipment that is covered by these standards. "Strength" measures the extent to which efficiency levels need to be improved. For example, if maximum refrigerator energy use was 1000 kilowatt hours (kWh) per year in 2000, and a new policy in 2010 lowered this to 750 kWh, the strength improvement is 25 percent. If the standard was lowered again in 2015 to 600 kWh, the strength improvement is 20 percent, with a cumulative strength increase of 40 percent since 2000.

In 2016, the IEA reported that 31.5 percent of global energy use was covered by mandatory codes and standards, representing an increase of 17 percent since 2005. However, coverage varies widely according to end use. Lighting is the end use with the highest coverage (75 percent). Light bulbs do not last as long as other end-use equipment, so the stock turns over quickly and coverage rates increase rapidly with the implementation of new policies. Furthermore, lighting accounts for a small amount of global final energy use, with a share of global coverage at less than 2 percent.

Energy Efficiency Programs in Selected Latin American and Caribbean Countries

Energy efficiency programs in the residential sector have been implemented mostly, but not entirely, by Ministries of Energy under different frameworks. Energy efficiency laws have provided overall regulatory support for these programs, but there are successful examples in countries with more specific laws, such as Mexico. These programs aim to accelerate the diffusion of energy efficiency among the general public. The long-term general objective is to generate energy savings by reducing demand while reducing greenhouse gas emissions and other pollutants associated with the generation, transport, and distribution of energy (IDB 2015). Thus, such programs serve multiple social objectives, reduce energy consumption, and increase energy affordability. They also aim to reduce intra-household pollution from cooking, heating, and lighting with traditional and transitional fuels.

Table 9.2 briefly describes selected energy efficiency programs implemented in the LAC residential sector. The table is not an exhaustive summary of energy programs and tools implemented in the region, but it provides an overview of some of the most well-known initiatives. Broadly, programs in the region can be separated into energy efficiency programs of standardization and labeling, and subsidized interventions with high social impact. Labeling programs seek to reduce problems of imperfect information by providing timely and strategic information on energy assets, which is displayed visually through labels. These energy efficiency standards look to reduce the principal-agent problem by setting a minimum of efficiency for equipment. The standards are applied to the local markets, and it is argued that without them such markets could quickly attract energy inefficient equipment that is not accepted in neighboring markets (IDB 2015). On another front, social energy efficiency programs focus on the most vulnerable population segments that face economic constraints in replacing old or inefficient appliances. These

8. Created by DS 29466 in 2008.

9. The Mexican carbon tax is US$3.50 per ton of emissions. However, natural gas is zero-rated because it is considered a relatively clean fossil fuel, and because zero-rating it helped boost political acceptance of the tax. This measure is expected to reduce annual carbon emissions by 1.6 million tons of greenhouse gas emissions and generate almost US$1 billion in revenue per year.

Implementing **energy efficiency** policies in the residential sector is more challenging, compared to other sectors. This may be due to **higher credit constraints** and information asymmetries.

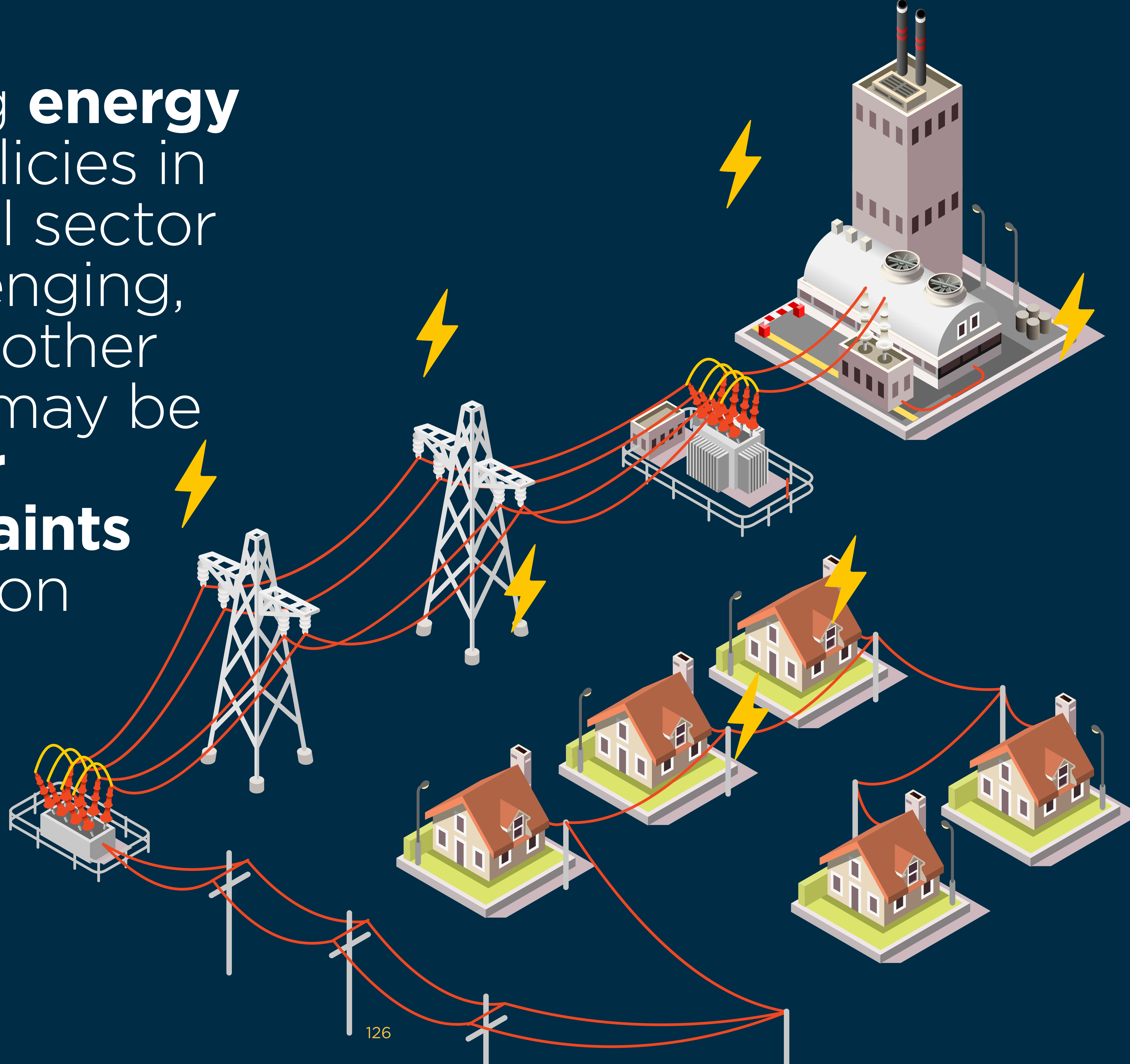
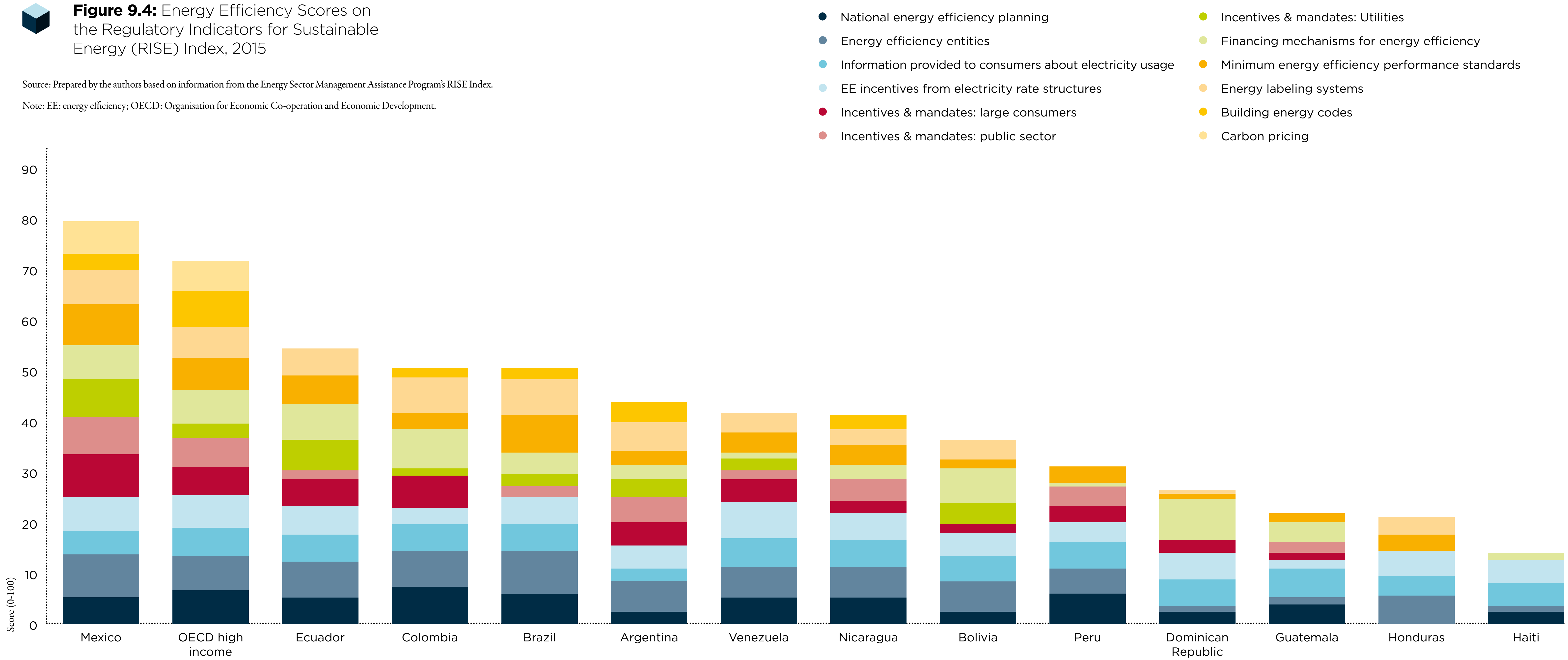


Figure 9.4: Energy Efficiency Scores on the Regulatory Indicators for Sustainable Energy (RISE) Index, 2015

Source: Prepared by the authors based on information from the Energy Sector Management Assistance Program's RISE Index.

Note: EE: energy efficiency; OECD: Organisation for Economic Co-operation and Economic Development.



are subsidized programs aimed at reducing credit or financing constraints to adopt energy efficiency.

The most common of these initiatives is the implementation of energy efficiency standards, followed by programs that subsidize the replacement of old electric appliances such as refrigerators, incandescent bulbs, or stoves. Subsidy programs tend not to continue over time, and they are highly dependent on the availability of fiscal resources. Establishing sustainable financing schemes remains a challenge, and few countries have funds or have allocated dedicated fiscal accounts to these types of programs. Some exceptions are Mexico and Uruguay, which have established specialized funds to facilitate financing under concessional conditions, although they focus on businesses. In Uruguay, the Fideicomiso Uruguayo de Ahorro y Eficiencia Energética was established in 2012 to regulate the efficient use of energy, and its financing was established at 0.13 percent of energy generation companies' sales in the domestic market.[10] In the residential sector, multilateral financing has represented a key source for implementing and escalating such programs. Still, the reach of such programs varies widely across countries, and there remains significant room for analyzing their impact and cost benefit in order to improve program design and replicate good practices.

Performance of Energy Efficiency Policies and Programs

Few evaluations have been conducted of the performance of energy efficiency programs and tools in LAC. The programs are implemented under the expectation that they will have important effects on energy consumption and savings. However, most evaluations are ex ante and based on engineering assumptions, limiting our understanding of how people's behavior can change the expected benefits, or what the ex post cost-benefit of the programs might be. Still, there is some relevant information that speaks of the sizable outcomes and potential of energy efficiency. For example, in Ecuador, the refrigerator replacement program replaced more than 28,000

Table 9.2: Selected Energy Efficiency Programs for the Residential Sector in Latin America and the Caribbean

Country	Programs	Description
Argentina	Labeling Program	Between 1999 and 2007, the program established mandatory incentive energy efficiency standards for refrigerators, incandescent bulbs, bulbs, and air conditioners. In 2014, it also included washing machines and fluorescent lamps.
Brazil	Labeling Program (Procel Selo)	This program was launched in 1993 and started by regulating energy efficiency standards for coolers and refrigerators in 1995. As of 2016, it covered 39 types of appliances.
Chile	Sustainable Construction	Started in 2012 by the Ministry of Housing and Urban Development, the program establishes and implements construction standards for reducing energy use.
Ecuador	Standardization and Labeling Plan	Since 2010, the Ministry of Electricity and Renewable Energy has gradually established efficiency standards for energy-saving light bulbs, refrigerators, air conditioners, water pumps, induction cookers, water heaters, and televisions, among other items.
	Program for the Renewal of Inefficient Energy Consumption Equipment	Since 2012, this program has worked to replace inefficient refrigerators that are more than 10 years old.
	Replacement of Bulbs through Incandescent Energy	This program began in 2008 with the objective of reducing electricity demand during peak hours. In 2008, 6 million lights were replaced, focusing on homes with consumption of less than 150 kWh/month. In 2010, 10 million lights were replaced in other sectors such as health, education, and social services, as well as residential users with consumption of up to 200 kWh/month.
	Induction Cooker Pilot Project	Started in 2010, the program aims to partially replace liquefied petroleum gas stoves with electric stoves. By 2014, approximately 3,433 induction cookers had been delivered.
Peru	Replacing of Incandescent Light Bulbs	Between 2009 and 2010, the program aimed to replace incandescent light bulbs in homes with consumption of less than 100 Kwh/month. During this period, it is estimated that 1.5 million lights were delivered.
	Energy Efficiency Labeling for Energy Equipment	This program was established in 2017 to implement energy efficiency labeling for refrigerators, washing machines, water heaters, air conditioning, spotlights, and ballasts for fluorescents.
	Improved Kitchen Program	This program was initiated in 2009 to replace inefficient firewood and kerosene stoves with improved stoves such as gas stoves. In 2015, 144,424 improved wood stoves were delivered.
Uruguay	Programs for Normalization and Labeling of Energy Efficiency	Started in 2006, this program establishes energy efficiency specifications for compact fluorescent lamps, electric water heaters, refrigeration appliances for domestic use, and air conditioners.

Source: Prepared by the authors based on public information as of 2017.

refrigerators, estimated to have saved around 15,780 MWh per year, equivalent to US$17 million.

To provide an overview of the performance of energy efficiency programs, this section discusses some available studies for countries of LAC. Overall, empirical studies show that energy efficiency policies can have significant and lasting effects in reducing energy consumption, although such effects may be less than ex ante projections. Behavior appears to play a central role in explaining differences between expected and actual outcomes, so studying behavior is relevant to improving the design and effectiveness of energy efficiency programs.

Energy Efficiency Public Policies and Residential Energy Consumption in Mexico, 1984–2014 [11]

Mexico has been one of the most dynamic countries in the region in terms of energy efficiency. Table 9.3 summarizes energy efficiency programs since 1990, including thermal isolation of dwellings, Daylight Saving Time (DST) tariff incentives, and replacement of appliances, among others. This dynamism in energy efficiency policies responds to an exponential growth in electricity residential demand, which is greatly explained by the growing number of users, growing rates of electricity coverage, and increasing ownership of appliances.

The evaluations of these measures are not comprehensive. However, according to available studies, the two polices that seem to have had the greatest impact are DST measures and energy standards. For the period 1996–2014, estimates on the savings from energy standards are around 100,000 GWh, equivalent to MX$300 billion. For the same period, the savings from DST measures are estimated at 21,807 GWh. To give a dimension of these magnitudes, in 2016, DST saved 975 GWh of electricity consumption, which is equivalent to the annual demand of more than 600,000 Mexican households. This represents approximately MX$1,542 million in economic terms.

Based on a trend-analysis, Buen, Hernández, and Navarrete (2016) derive the overall savings from energy efficiency policies in Mexico. They estimate a cumulative saving over 1996–2014 of around 175,000 GWh, which is equivalent to three times the residential electricity consumption of Mexico in 2014. This represents savings of around MX$175 billion that households can allocate to alternative expenditures or investments. Given the levels of subsidies to electricity supply in Mexico, those savings also translate into MX$350 billion in relief for the fiscal budget. In terms of greenhouse gases, they represent approximately 82.5 million tons of CO_2 equivalent of avoided emissions.[12] Figure 9.5 shows the scenarios with and without energy

11. This section is based mainly on Buen, Hernández, and Navarrete (2016). Information was complemented with data from the Fideicomiso para el Ahorro de Energía Eléctrica (FIDE).

12. Respectively assuming a tariff of US$1/kWh, a subsidy of US$2/kWh, and an emission coefficient of 0.5 tons of CO_2/MWh.

Table 9.3: Timeline of Energy Efficiency Policies in the Mexican Residential Sector

Program	Scope
FIPATERM: Thermal isolation of properties	Since 1990, more than 100,000 properties have been upgraded, mainly in Mexicali, BC.
Ilumex: Changing incandescent lamps with compact fluorescents	Between 1993 and 1996, more than 2.3 million lamps were changed in Guadalajara and Monterrey.
Daylight Saving Time: Advance the clocks one hour in summer	Since 1996, DST has been implemented in 33 municipalities on the northern border (except Sonora).
Fideicomiso para el Ahorro de Energía Eléctrica (FIDE): Replacing incandescent lamps with compact fluorescents	Between 1996 and 2006, more than 10 million lamps were changed in operating areas of the Comisión Federal de Electricidad.
Mandatory energy performance regulations for electrical equipment used in homes	As of 1996, 10 regulations had entered into force for refrigeration, lighting, air conditioning, water pumping, clothes washing and standby equipment.
High-Consumption Domestic Rate: Tariff without subsidy to users of the residential sector	Came into effect in 2002 and applies to more than half a million domestic users throughout the country.
Green Mortgage: Financing for energy-saving measures in new housing	Implemented in 2008, this program employs measures such as compact fluorescent lamps and thermal insulation of property areas.
Sustainable Light: Changing incandescent lamps with compact fluorescents	Between 2011 and 2012, around 46 million compact fluorescent lamps were distributed throughout the country.
Appliance Replacement Program: Change of refrigerators and air conditioning equipment	Between 2009 and 2012, around 1.9 million equipment units, mainly refrigerators, were changed throughout the country.

Source: Buen, Hernández and Navarrete (2016).

efficiency policies, assuming consumption-as-usual in the case of the simulated trend. Regardless of population growth, the increase in income and in holdings of appliances, and a downward trend in electricity prices, there was a continuous reduction in average residential consumption, suggesting that those energy savings are mainly due to energy efficiency interventions.

A full accounting of the effectiveness and cost-benefit analysis can be challenging. The cost of a MWh saved is rarely compared across different programs, and following households over time to evaluate their behavioral changes in energy consumption is not a widespread practice within the design and implementation of energy efficiency programs. One exception is the study by Davis, Fuch, and Gertler (2014), who concentrate on the large-scale replacement program of old refrigerators and air conditioners with energy efficiency models. The authors find that refrigerator replacement reduced electricity consumption by 7 percent, about one-quarter of the ex ante engineering estimates, while air conditioning replacement actually increased electricity consumption. According to the authors' calculations, the program was expensive: the cost of reducing electricity consumption was US$.30 per kilowatt hour and the cost of reducing carbon dioxide emissions was US$500 per ton. They argue that the difference between their estimates and ex ante evaluation lies in the fact that ex post evaluation incorporates households' actual behavior, which may be considerably different from ex ante assumptions in terms of the participation incentive for given levels of subsidies and energy consumption.

Energy Efficiency Labeling and Electricity Rationing in Brazil

National Program for Conservation of Electricity (PROCEL) Selo

Procel Selo encompasses programs of energy efficiency labeling, public information, education, and partnerships with institutes and universities directed toward diffusing energy-efficient equipment. *PROCEL* is strongly focused on the household sector, through its labelling program *Etiqueta Nacional de Conservação de Energia* (ENCE), and over the years it has become the main source of energy savings among the different initiatives implemented by the Brazilian government.

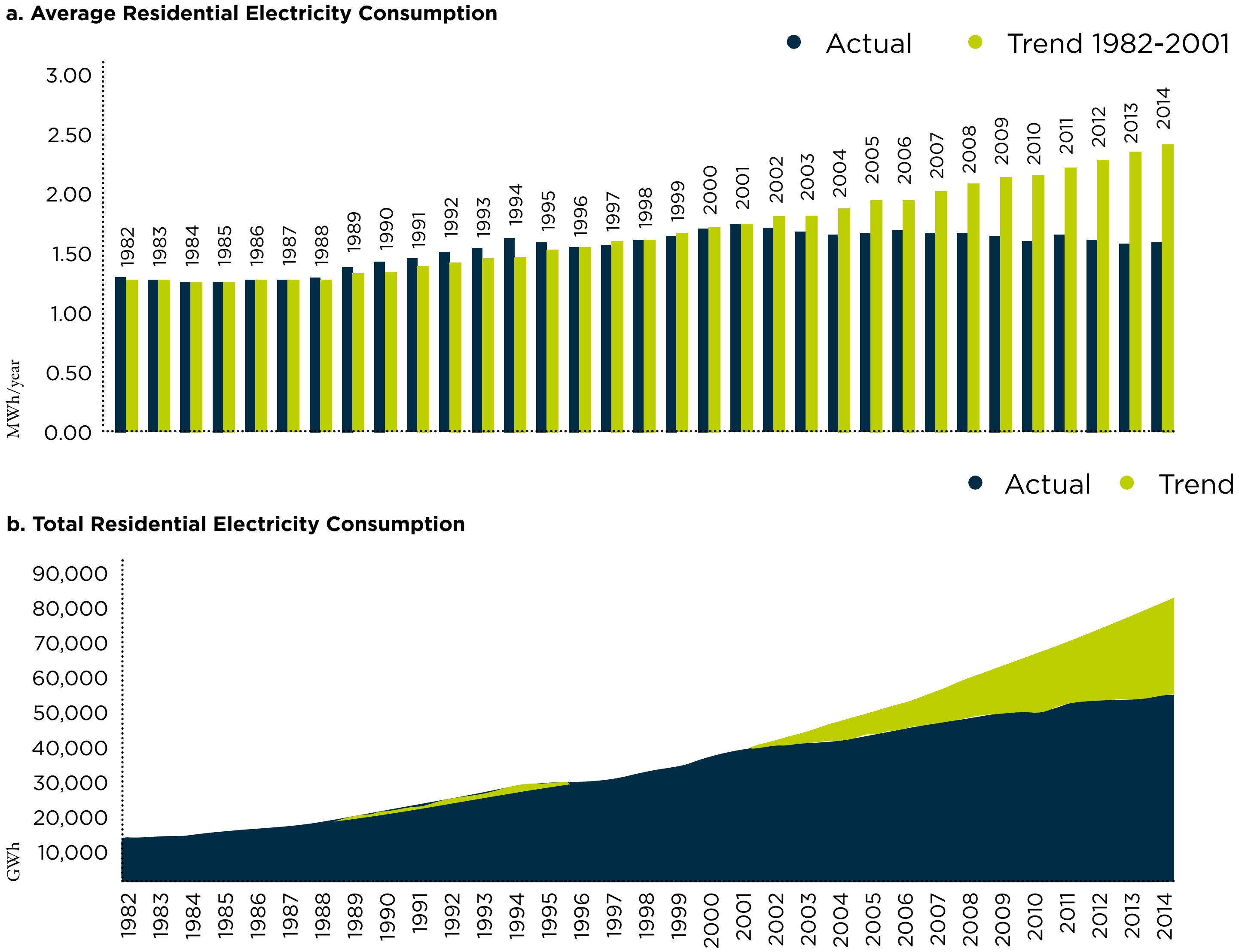
ENCE was launched in 1993 and started by regulating energy efficiency standards for coolers and refrigerators in 1995. As of of 2016, it covered 39 categories appliances that include 3,722 models of equipment. Since its implementation, it is estimated that around 42 million equipment units were sold in the country under PROCEL Selo. The use of equipment complying with the organization's energy efficiency standards helped to save 15 billion of KWh per year, equivalent to 15 million tons of CO_2 emissions.

Overall, since 1986, PROCEL estimates that it has helped save around 107 billion KWh, with about half of that having occurred since 2012, by which time most energy categories were already accounted for in the regulated energy labeling (Figure 9.6). Over 2012–2016, financing for PROCEL reached approximately US$90 million.

Mexico is the poster boy of energy efficiency.

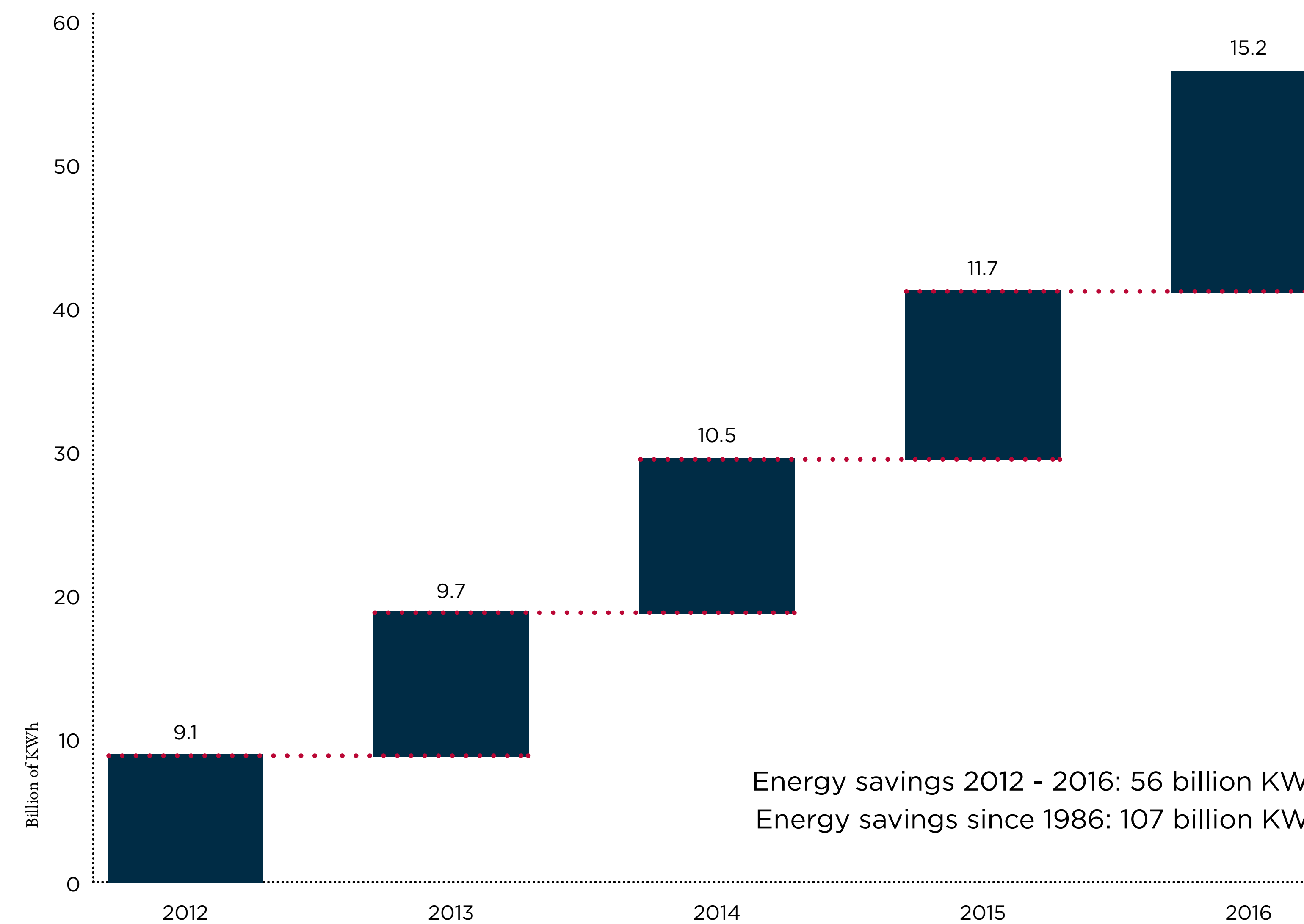
The country has been implementing programs since 1990, **including thermal isolation of dwellings, daylight saving times tariff incentives, and subsidies for appliance replacement.**

Figure 9.5: Mexico: Simulation With and Without Energy Efficiency Policies



Source: Buen, Hernández, and Navarrete (2016).Note: Categories on the x axis of panel A indicate years (e.g., <5 less than 5 years old).

Figure 9.6: Brazil: Cumulative Energy Savings per Year from the National Program for Conservation of Electricity (PROCEL)



Source: Electrobras (2017)

Most of the energy savings from PROCEL are due to its labelling program, suggesting the effectiveness of providing information and encouraging consumers to adopt more efficient equipment. It is important to note that ENCE does not provide subsidies to customers. Instead, most of the program resources are allocated to financing research and dissemination. This involves partnerships with universities and laboratories to evaluate and establish the technical aspects of the energy efficiency requirements that are imposed. As a result of its success, ENCE forms part of the National Energy Efficiency Plan in terms of establishing minimum energy efficiency labels and saving targets towards 2030.[13]

13. The National Energy Efficiency Plan was established in 2001 by Law 10.295, and was updated in 2016 by Law 13.280. Other programs implemented under PROCEL are Procel Educação, Procel Infor, Procel Edificaçoes, Procel Predios Publicos (EEP), Procel Gestao Energertic Municipal (GEM); Procel Industria, Procel Iluminacao Publica e Sinalizacao Semaforica Eficientes (Reluz), and Procel Saneamiento Ambiental (Sanear).

Energy Scarcity Shocks, Rationing Policies, and Habit Formation in Brazil[14]

Another program that seems to have had a substantial impact on household energy consumption originates in a policy response to an energy scarcity shock in Brazil. Historically, Brazil has relied on hydroelectricity. As of 2017, around 70 percent of electricity was provided by hydro sources, which in turn may represent a significant vulnerability to droughts. This was the case in 2001, when the country experienced a major energy crisis as a result of a severe drought that reduced water levels in reservoirs, in turn dramatically reducing electricity generation in some regions. In order to prevent generalized blackouts, the government implemented a temporary electricity saving program between June 2001 and February 2002 aimed at reducing residential electricity use by 20

14. This section is based on Costa and Gerard (2018).

percent. Residential customers were assigned individual quotas and were subject to a series of incentives to consume below their quota.

Costa and Gerard (2018) study the long-term effects of this event. Using detailed utility-level administrative data, they find that this policy led to a large short-run electricity consumption decline of about 23 percent (more than initially targeted). Energy consumption levels partially rebounded after the policy ended, but still-relevant saving levels of around 11 percent continued over the long run. Figure 9.7 shows the short-run effect of implementation of the policy and the long-term effects until 2014. The fact that the region where the policy was implemented reduced its energy consumption levels for over a decade after the rationing ended suggests that this experience affected energy consumption habits in a substantive way.

The authors further investigate the channels behind this habit change and find that most of them are associated with a change in the conservation and use of electricity, and to a less extent with replacement with more efficient appliances. For example, households seem to react to the policy by reducing their time of use of electric appliances such as lighting and electric showers. Appliance replacement mostly seems to have occurred in low-cost equipment such as swapping incandescent lightbulbs for fluorescent ones.

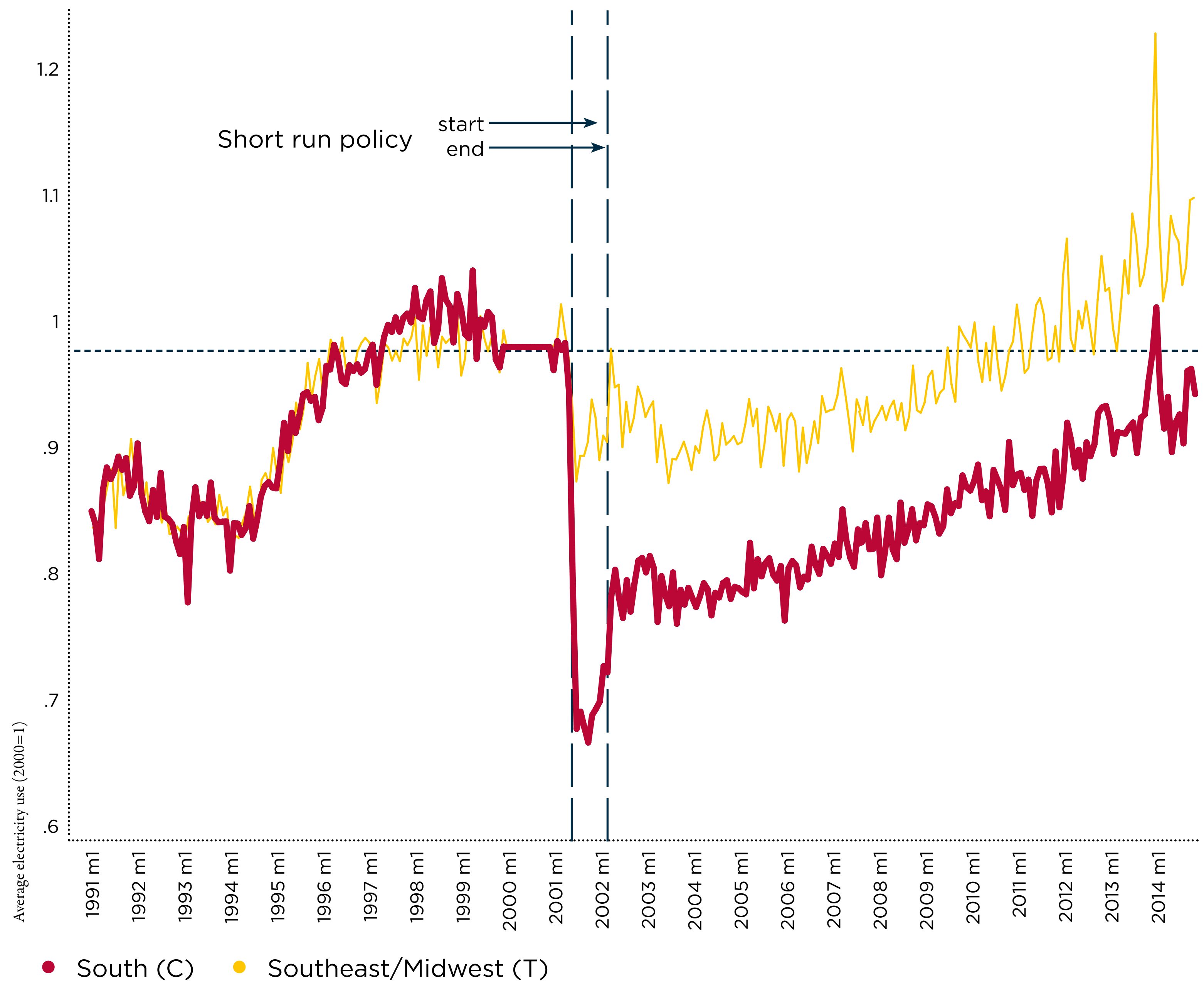
The study by Costa and Gerard (2018) provides important insights. From the behavioral viewpoint, it sheds light on the relevance of accounting for habit formation in the evaluation of the social cost of long-run corrective policies. It also suggests that shaping consumption patterns at an earlier stage of development may help attenuate the pressure of energy demand growth in developing countries.

Daylight Saving Time Measures: Meta-Analysis and Applications to Argentina and Chile

A more generic type of energy saving policy is the Daylight Saving Time program, which relies on replacing artificial lighting with natural lighting during time periods of typical human activities – that is, taking the most advantage of the natural light endowment. It is implemented by changing clocks forward (e.g., one hour) in line with the change of season when the sun appears early, so as to use this extra time of natural light instead of using artificial light. Having virtually no fiscal cost, DST is one of the oldest and most widespread energy conservation tools in the world. The first applications date to World War I and II in Germany and the United States, and the use of DST endured during times of energy crisis such as the 1970s. Today, DST is observed in over 70 countries worldwide (Figure 9.8) (Downing 2005; Kellogg and Wolff 2008).

As reported by Kellogg and Wolff (2008), previous literature estimates the effect of DST on total electricity demand savings of between 0.6 and 3.5 percent, with 1 percent being the most widely cited savings estimate. These studies, however, include simulations or analyses conducted over 30 years ago. More recently, the effect of DST has been widely questioned. In a meta-analysis of 162 estimates for 44 studies, Havranek, Herman, and Irsova (2018) find small average energy savings of around 0.34 percent during days when DST applies. One relevant reason why the effect of DST is low (or has declined since the older calculation), is that lighting today is no longer the most energy-intensive activity, and the increasing adoption of heating and air conditioning, among other technologies, seems to have altered the intra-day patterns of electricity consumption (Kellogg and Wolff 2008). Along these lines, most recent studies tend to find no effect of DST. Based on Havranek, Herman, and Irsova (2018), Figure 9.9 presents the point estimates of the average effect of DST from 45 studies. It shows mixed and mostly small effects, and, overall, highly heterogeneous results.

Figure 9.7: Brazil: The Impact of the Temporary Energy-Saving Program on Residential Electricity Use



Source: Costa and Gerard (2018).

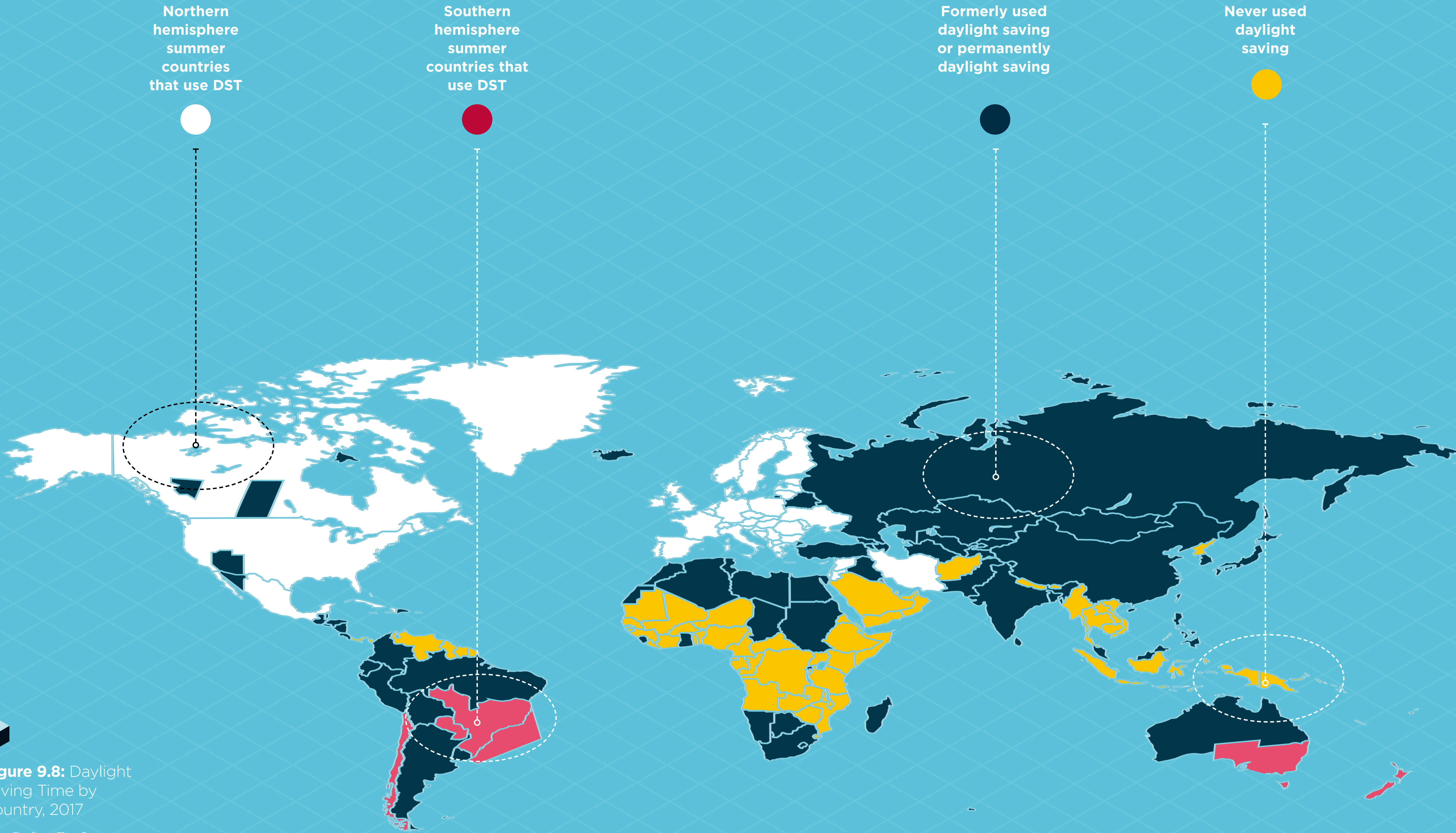
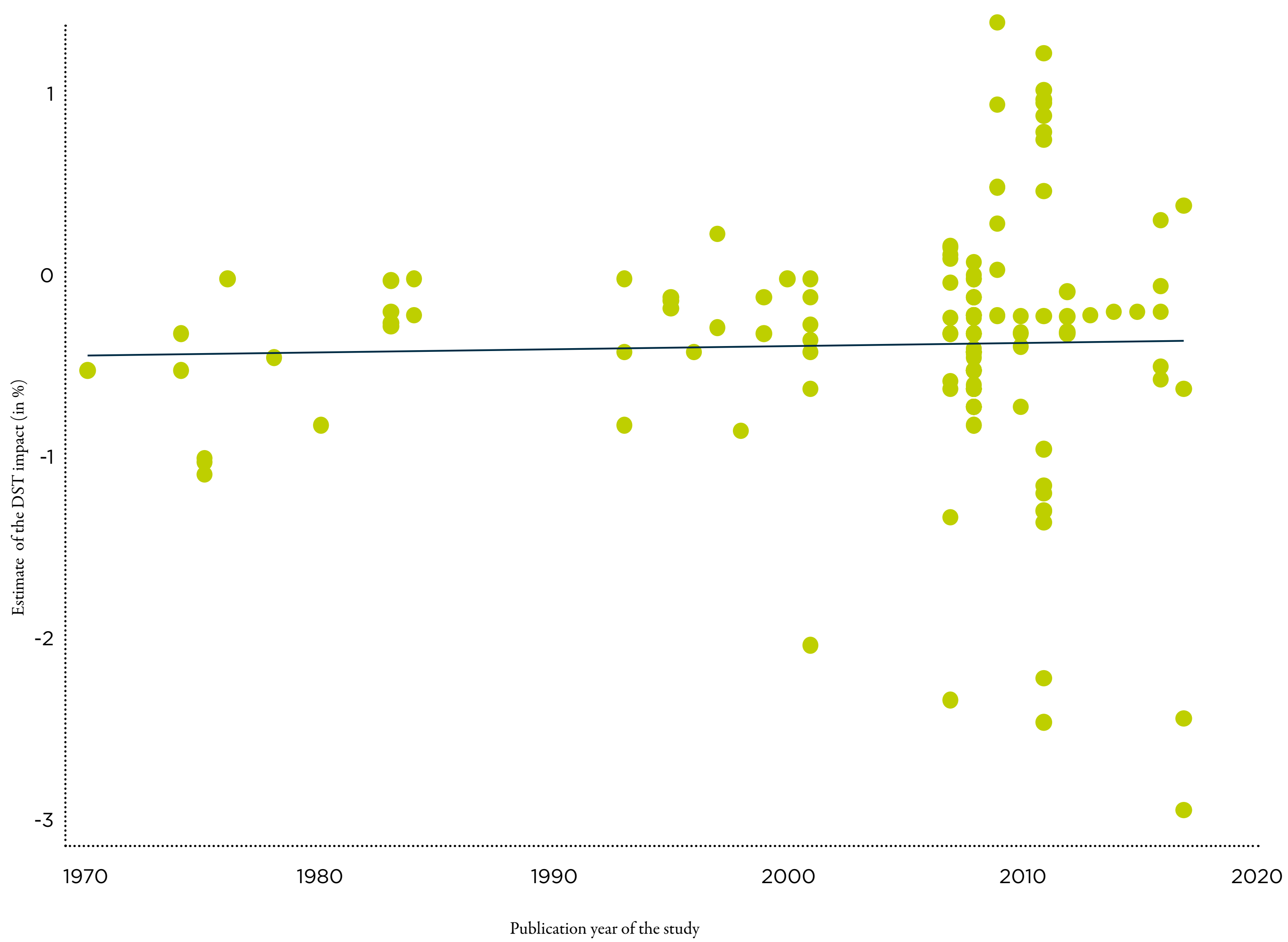


Figure 9.8: Daylight Saving Time by Country, 2017

Source: Day Saving Time Program Database (data.iana.org).

Figure 9.9: Estimated Daylight Saving Time (DST) Effects



Sources: Havranek, Herman, and Irsova (2018). The figure also contains estimations by Hancevic and Margulis (2017).
Note: Y-axis presents the estimated impact expressed as percent of electricity demand.

In LAC, DST measures are applied in Argentina and Chile. Table 9.4 shows the methodology and estimations of studies in those countries. In Argentina, the average effect is not clear, ranging from -0.6 to +0.4 percent, actually increasing consumption. In Chile, the average effect is negative at between -2 and -3 percent. In both cases, however, estimations during peak demand suggest that DST reduces peak consumption by at least -2.4 percent in Argentina and -4.4 percent in Chile. These are sizable effects for peak hours and provide an interesting insight into the potential of DST to influence intra-day load consumption of households.

The results for LAC countries align with the literature. Interestingly, studies that find greater effects of DST are those where stronger assumptions are made regarding the intra-day behavior of energy consumption. In contrast, studies with greater data granularity tend to find no effect, or even an increase, in overall electricity consumption, but a reduction during peak hours. It seems that how users' behavior responds to the change in natural light plays a key role. For example, Sexton and Beatty (2014) find modest evidence of significant behavioral changes that occur as a result of DST. However, they suggest that the DST time shift causes individuals to get up earlier in the morning and spend the additional time at home, which in turn may imply greater use of air conditioning or other appliances. This time reallocation of intra-household chores was not predicted by simulation studies and provides insights into the discrepancies between the predicted energy savings and the realized savings.

Better Energy Efficiency Policies

This chapter has discussed several cases of energy efficiency policies and their impact in energy consumption patterns, in order to build an evidence basis for effective energy efficiency policy design in the LAC context.

Energy efficiency policies and programs need long-term institutional and financial back-up. Overcoming barriers to the diffusion of energy efficiency in the residential sector may need a policy compromise to empower the implementation of energy efficiency initiatives. This institutional platform facilitates learning-by-doing which allows developing economies to scale previous and ongoing experiences.

- ***Design of energy efficiency interventions needs to incorporate behavioral dimensions of consumer responses to the policy.*** Estimated energy savings need to be corrected for behavioral factors in order to appropriately assess the cost-benefit of energy efficiency programs. Interrelated dimensions to be considered include participation in energy efficiency programs, optimal size subsidies and ways of delivering them. For example, household participation is mainly encouraged through subsidies; however, there may be less expensive ways to incentivize participation, including "nudges" (i.e., to reduce inattention problems or as moral suasion tools), dedicated financing lines or guarantees to target beneficiaries.[15] Even if subsidies are necessary,

Table 9.4: Effect of Daylight Saving Time in Argentina and Chile

Study	Method	Effect on Electricity Consumption	Country
Hancevic and Margulis (2017)	Natural experiment and double differences	+0.4 to -0.6 percent (overall) -2.4 percent-2.9 percent (peak demand)	Argentina
Verdejo et al. (2016)	Double differences	-2 percent to -3.18 percent (overall) -4.4 percent to -7.76 percent (peak demand)	Chile

Source: Prepared by the authors.

previous experiences show the need to evaluate their optimal amount in order to achieve cost-effective levels of participation. For Mexico, Davis et al. (2014) show that most households would have participated with much lower subsidy amounts. To design better programs, these dimensions, along with an analysis of possible deviations from initial assessments (i.e. ex-ante analyses, engineering estimations), need to be evaluated through pilots and ex-post evaluations.

Policies with well-defined behavioral components may be less costly while having a significant and persistent effect on energy consumption. Such policies include energy efficiency labeling and standards. Also, DST policies seem to work to reduce peak demand. Incentivizing conservation has also been shown to have sizable and lasting effects, as shown by the energy rationing experience in Brazil.

- ***Information on pricing and transparent energy tariffs may help facilitate an energy-efficient consumption path.*** For example, Ito, Ida, and Tanaka (2018) show that economic (price) incentives produce substantial and persistent reductions in electricity consumption between 14 and 17 percent. These price incentives alone generate a change in habits related to energy conservation within the household. However, for these changes to be effective, it is key to provide adequate information to consumers and ensure that such information is understood.

- ***Facilitating access to modern fuel increases energy efficiency.*** Firewood is an inefficient and highly pollutant fuel that mainly harms lower-income households. Depending on traditional fuels leads to higher but lower-quality energy consumption in less-developed economies. Further, in the case of Argentina, Hancevic and Navajas (2015) find that access to natural gas is associated with greater consumption of electricity, mainly due to the use of electricity as an inefficient fuel for heating. Therefore, providing universal access to modern energy sources represents not only a matter of equity and social justice, but also a policy to boost the efficient use of energy in the residential sector.

15. For example, Palmer and Walls (2015) show that inattention can be an important factor behind low energy audit uptake in California. They argue that energy operating costs associated with durables such as vehicles and major appliances can be difficult to observe and fully comprehend. As a result, a consumer may focus less on future energy costs and more on other more salient characteristics like current cost. This situation/behavioral bias is more likely in low-income segments.

The Brazilian government's labeling program *Etiqueta Nacional de Conservação de Energia* has become the main source of energy savings.

It has helped **save 15 billion of KWh per year**

which is equivalent to **15 million tons** of CO_2 emissions.

CONCLUSION

This book makes a valuable contribution to the debate on the distribution of energy expenditures in Latin America and the Caribbean (LAC) by examining the evolution of energy consumption, the impact of subsidies, and the drivers of energy consumption across the income distribution of the population. In LAC, household demand plays a key role in shaping aggregate energy consumption. Household consumption of electricity and gas has more than tripled since 1971, outpacing high-energy consumption sectors such as transportation and industry. Therefore, energy policymaking by governments must take into account the affordability concerns of the residential sector. Understanding how household energy consumption and expenditure take place is essential to effectively design and implement energy policy. However, households differ in their consumption patterns across time, geography, and income levels. One of the many objectives of this book has been to ascertain and inform these differences using data from different national household surveys in order to evaluate how income expenditure on energy changes its consumption patterns.

Lower-income households concentrate their energy expenditures on domestic and heating fuels. Conversely, affluent citizens tend to spend more on transport. Overall, 20 percent of the population in LAC with the highest income accounts for more than 40 percent of total expenditure on energy. By contrast, the bottom 20 percent of the population accounts for around 8 percent of total energy expenditure. Additionally, lower-income households have remained dependent on transition fuels as higher-incomes households have moved away from the use of dirtier fuels and into more efficient and less polluting fuels, such as liquefied natural gas and electricity.

Looking at the determinants of household energy expenditure, results show that household characteristics play a significant role, and that their influence is as expected. Conditional to a set of covariates, the relationship between energy expenditure share and income is assumed to be linear. The highest sensitivity to income change is for transport fuels, followed by electricity and domestic gas. When splitting the expenses by final consumption use, it is found that transportation fuel prices have a particularly large impact on the domestic budget. An increase of 10 percent in gasoline prices would impact the expenses of high-income consumers by 0.44 percent, and those of low-income consumers by only 0.1 percent. Location seems to be another important determinant of household energy expenditure. Overall, urban households tend to spend more of their budgets on energy relative to their rural counterparts. This result seems to derive mainly from electricity expenditure, while the association with domestic gas is quite small and less clear. Families living in urban areas spend 1.5 percent less on domestic gas than families in rural areas. Finally, the analysis finds that ownership of appliances, such as refrigerators, computers, and televisions, is strongly correlated with higher electricity expenditure and the share of electricity in the household budget. Having a refrigerator, computer, or television leads to percentual increments in energy expenditure (and shares) of about 30.8 (80.6), 13.8 (0.41), and 11.3 (0.31) percent, respectively. Although energy expenditures increase with income, the results show that there is a large decrease in their budget weight as families become wealthier. While poorer households spend less on energy in absolute terms, this expenditure still consists of a large share of their income, highlighting the significance of the affordability issue.

These patterns of consumption are intertwined with the demand elasticity of different echelons of the income distribution. High-income and low-income groups show lower levels of elasticity than their middle-income peers in terms of energy consumption, causing a reversed U-shaped curve. This curve in elasticity is probably linked to the minimum threshold of electricity consumed by those on the lower end of the scale, for which normal consumption levels sustain fundamental consumption activities. Those at the top, conversely, face a lower relative impact on their expenses. This implies that reducing consumption makes little difference on their household budget.

From a household perspective, in some countries energy expenditures constitute the second highest expense to which households devote their income after food, amounting to 8.9 percent for low-income households and 7.7 percent for high-income ones. However, absolute differences across the region are considerable, with the average Bolivian household spending on average only US$330 annually on energy and the average Bahamian household spending on average US$5,500 annually. Overall, on average, a low-income household in LAC spends US$400 annually on energy, while the top quintile LAC household spends almost five times more (around US$1,900 annually). The differential levels of consumption paint starkly distinct energy realities for households in different income quintiles, meaning that formulation and implementation of policy needs to take this difference into account.

The cost of energy consumption can have a considerable impact on low-income households, so energy policy decisions may have significant redistributive effects and thus constrain access to quality energy services. Price changes for energy and electricity tariffs, as well as tax regimes on energy services, should be carefully designed to promote affordability and greater equity. Some opportunities to improve affordability depend on more equitable subsidy designs. Depending on the tax structure of the countries, these taxes on energy services can generate regressivity and should therefore be avoided.

The redesign of subsidies and taxes is important, but its implementation is subject to elements of political economy and implementation preferences that prioritize communication with the general population and particularly with the affected groups. To implement a successful tariff adjustment, it is essential that agents of the economy and, importantly, the general public understand and accept the policy. Otherwise some political disruptions may arise.

One of the costly practices used by some countries in the region is to implement generalized subsidies in pricing mechanisms to mitigate the variation and impact that energy prices have on the livelihoods of consumers. Price schemes are heterogeneous across LAC. Countries in the region tend to have subsidies and transfers that maintain the system's operation, since the price structure alone does not reach the point of cost recovery for utilities. These subsidies tend to grow large in cost and heavily burden national budgets, while granting relatively larger subsidy benefits to the most affluent segments of population. This book has suggested several alternatives to this constraining circumstance, including aligning regulations, employing distributed generation, applying technically-designed-based block pricing for electricity, and using well-targeted progressive price relief schemes to reduce the costs and regressive effects of generalized subsidies.

Energy efficiency is regarded as the most effective and least costly way to meet energy demand. Certainly, to the extent that energy efficiency reduces household energy consumption, it will in turn impact energy spending, increasing the affordability of energy services. At the same time, energy efficiency may affect the configuration of the energy portfolio. As households switch to more efficient energy carriers, energy-efficiency programs reduce the economic burden of the cost of energy on households' monthly income. From a country-level perspective, these policies can help curb the overall growth of energy consumption and reduce the need for governments to invest in the expansion of generation capacity, which is costly.

In LAC countries such as Brazil, Chile, Mexico, and Ecuador, governments have managed to save on energy consumption through successful implementation of energy-efficiency programs based on the standardization of construction processes, labeling of refrigerators, and replacement of incandescent lightbulbs. As a result, Ecuador attained savings of 15,782 MW per year, or about US$17 million; Mexico is estimated to have prevented 82.5 million tons of CO_2 emissions while saving MX$175 million; and Brazil prevented 15 million tons of CO_2 emissions by establishing a long-run energy conservation program. Thus, energy efficiency is one the most effective approaches to reduce energy demand while sustaining the same level of welfare, services, and products delivered by the energy system.

In sum, this book has outlined an array of findings showing the way energy is consumed and characterizing consumption and energy expenditure in LAC households. These findings have policymaking implications, because whenever a subsidy or pricing energy is decided upon, the way energy is consumed is indeed a factor that needs to be taken into account. The book includes an overview of the composition of residential energy consumption for the period between 1971 and 2013. The findings presented in this book will enable policymakers to formulate better subsidy schemes and offer relief pricing to those households that need it the most. In parallel, the analysis shows that this effort would be well complemented by deploying energy-efficiency policies and programs that curve the upward trend in energy consumption. In that way, the growth in energy consumption will respond to higher productive needs rather than to inefficiencies in energy systems.

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Annex 1:
Data from National Household Surveys

In Chapters 4-6, the main unit of observation is the household, and uses a cross-sectional collection of 19 national representative household surveys with information on energy expenditures. While these surveys are generally implemented and designed under similar standards, their level of coverage—in terms of expenditures items—and disaggregation—in terms of sub-categories—varies from country to country. Therefore, of the 19 surveys with energy expenditure information, 17 have disaggregated information on domestic fuels and also information on overall household expenditures on transport fuels. Of those, 12 surveys provide expenditures by type of fuel for private transportation. Table A1 details the surveys used and the available information by energy component.

It is relevant to point out that most of these surveys do not contain information on quantities of energy consumption or on prices paid by the households. In our sample, two LAC countries present information on energy consumption (quantities): Argentina and Guatemala. Further, national surveys or regulatory agencies generally do not book energy prices with enough disaggregation to allow for the calculation of consumption at the household level. This represents a serious limitation in terms of estimating energy demand or price elasticities. For example, the results of imputing average prices would show a weaker relationship between consumption and expenditures for large geographic areas, where significant price variations tend to occur.

All expenditures are expressed in US dollars and adjusted for purchasing power parity ($USPPP), using exchange rates provided in the World Development Indicators database: official average exchange rate and PPP conversion factor for private consumption. Since different products or services have different periodicity of purchase, the data were multiplied by the corresponding factor in order to express expenditures in annual terms (i.e. the monthly value would be multiplied by 12).

Recorded expenditure data can be misrepresentative due to miss-booking, item non-response, among others problems. To reduce this issue, a common practice is cleaning for outliers, and unlikely situations. Identification of outliers may be challenging, especially in the case of bottom outliers because it is difficult to define minimum level of consumption by commodity. Therefore, the data set was only cleaned for top-outliers by trimming out values –of per capita household income, per capita household expenditure, and energy shares– higher than the 99th percentile, within each country[1]. Besides, households with no booked information on income, expenditure, or energy expenditure were dropped from the sample. Households with energy expenditure greater than income, or only booking transport fuels expenditures –but not expenditures on domestic fuels– were also dropped.

Since national surveys are available for different years, all values were extrapolated to 2014 based on the change in the current households' final consumption expenditure per capita (y). For example, in the Dominican Republic where the last survey available is for 2007, all values were multiplied by the factor $y_{,14}/y_{,07}$. This adjustment accounts for both inflation and real growth in household consumption. The data on households' final consumption are obtained from the World Development Indicators database. This extrapolation only affects the absolute expenditure amount, not the expenditure structure.

The same procedure was followed for the population sample weights. These factors are provided by the national statistical agencies in each survey, and (for years prior to 2014) adjusted to account for growth in urban, and rural population.

The harmonization of income and expenditure headings closely follows the International Comparison Program (IPC) classification, which is broadly used in national household surveys. This classification allows for a whole picture of the household budget structure by relevant expenditure items. In the case of energy commodities, it can distinguish between the energy used in the dwelling and the fuel used for private vehicles (transport fuel). The former includes associated expenditures such as the purchase and installation of meters, meter reading, storage containers, and outstanding charges. In some cases, it was not possible to separate expenditures by product or even by category. This is the case of Bolivia, Colombia, Honduras, Jamaica, and Nicaragua, which present information that aggregates all transport fuels into one category. Barbados does not present information on transport fuel expenditures.

1. In the case of The Bahamas, due to pronouncedly right skewed distribution, the data was trimmed out for values higher than 90%.

Table A1: Available Energy Expenditure Components in National Expenditure Surveys

Countries	Survey Name	Year	Energy Components			
			Electricity	Gas	Others	Transport
Argentina	Encuesta Nacional de Gasto de Hogares (urban only)	2012/2013	Y	Y	Y	Y
Bahamas	Bahamas Household Expenditure Survey (urban only)	2013	Y	Y	Y	Y
Bolivia	Encuesta de Hogares	2013	Y	Y	Y	Y
Brazil	Pesquisa de Orçamentos Familiares	2008/2009	Y	Y	Y	Y
Barbados	Survey of Living Conditions (urban only)	2010	Y	Y	N	N
Chile	Encuesta Nacional de Presupuestos Familiares (urban only)	2011/2012	Y	Y	Y	Y
Colombia	Encuesta Nacional de Calidad de Vida	2014	Y	Y	Y	Y
Costa Rica	Encuesta Nacional de Ingresos y Gastos	2013	Y	Y	Y	Y
Dom. Republic	Encuesta Nacional de Ingresos y Gastos de los Hogares	2007	Y	Y	Y	Y
Ecuador	Encuesta Nacional de Ingresos y Gastos de los Hogares Urbanos y Rurales	2011/2012	Y	Y	Y	Y
El Salvador	Encuesta de Hogares de Propósitos Múltiples	2013	Y	Y	Y	N
Guatemala	Encuesta Nacional de Ingresos y Gastos Familiares	2009/2010	Y	Y	Y	Y
Honduras	Encuesta Nacional de Condiciones de Vida	2004	Y	Y	Y	Y
Jamaica	Jamaica Survey of Living Conditions	2012	Y	Y	Y	Y
Mexico	Encuesta Nacional de Ingreso-Gasto de los Hogares	2014	Y	Y	Y	Y
Nicaragua	Encuesta Nacional de Hogares sobre Medición de Nivel de Vida	2014	Y	Y	Y	Y
Panama	Encuesta de Ingresos y Gastos de los Hogares (urban only)	2007	Y	Y	Y	N
Paraguay	Encuesta de Ingresos y Gastos y de Condiciones de Vida	2011/2012	Y	Y	Y	Y
Peru	Encuesta Nacional de Hogares sobre Condiciones de Vida y Pobreza	2014	Y	Y	Y	Y
Uruguay	Encuesta Nacional de Gastos e Ingresos de los Hogares	2005/2006	Y	Y	Y	Y

Note: Fuels are classified according to the ICP Classification. Gas includes town gas, natural gas, or liquefied hydrocarbons (butane, propane, etc.). Other fuels include: Liquid fuels: domestic heating and lighting oils; Solid fuels: coal, coke, briquettes, firewood, charcoal, peat; Heat energy: hot water and steam, purchased from district heating plants; Transport fuels include petrol, diesel, liquid petroleum gas, and other such as alcohol and lubricants, brake and transmission fluids, coolants and additives.

Annex 2:
Income and Energy Relationship

This annex describes the methodology used to estimate the income elasticities of energy demand at the country level, and their corresponding marginal income effects presented in Chapter 4. The main specification is as follows:

$$\ln y_{it} = \beta_{1i} \ln x_{it} + \beta_{2i} \ln p_t + \beta_i t + \varepsilon_{it} \quad \text{(eq. a.2.1)}$$

where y_{it} represents per capita energy consumption of country i in year t, measured in tons of oil equivalent (toe). x_{it} represents the main variable of interest, per capita gross domestic product, measured in terms of purchasing power parity (PPP), at constant 2005 US dollars. We also include international oil prices, p_t, in constant 2005 US prices. These prices are common for all countries representing an imperfect proxy of energy prices. The model also includes country-specific trends (t), and a noise term, ε_{it}. All variables are expressed in natural logarithms, so that of the main coefficient of interest (β_{1i}) can be directly interpreted as an elasticity. We use the Mean Group estimator proposed by Pesaran and Smith (1995) allowing us to take into account for coefficient heterogeneity across countries, which would otherwise represent a strong assumption, given the relatively long period under examination.[1]

With regard to the sources of information, total final consumption by energy source, population and gross domestic product at PPP prices are obtained from the International Energy Agency. Oil prices are obtained from British Petroleum (BP) annual statistics. The final data set is a balanced panel of 104 countries, covering the period 1971–2013, including 21 from Latin America and the Caribbean. All variables examined are integrated of order 1 –I(1). Co-integration is tested in a panel setting, using two different groups of tests proposed by Pedroni (1999), and Westerlund (2007). The main results are presented in Table A.2.1, and support the assumption that, in most cases, the proposed specifications co-integrate.

The results from the estimations are summarized in Tables A.2.1 and A.2.2. Table A.2.2 presents the short- and long-run elasticities of the modern fuels used in the residential sector (electricity and natural gas), in the transportation and industrial sectors and in aggregate energy consumption. Income elasticities in LAC are close to those estimated for the rest of the world, with the exception of transport, which seems to drive the higher energy dependence of LAC. The main difference in average elasticities appears when they are estimated by income group, as shown in Table A.2.2. Income elasticity tends to increase and then decrease as a country reaches higher income levels.

1. Further discussion in Jimenez and Yepez-Garcia (2016).

Table A.2.1: Cointegration Tests for Domestic Fuels

			LAC				World			
			Elect.	Gas	E&G	TFC	Elect.	Gas	E&G	TFC
Westerlund (2007)	Z-value	Ga	1,84	-0,44	1,62	2,71	2,61	0,11	2,24	5,59
		Gt	-3,53	-4,22	-3,57	0,32	-8,35	-11,93	-11,03	-0,67
		Pa	-0,61	-3,34	-2,16	-0,09	-5,04	-3,10	-5,24	-6,86
		Pt	-3,82	-7,02	-6,70	-1,29	-15,77	-6,77	-14,24	-17,12
	P-value	Ga	0,97	0,33	0,95	1,00	1,00	0,55	0,99	1,00
		Gt	0,00	0,00	0,00	0,63	0,00	0,00	0,00	0,25
		Pa	0,27	0,00	0,02	0,47	0,00	0,00	0,00	0,00
		Pt	0,00	0,00	0,00	0,10	0,00	0,00	0,00	0,00
	"Robust P-value"	Ga	0,79	0,10	0,66	0,96	0,41	0,09	0,35	0,99
		Gt	0,04	0,01	0,02	0,58	0,00	0,00	0,00	0,40
		Pa	0,35	0,03	0,07	0,55	0,02	0,17	0,07	0,28
		Pt	0,03	0,00	0,00	0,32	0,00	0,01	0,00	0,17
Pedroni (1999)	"Panel test"	adf	-2,44	-3,35	-2,89	-1,98	-2,18	-5,33	-3,20	-2,71
		rho	-1,69	-2,77	-2,18	-1,69	-0,60	-2,85	-0,65	-1,62
		t	-3,15	-4,28	-3,32	-2,38	-3,32	-5,98	-4,16	-4,09
		v	0,11	0,71	0,65	1,11	0,87	1,22	0,28	2,15
	"Group test"	adf	-2,60	-3,97	-2,72	-1,82	-2,64	-5,31	-4,58	-2,66
		rho	-1,05	-1,60	-0,98	-0,42	1,36	-0,57	0,97	0,09
		t	-3,46	-4,02	-3,03	-1,86	-2,55	-5,51	-4,34	-3,49

Source: Authors' calculations.

TABLE A.2.2: Short- and Long-Run Elasticities by Type of Fuel and Sector

Variable			Electricity	Gas	Modern fuels	Residential	Transport	Industry	TFC
	Short run elasticity								
	Ln(GDP ppp pe capita)		0,51	0,57	0,50	0,24	1,07	0,70	0,70
			0,19	0,17	0,14	0,10	0,15	0,14	0,11
	Ln(oil price)		-0,04	-0,08	-0,04	0,00	-0,06	0,01	-0,03
			0,03	0,03	0,04	0,03	0,02	0,03	0,01
	Long run elasticity								
LAC	Ln(GDP ppp pe capita)		0,66	0,98	0,83	0,39	1,30	0,89	0,89
			0,19	0,28	0,17	0,15	0,19	0,20	0,16
	Ln(oil price)		(0,06)	(0,14)	(0,07)	(0,02)	(0,14)	0,00	(0,04)
			0,04	0,04	0,03	0,03	0,03	0,03	0,01
	Observations		903	903	903	903	903	903	903
	Countries		21	21	21	21	21	21	21
	chi2		8,7	19,2	13,4	5,5	57,1	25,4	41,7
	Short run elasticity								
	Ln(GDP ppp pe capita)		0,60	0,44	0,58	0,25	0,89	0,68	0,51
			0,12	0,18	0,15	0,06	0,08	0,10	0,05
	Ln(oil price)		-0,02	0,00	-0,02	-0,01	-0,01	0,01	0,00
			0,01	0,02	0,02	0,01	0,01	0,02	0,01
	Long run elasticity								
WDL	Ln(GDP ppp pe capita)		0,85	0,57	0,69	0,32	1,09	0,94	0,68
			0,16	0,20	0,17	0,09	0,12	0,16	0,09
	Ln(oil price)		(0,04)	(0,07)	(0,02)	(0,03)	(0,06)	(0,02)	(0,03)
			0,02	0,03	0,02	0,01	0,02	0,02	0,01
	Observations		3.458	3.413	3.569	3.569	3.569	3.543	3.569
	Countries		83	83	83	83	83	83	83
	chi2		25,1	6,0	15,7	17,6	133,2	42,9	106,2

Note: The WDL estimations include 83 non-LAC countries. Long-run elasticities are estimated through a dynamic version of eq. a.2.1, and their variances are estimated by the delta method.

TABLE A.2.2: Short- and Long-Run Income Elasticities by Income Group

Dependent: ln(modern fuels consumption)	Income Group			LAC
	High	Middle	Low	
Lagged dependent	0,78	0,79	0,74	0,71
	0,03	0,05	0,03	0,04
Ln(GDP ppp pe capita)	0,10	0,23	0,20	0,24
	0,06	0,10	0,06	0,03
Ln(oil price)	-0,01	-0,02	0,01	-0,02
	0,01	0,02	0,01	0,01
Trend	0,00	0,00	0,01	0,00
	0,00	0,00	0,00	0,00
Constant	0,25	-1,03	-1,22	-1,02
	0,61	0,82	0,42	0,36
Income elasticity	0,48	1,08	0,77	0,83
	0,29	0,53	0,24	0,17
Observations	1638	630	1176	882
Countries	39	15	28	21
chi2	927,4	246,1	776,8	321,9

Note: Long-run elasticities are estimated through a dynamic version of eq. a.2.1, and their variances are estimated by the delta method.

TABLE A.2.3: Granger Causality between GDP Per Capita and Residential Energy Consumption Per Capita

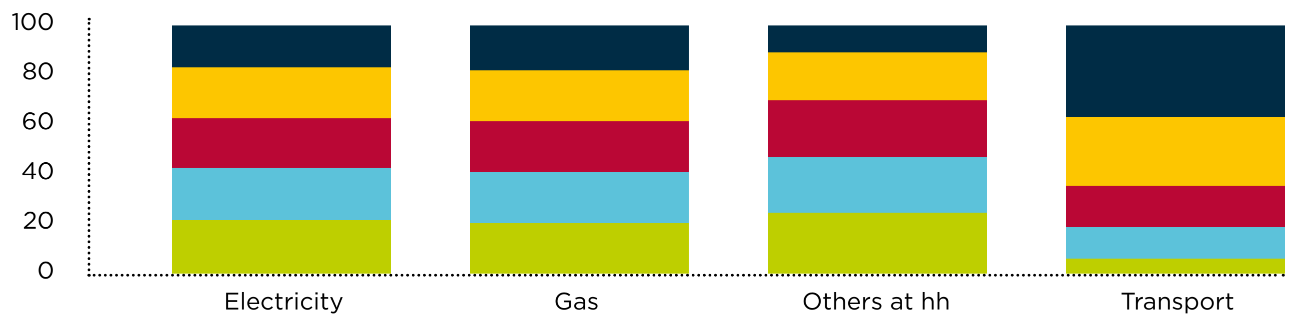
Variable	LAC				World			
	PMG	MG	DF	VAR	PMG	MG	DF	VAR
Energy->Income								
ECT	-0.08	-0.10	-0.08	-	-0.07	-0.14	-0.07	-
	0.02	0.02	0.01	-	0.01	0.01	0.00	-
Income$_{t-1}$	0.26	0.23	0.24	1.45	0.02	-0.06	0.02	1.10
	0.10	0.11	0.06	0.06	0.06	0.06	0.03	0.09
Income$_{t-2}$	-0.01	-0.04	-0.03	-0.42	0.17	0.09	-0.02	-0.13
	0.07	0.07	0.06	0.06	0.05	0.05	0.03	0.08
Energy$_{t-1}$	-0.03	-0.04	-0.08	-0.03	-0.09	-0.08	-0.08	0.03
	0.06	0.06	0.03	0.02	0.02	0.02	0.01	0.02
Energy$_{t-2}$	-0.10	-0.11	0.00	0.03	-0.06	-0.06	0.00	-0.01
	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.02
Constant	-0.10	-0.46	-0.42	-	0.36	-0.48	-0.26	
	0.03	0.24	0.12	-	0.04	0.19	0.06	
Weak chi2(2)	6.40	5.36	16.14	2.11	16.71	4.07	1.04	16.73
Prob>	0.04	0.07	0.00	0.35	0.00	0.13	0.59	0.00
Strong chi2(3)	22.80	30.84	118.06		116.80	134.62	372.75	
Prob>	0.00	0.00	0.00		0.00	0.00	0.00	
Income->Energy								
ECT	-0.03	-0.09	-0.04	-	-0.05	-0.11	-0.05	-
	0.01	0.02	0.01	-	0.01	0.01	0.00	-
Income$_{t-1}$	0.39	0.40	0.43	0.32	0.28	0.28	0.13	-0.18
	0.05	0.05	0.03	0.09	0.03	0.03	0.02	0.09
Income$_{t-2}$	-0.08	-0.03	-0.05	-0.30	-0.06	-0.04	0.02	0.05
	0.04	0.05	0.04	0.08	0.02	0.02	0.02	0.08
Energy$_{t-1}$	-0.04	-0.05	-0.02	0.89	-0.01	-0.01	0.00	0.95
	0.02	0.02	0.02	0.06	0.01	0.01	0.01	0.04
Energy$_{t-2}$	-0.06	-0.06	0.00	0.07	-0.03	-0.03	0.00	0.06
	0.03	0.03	0.02	0.06	0.01	0.01	0.01	0.04
Constant	0.08	0.58	0.25	-	0.44	0.84	0.36	-
	0.03	0.12	0.07	-	0.08	0.10	0.03	-
Weak chi2(2)	8.22	11.64	1.05	13.58	6.11	8.94	0.05	33.88
Prob>	0.02	0.00	0.59	0.00	0.05	0.01	0.97	0.00
Strong chi2(3)	10.83	50.94	16.02		36.34	109.10	131.70	
Prob>	0.01	0.00	0.00		0.00	0.00	0.00	
Observations	840	840	840	840	4,160	4,160	4,160	4,160
Countries	21	21	21	21	104	104	104	104

Note: Coef./se. Income stands for GDP per capita PPP at constant 2005 prices. Energy stands for per capita residential consumption of modern domestic fuels. ECT stands for error correction term.

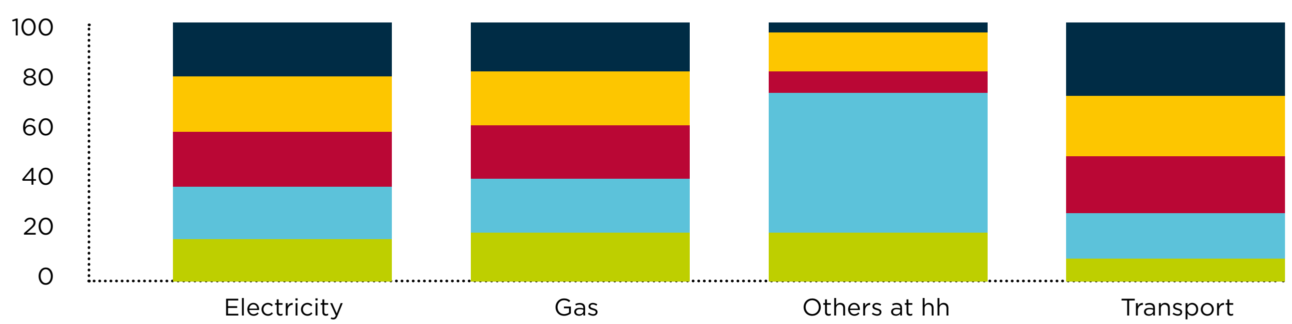
Annex 3: Structure of National Energy Expenditures

(Percent of expenditures on each fuel, by quintile, at the national level)

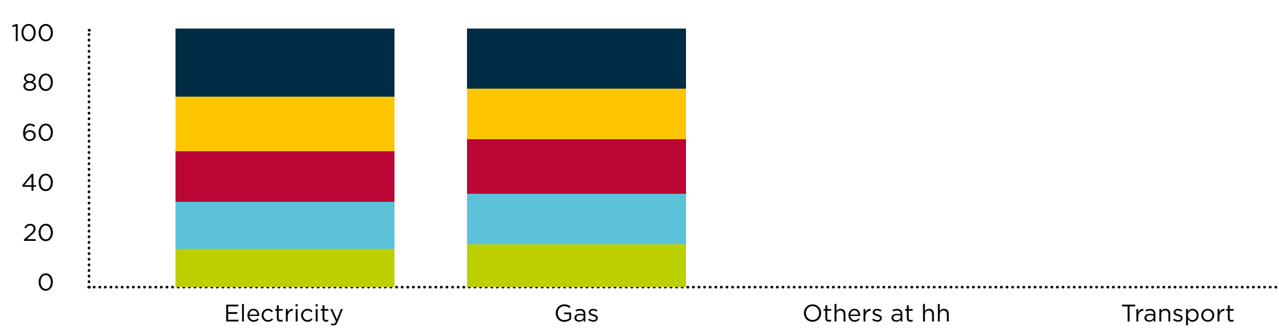
Argentina



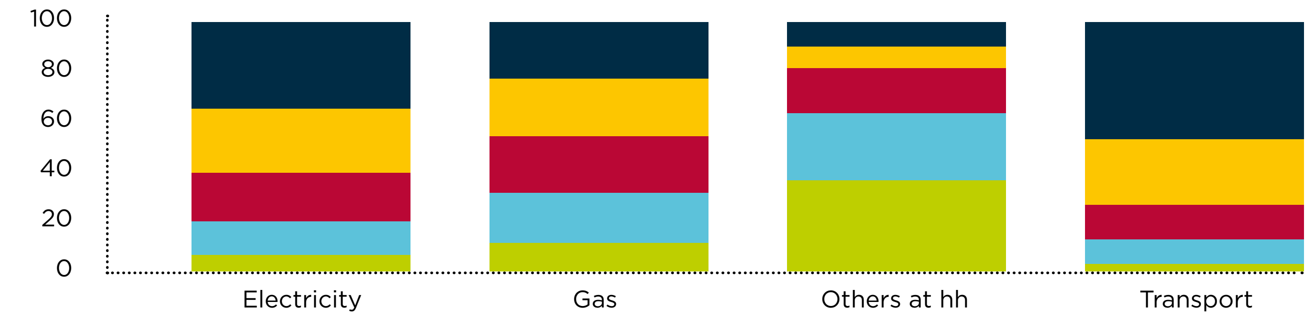
Bahamas



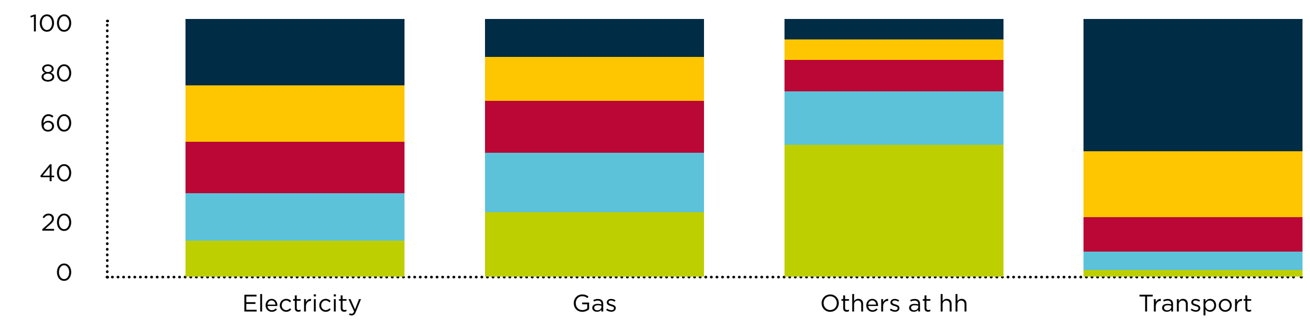
Barbados



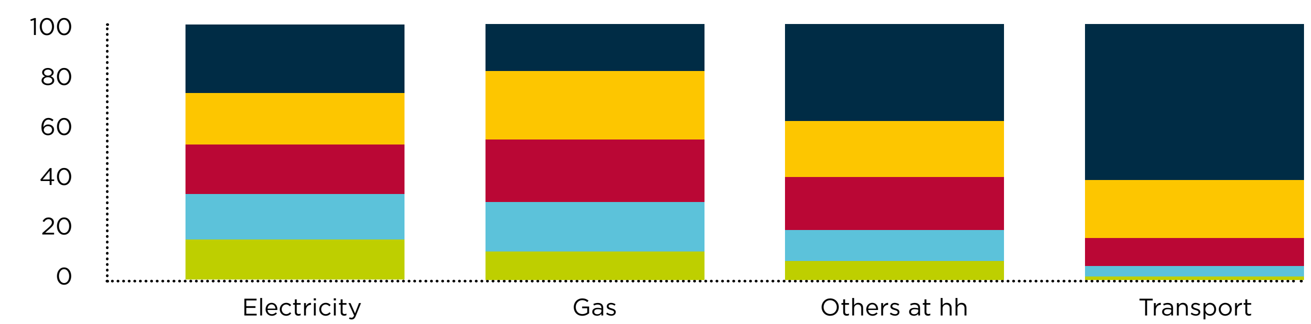
Bolivia



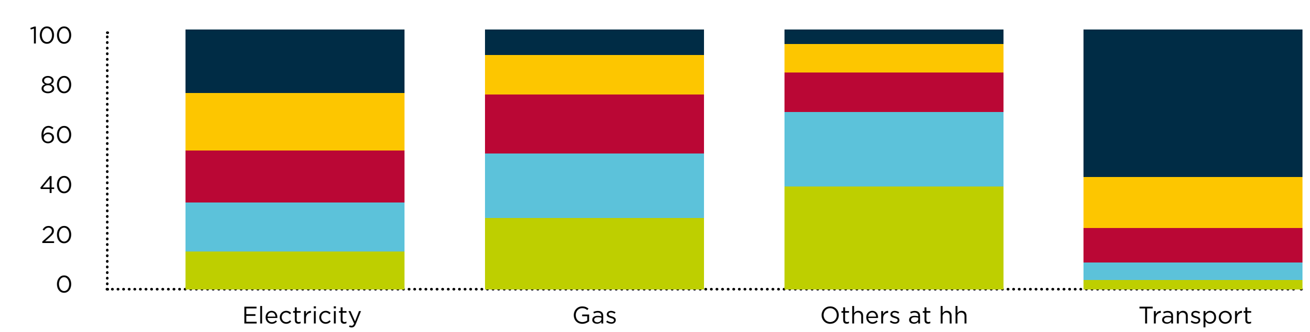
Brazil

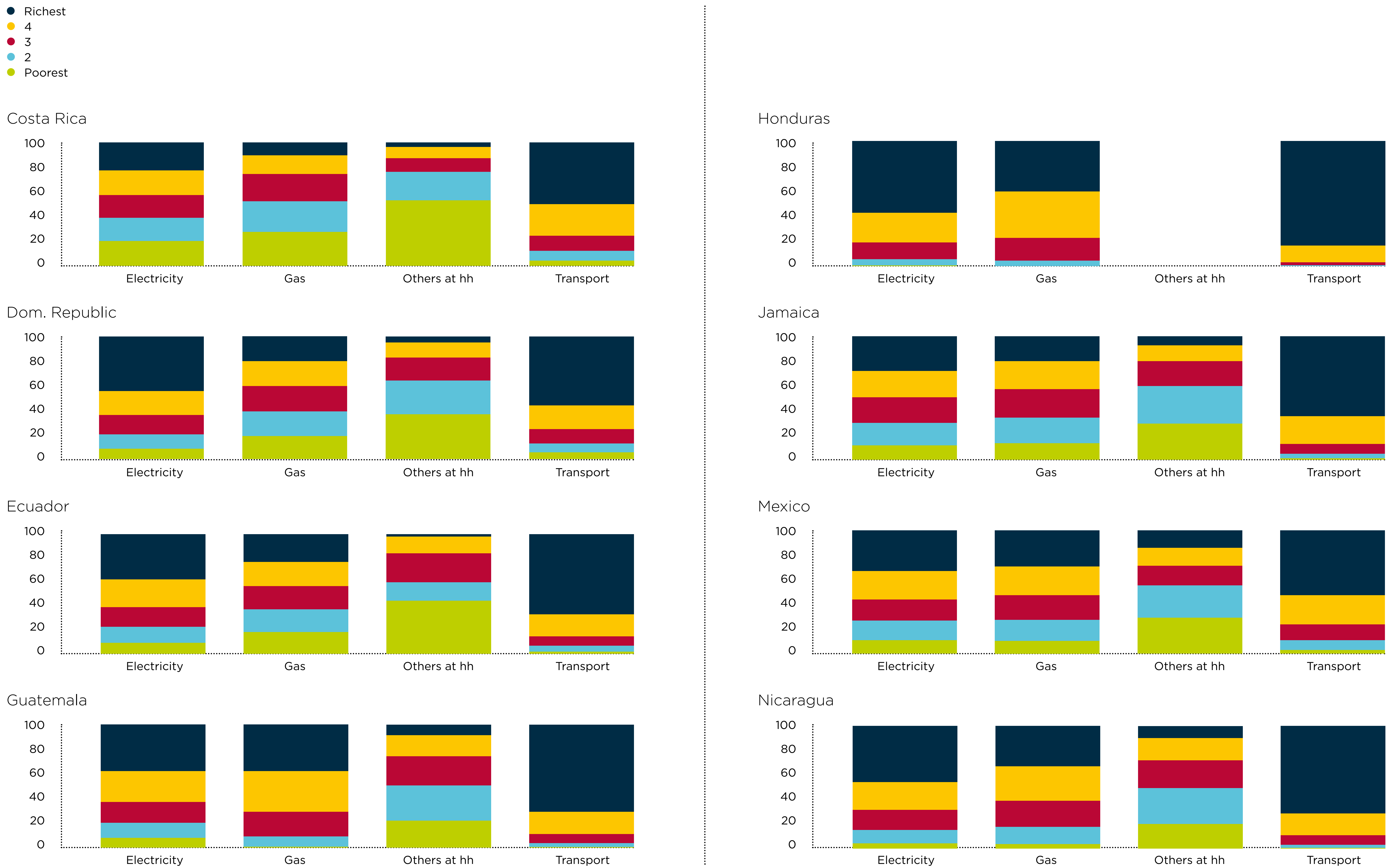


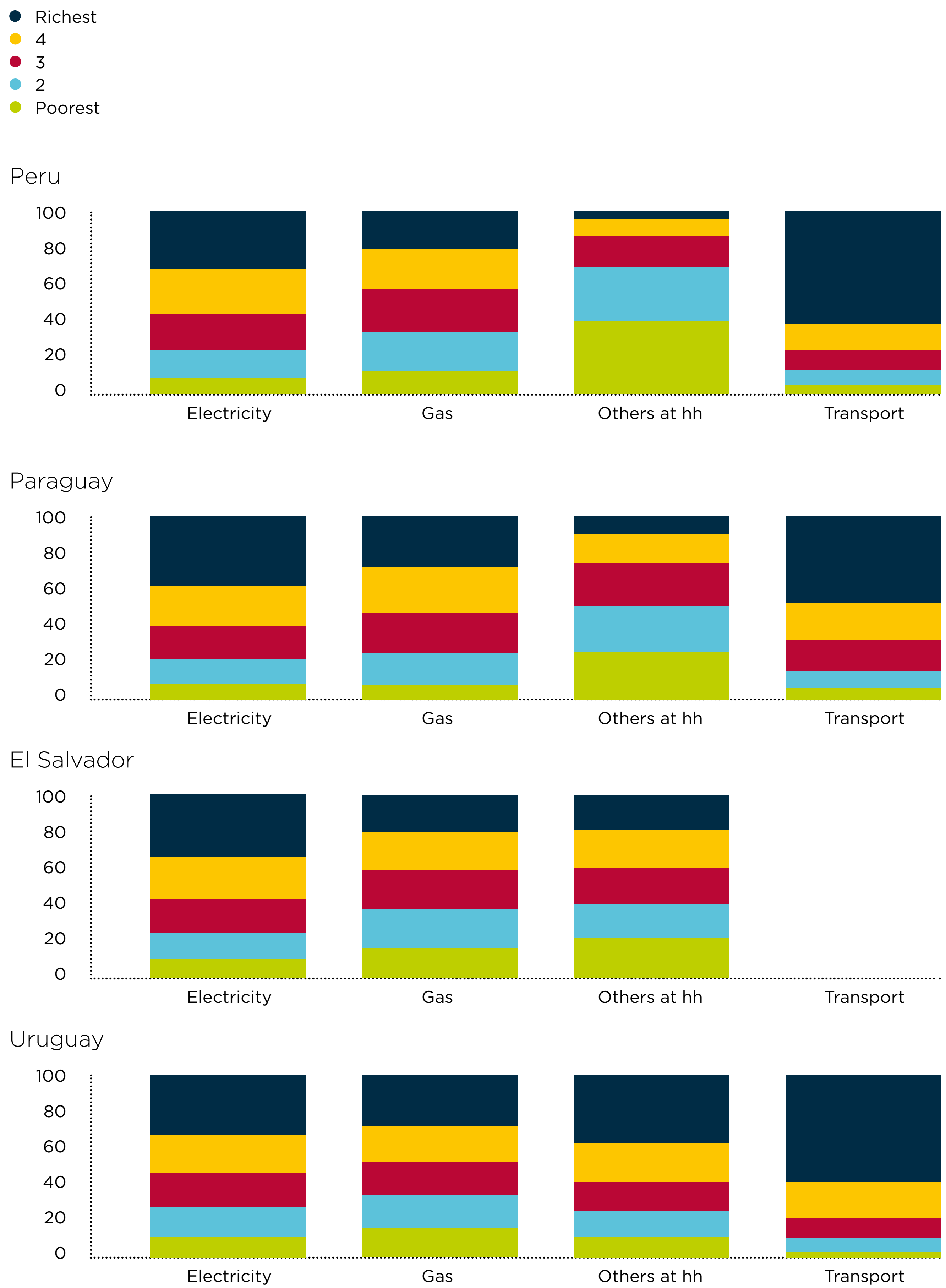
Chile

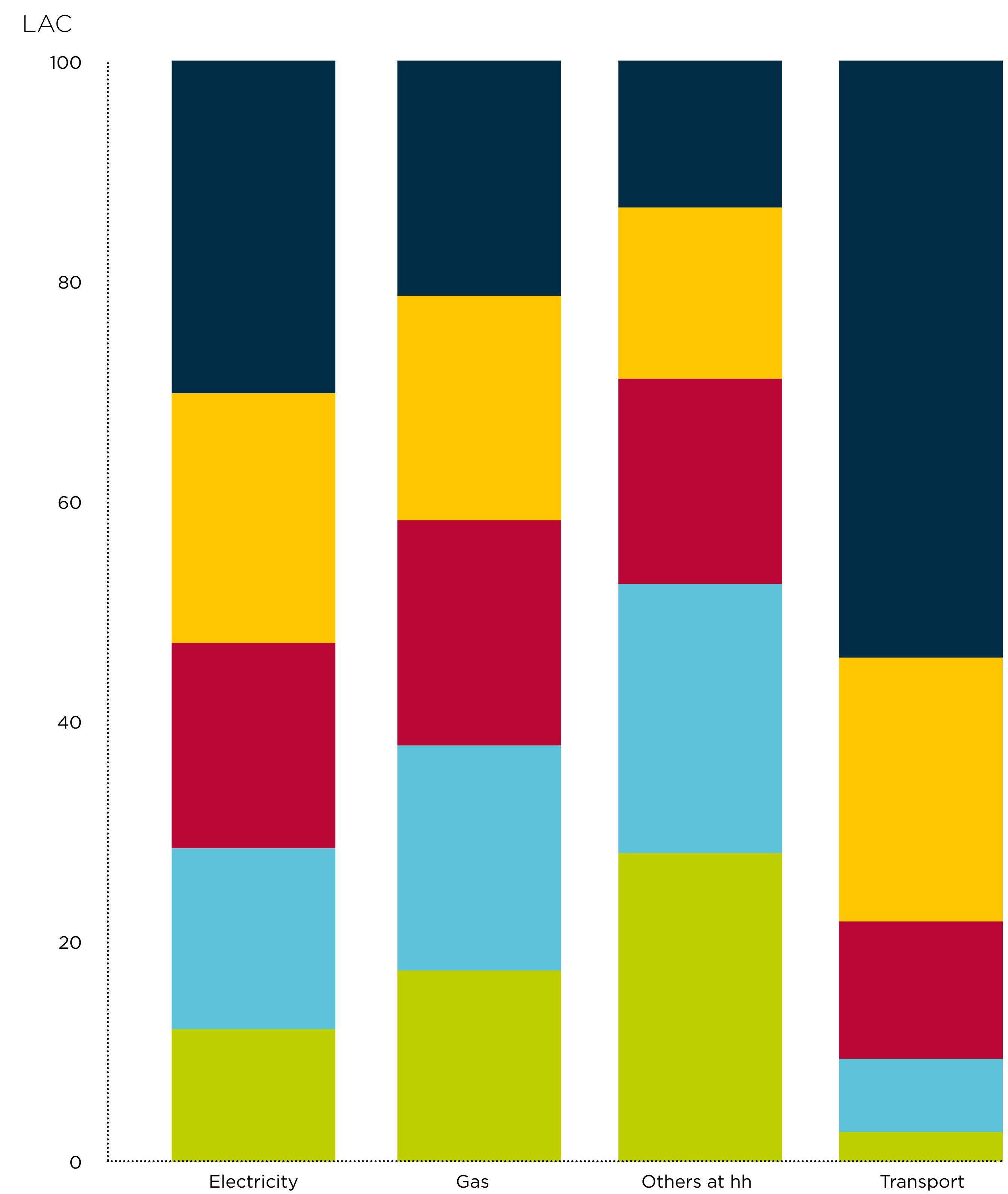


Colombia




Richest
4
3
2
Poorest
Costa Rica
Dom. Republic
Ecuador
Guatemala
Honduras
Jamaica
Mexico
Nicaragua
100
80
60
40
20
0
Electricity
Gas
Others at hh
Transport





Source: National household expenditure surveys.

Note: Barbados, El Salvador, Honduras, and Panama do not book information for all fuels

Annex 4:
Household Expenditures on Energy Sources by Income Quintile and Area

(In US dollars)

Source: National household expenditure surveys.

Note: Barbados, El Salvador and Honduras and Panama do not book information for all fuels

Country		Urban					Rural				
		Quintile					Quintile				
		Poorest	2	3	4	Richest	Poorest	2	3	4	Richest
ARG	Energy	7,9	7,1	6,3	6,8	5,8					
	Electricity	3,8	2,5	1,8	1,5	0,9					
	Gas	2,0	1,2	1,0	0,7	0,5					
	Others	0,1	0,1	0,1	0,0	0,0					
	Transport fuels	2,1	3,3	3,4	4,5	4,4					
BHS	Energy	12,2	14,8	13,1	11,5	10,8					
	Electricity	7,3	7,0	5,9	5,0	4,1					
	Gas	1,2	1,1	0,8	0,7	0,5					
	Others	0,1	0,1	0,0	0,0	0,0					
	Transport fuels	3,7	6,6	6,5	5,8	6,2					
BOL	Energy	3,9	3,8	3,6	3,8	3,6	2,9	2,9	3,2	3,4	2,7
	Electricity	2,3	2,2	2,1	2,2	1,8	1,5	1,3	1,3	1,1	1,0
	Gas	1,2	0,8	0,7	0,5	0,4	0,8	0,9	0,8	0,8	0,5
	Others	0,0	0,0	0,0	0,0	0,0	0,2	0,1	0,1	0,0	0,1
	Transport fuels	0,4	0,8	0,8	1,1	1,4	0,5	0,7	1,0	1,5	1,1
BRA	Energy	9,8	8,2	8,0	7,7	6,9	8,5	7,7	7,7	7,7	7,2
	Electricity	5,5	4,6	4,0	3,3	2,2	4,0	3,0	2,6	2,4	1,9
	Gas	3,8	2,2	1,5	1,0	0,5	3,0	2,0	1,5	1,0	0,6
	Others	0,0	0,0	0,0	0,0	0,0	0,2	0,1	0,1	0,0	0,0
	Transport fuels	0,6	1,4	2,4	3,4	4,2	1,2	2,6	3,5	4,2	4,7
BRB	Energy	19,9	10,8	8,4	5,9	3,6					
	Electricity	13,6	7,8	6,2	4,4	2,8					
	Gas	6,3	3,0	2,2	1,4	0,8					
	Others										
	Transport fuels										
CHL	Energy	8,1	7,5	7,5	7,4	6,4					
	Electricity	5,9	4,1	3,3	2,4	1,4					
	Gas	1,4	1,7	1,6	1,4	0,4					
	Others	0,3	0,4	0,4	0,3	0,3					
	Transport fuels	0,4	1,1	2,0	2,7	3,5					

Country		Urban					Rural				
		Quintile					Quintile				
		Poorest	2	3	4	Richest	Poorest	2	3	4	Richest
COL	Energy	10,3	8,4	7,6	6,9	6,3	9,1	7,8	7,9	8,3	6,8
	Electricity	6,9	5,6	4,8	4,0	2,5	4,5	3,0	2,9	3,1	2,0
	Gas	2,5	1,4	0,9	0,5	0,3	3,1	2,7	2,7	2,6	1,6
	Others	0,1	0,0	0,0	0,0	0,0	0,4	0,2	0,2	0,1	0,1
	Transport fuels	0,7	1,3	2,0	2,3	3,5	1,1	1,8	2,1	2,5	3,1
CRI	Energy	8,7	6,1	5,5	5,6	5,2	10,4	7,7	7,0	7,2	7,5
	Electricity	6,7	4,1	3,2	2,5	1,6	5,7	3,6	3,1	2,4	1,8
	Gas	1,1	0,7	0,5	0,3	0,1	1,5	0,9	0,9	0,5	0,3
	Others	0,4	0,1	0,0	0,1	0,0	1,6	0,6	0,3	0,2	0,1
	Transport fuels	0,6	1,2	1,7	2,8	3,5	1,5	2,4	2,8	4,1	5,3
DOM	Energy	7,5	7,4	7,2	7,9	9,6	6,7	6,3	7,2	7,2	7,2
	Electricity	2,2	2,5	2,5	2,6	2,8	1,4	1,1	1,4	1,1	1,3
	Gas	3,3	2,7	2,3	1,8	1,2	2,5	2,4	2,2	2,1	1,5
	Others	0,4	0,3	0,1	0,1	0,0	0,8	0,5	0,4	0,3	0,3
	Transport fuels	1,6	2,0	2,3	3,3	5,5	2,1	2,3	3,1	3,6	4,1
ECU	Energy	2,7	2,7	2,7	3,0	3,5	3,1	2,8	2,8	2,8	2,6
	Electricity	1,8	1,8	1,8	1,8	1,6	1,8	1,6	1,5	1,4	1,1
	Gas	0,7	0,5	0,4	0,3	0,2	0,8	0,6	0,5	0,4	0,3
	Others	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,0	0,0
	Transport fuels	0,2	0,3	0,5	0,8	1,7	0,3	0,6	0,7	1,0	1,2
GTM	Energy	12,5	11,1	9,8	9,5	9,3	9,3	9,0	10,0	9,2	8,6
	Electricity	6,3	4,8	4,5	4,3	3,5	4,0	3,5	3,8	3,5	3,1
	Gas	0,4	1,7	2,5	2,4	1,5	0,1	0,6	1,0	1,3	1,1
	Others	5,6	4,2	2,0	0,9	0,3	4,9	4,1	3,6	2,6	1,2
	Transport fuels	0,2	0,4	0,8	1,9	3,9	0,3	0,9	1,5	1,8	3,1
HND	Energy	4,7	4,2	5,1	5,9	8,1	4,4	2,9	4,1	4,9	7,4
	Electricity	2,2	2,9	3,2	3,0	3,0	0,5	1,2	1,9	1,6	2,3
	Gas	0,1	0,7	1,1	1,3	0,7	0,0	0,2	0,8	1,2	0,6
	Transport fuels	0,0	0,2	0,6	1,5	4,4	0,0	0,1	0,7	1,6	4,1
JAM	Energy	14,4	12,6	12,4	11,4	11,4	13,3	12,5	12,2	12,1	11,0
	Electricity	7,5	7,2	7,7	6,5	5,1	7,1	6,7	6,6	6,0	4,8
	Gas	2,6	2,8	2,7	2,3	1,4	2,4	2,8	2,7	2,6	2,0
	Others	4,1	2,0	1,1	0,4	0,3	3,6	2,5	1,9	1,4	0,7
	Transport fuels	0,2	0,6	0,9	2,2	4,7	0,1	0,4	1,0	2,1	3,4
MEX	Energy	10,7	10,4	10,3	10,8	10,2	8,6	9,9	10,0	10,3	11,4
	Electricity	4,1	3,4	2,8	2,6	1,9	3,4	2,5	2,1	2,1	1,6
	Gas	4,0	3,7	3,5	2,8	1,8	2,1	3,1	2,8	2,8	2,1
	Others	0,7	0,4	0,2	0,1	0,1	1,3	0,9	0,8	0,3	0,2
	Transport fuels	1,9	2,9	3,9	5,3	6,4	1,8	3,5	4,2	5,1	7,5

Country		Urban					Rural				
		Quintile					Quintile				
		Poorest	2	3	4	Richest	Poorest	2	3	4	Richest
NIC	Energy	9,6	9,2	9,0	9,0	10,5	3,1	3,5	3,7	4,3	4,6
	Electricity	3,6	3,7	3,6	3,7	3,8	1,0	1,3	1,2	1,1	0,9
	Gas	2,4	2,9	3,0	2,8	1,9	0,1	0,3	0,7	0,7	0,7
	Others	3,4	1,9	0,9	0,5	0,2	2,1	1,6	1,1	1,0	0,6
	Transport fuels	0,2	0,6	1,5	2,0	4,6	0,0	0,3	0,6	1,5	2,4
PAN	Energy	3,9	3,4	3,4	3,0	2,5					
	Electricity	3,0	2,8	2,9	2,6	2,2					
	Gas	1,0	0,6	0,5	0,5	0,3					
	Others	0,0	0,0	0,0	0,0	0,0					
	Transport fuels										
PER	Energy	10,0	7,1	6,0	5,2	4,8	7,2	5,5	5,2	4,7	4,8
	Electricity	3,8	3,1	3,0	2,8	2,4	2,7	1,7	1,7	1,6	1,3
	Gas	4,3	3,1	2,4	1,9	1,2	2,2	2,2	1,9	1,7	1,5
	Others	1,6	0,5	0,2	0,1	0,0	1,8	0,8	0,6	0,4	0,4
	Transport fuels	0,2	0,3	0,4	0,5	1,1	0,4	0,8	1,0	1,0	1,6
PRY	Energy	8,0	7,9	8,1	8,3	8,4	5,8	6,6	8,0	6,6	7,9
	Electricity	2,6	2,8	2,9	3,2	2,8	1,8	1,9	2,2	1,6	2,3
	Gas	1,2	1,8	1,6	1,5	1,1	0,6	1,1	1,1	1,4	1,2
	Others	2,6	1,3	0,8	0,6	0,2	0,9	1,0	1,2	0,6	0,5
	Transport fuels	1,6	2,1	2,8	3,1	4,4	2,6	2,6	3,5	3,0	3,9
SLV	Energy	7,2	6,8	6,7	6,3	5,7	5,6	5,7	5,5	5,3	5,2
	Electricity	4,2	4,3	4,5	4,5	4,6	3,2	3,3	3,4	3,5	3,7
	Gas	2,4	2,1	1,9	1,5	1,0	1,8	2,0	1,8	1,5	1,2
	Others	0,7	0,3	0,3	0,2	0,2	0,5	0,3	0,3	0,3	0,3
	Transport fuels										
URY	Energy	16,6	14,8	12,4	11,0	10,0	17,0	16,3	16,0	14,5	13,8
	Electricity	10,3	9,1	7,4	6,0	4,4	7,0	6,8	5,9	4,9	4,1
	Gas	4,1	2,9	2,2	1,6	1,1	4,7	3,9	3,2	2,5	1,3
	Others	0,9	0,7	0,5	0,5	0,4	0,8	0,7	0,9	0,6	0,3
	Transport fuels	1,3	2,1	2,3	2,9	4,1	4,6	4,9	5,9	6,5	8,2
LAC	Energy	9,5	8,3	7,9	7,9	7,3	7,8	7,5	7,7	7,8	7,8
	Electricity	5,0	4,0	3,4	3,0	2,1	3,4	2,6	2,4	2,3	1,8
	Gas	3,2	2,3	1,9	1,4	0,8	2,2	2,1	1,9	1,7	1,2
	Others	0,3	0,2	0,1	0,1	0,0	0,9	0,6	0,5	0,3	0,2
	Transport fuels	1,0	1,8	2,5	3,4	4,3	1,2	2,2	2,9	3,5	4,7

Annex 5:
Structure of Household Energy Shares by Income Quintile and Area

Source: National household expenditure surveys.

Note: Barbados, El Salvador, Honduras and Panama do not book information for all fuels

(As a share of total household expenditure)

Country		Urban					Rural				
		Quintile					Quintile				
		Poorest	2	3	4	Richest	Poorest	2	3	4	Richest
ARG	Energy	275,1	426,8	549,8	846,6	1228,0					
	Electricity	116,2	129,7	133,9	155,8	150,9					
	Gas	55,5	60,9	70,5	74,6	82,2					
	Others	3,9	3,9	4,6	4,2	2,9					
	Transport fuels	99,5	232,3	340,8	612,1	992,3					
BHS	Energy	3000,0	4577,0	5268,0	5241,0	5929,0					
	Electricity	1685,0	2101,0	2230,0	2196,0	2199,0					
	Gas	242,0	266,4	282,5	266,9	242,9					
	Others	5,1	15,1	2,2	4,2	1,0					
	Transport fuels	1068,0	2194,0	2753,0	2774,0	3487,0					
BOL	Energy	177,0	253,1	292,5	404,1	582,0	92,7	144,8	203,8	273,4	303,4
	Electricity	104,0	144,3	169,2	216,3	277,6	41,9	58,5	72,1	74,7	111,5
	Gas	47,2	49,0	48,3	47,9	45,7	23,1	37,2	43,3	48,2	45,2
	Others	0,9	0,5	0,4	0,4	0,2	3,6	3,4	3,5	0,8	3,2
	Transport fuels	24,9	59,2	74,6	139,4	258,5	24,2	45,7	84,9	149,8	143,5
BRA	Energy	494,8	739,4	1037,0	1558,0	3027,0	359,6	651,1	929,4	1431,0	2787,0
	Electricity	277,9	405,6	493,6	596,6	856,6	156,2	230,2	286,3	419,0	656,5
	Gas	176,5	180,7	175,9	167,8	182,5	119,9	154,3	159,3	162,1	174,6
	Others	0,7	0,3	0,2	0,2	0,9	10,3	8,9	7,5	8,0	3,1
	Transport fuels	39,7	152,8	367,5	793,6	1987,0	73,3	257,7	476,2	842,0	1953,0
BRB	Energy	895,5	1095,0	1207,0	1225,0	1538,0					
	Electricity	652,4	797,3	889,6	934,2	1184,0					
	Gas	243,1	297,7	317,3	291,1	354,2					
	Others										
	Transport fuels										

Country		Urban					Rural				
		Quintile					Quintile				
		Poorest	2	3	4	Richest	Poorest	2	3	4	Richest
CHL	Energy	654,2	938,0	1274,0	1823,0	3514,0					
	Electricity	451,4	479,1	507,8	521,5	641,5					
	Gas	125,8	215,5	248,1	276,1	174,1					
	Others	29,6	45,4	74,8	79,6	124,6					
	Transport fuels	41,3	175,9	400,3	799,5	2042,0					
COL	Energy	287,9	382,8	489,1	634,8	1350,0	222,0	333,6	473,5	588,6	876,0
	Electricity	196,5	257,8	294,5	340,9	440,0	103,0	126,0	158,6	212,1	248,8
	Gas	61,8	53,0	45,5	37,5	29,6	70,4	105,7	147,7	150,5	158,5
	Others	2,3	1,9	0,3	1,4	0,2	10,0	10,4	12,0	7,0	16,2
	Transport fuels	27,3	70,2	148,8	255,1	880,4	38,7	91,6	155,1	219,0	452,5
CRI	Energy	518,9	629,7	788,6	1200,0	2307,0	564,3	731,8	917,3	1346,0	2313,0
	Electricity	388,8	402,7	426,5	483,7	636,9	301,0	326,4	351,5	369,9	523,4
	Gas	64,9	70,3	66,0	48,7	38,2	79,8	85,3	88,1	78,7	82,4
	Others	15,4	8,9	4,6	5,6	2,8	71,3	43,7	30,9	26,4	18,6
	Transport fuels	49,9	147,8	291,6	662,2	1629,0	112,1	276,4	446,8	871,3	1688,0
DOM	Energy	344,4	485,7	629,8	942,2	2732,0	283,5	408,8	552,7	781,7	1127,0
	Electricity	88,4	153,3	200,7	271,9	759,0	52,7	66,4	103,1	107,5	174,1
	Gas	148,8	168,9	182,7	190,2	235,5	101,3	152,9	158,0	194,7	189,8
	Others	15,7	14,4	9,1	6,0	2,3	27,3	25,6	22,9	21,9	23,8
	Transport fuels	91,5	149,1	237,3	474,1	1735,0	102,3	163,9	268,7	457,5	739,4
ECU	Energy	144,6	199,2	254,2	368,7	827,4	122,7	179,4	220,3	296,4	507,0
	Electricity	100,8	136,4	165,6	210,1	322,9	70,1	96,3	105,9	131,5	178,6
	Gas	33,4	33,7	32,9	32,9	36,1	31,9	36,0	36,4	35,4	37,4
	Others	0,3	0,1	0,6	0,4	0,1	4,4	2,3	3,8	2,3	0,1
	Transport fuels	10,1	29,0	55,1	125,2	468,3	16,3	44,9	74,1	127,3	290,9
GTM	Energy	295,9	418,0	506,9	735,2	1488,0	198,5	329,7	510,9	609,8	1155,0
	Electricity	142,0	179,2	230,5	328,7	509,2	79,9	123,6	186,4	214,1	404,9
	Gas	10,1	63,7	126,0	171,3	197,4	2,5	20,8	47,6	77,3	119,9
	Others	138,2	154,7	98,5	62,1	36,6	107,9	147,5	184,0	167,2	125,9
	Transport fuels	5,7	20,4	52,0	173,0	745,0	8,2	37,8	92,9	151,1	504,6

Country		Urban					Rural				
		Quintile					Quintile				
		Poorest	2	3	4	Richest	Poorest	2	3	4	Richest
HND	Energy	67,6	167,9	340,4	607,3	1876,0	50,6	93,9	246,1	484,8	1515,0
	Electricity	36,9	116,5	212,8	305,3	629,7	8,1	41,8	107,4	140,2	476,0
	Gas	1,2	24,5	70,2	108,7	104,8	0,8	8,0	45,8	95,3	107,5
	Others	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Transport fuels	0,0	11,3	45,1	186,5	1135,0	0,0	6,3	54,2	194,5	872,9
JAM	Energy	496,5	778,1	922,3	1171,0	2225,0	502,9	726,9	832,6	1002,0	1481,0
	Electricity	264,0	445,8	562,9	619,1	920,8	271,0	391,3	444,2	480,8	606,5
	Gas	106,9	172,2	207,8	205,8	193,8	103,4	166,2	177,8	199,8	234,3
	Others	116,4	111,2	61,2	32,7	22,9	120,0	131,3	111,0	84,0	71,3
	Transport fuels	9,2	48,8	90,4	313,1	1088,0	8,4	38,2	99,6	237,4	568,9
MEX	Energy	326,7	494,0	636,9	935,2	1771,0	211,0	422,1	536,0	741,7	1456,0
	Electricity	110,5	154,2	160,3	210,3	308,9	72,4	99,0	108,3	132,4	188,8
	Gas	127,9	168,3	197,6	215,9	286,1	53,5	119,9	141,7	188,4	234,0
	Others	17,6	14,4	8,5	9,3	10,2	27,3	34,6	31,0	22,0	21,3
	Transport fuels	70,7	157,1	270,5	499,7	1166,0	57,9	168,5	255,0	398,9	1012,0
NIC	Energy	185,2	246,6	318,0	420,6	952,1	48,4	83,0	129,5	184,0	278,1
	Electricity	72,1	103,9	131,0	172,6	324,9	16,2	30,6	38,9	44,3	55,8
	Gas	48,1	75,8	98,9	115,2	121,3	1,4	7,7	20,7	27,4	40,1
	Others	59,1	45,74	27,45	17,97	9,197	29,96	34,57	37,39	36,3	26,66
	Transport fuels	5,871	21,24	60,57	114,8	496,8	0,9296	10,03	32,61	76,03	155,5
PAN	Energy	421,4	523,5	628,3	767,1	1522,0					
	Electricity	327,5	432,9	540,3	654,9	1363,0					
	Gas	93,1	89,5	87,5	111,2	155,9					
	Others	0,8	1,1	0,5	1,0	2,8					
	Transport fuels										
PER	Energy	207,4	313,2	376,5	427,4	641,2	103,3	193,7	251,5	292,5	403,3
	Electricity	81,2	140,9	187,7	230,0	297,9	35,4	58,8	79,6	92,7	102,8
	Gas	88,9	132,5	145,6	143,9	134,4	35,1	73,2	88,9	98,0	107,0
	Others	29,7	22,5	13,4	7,8	3,0	22,0	25,2	25,9	24,8	29,8
	Transport fuels	7,6	17,3	29,8	45,7	206,0	10,9	36,5	57,1	77,1	163,8

Country		Urban					Rural				
		Quintile					Quintile				
		Poorest	2	3	4	Richest	Poorest	2	3	4	Richest
PRY	Energy	573,4	753,5	1000,0	1230,0	2160,0	374,3	581,3	901,3	893,6	1509,0
	Electricity	194,1	266,9	347,2	444,2	674,3	108,6	158,9	243,1	208,6	463,7
	Gas	82,3	158,4	174,4	190,0	204,9	35,5	90,9	116,2	158,6	182,0
	Others	175,6	121,2	84,3	66,4	34,3	56,6	80,9	116,9	69,1	62,9
	Transport fuels	121,2	207,0	394,1	529,7	1246,0	173,7	250,7	425,1	457,3	800,5
SLV	Energy	151,0	209,3	266,9	334,7	507,8	107,6	161,7	193,2	226,3	320,9
	Electricity	89,9	137,0	186,3	246,6	413,5	63,4	97,5	122,4	152,6	239,4
	Gas	49,4	63,4	69,7	75,9	81,2	35,7	55,4	60,2	59,9	67,3
	Others	11,8	8,9	10,8	12,2	13,1	8,5	8,8	10,7	13,8	14,3
	Transport fuels	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
URY	Energy	969,6	1430,0	1755,0	2297,0	4087,0	1013,0	1558,0	2127,0	2995,0	5410,0
	Electricity	581,0	841,5	1006,0	1145,0	1555,0	403,5	634,9	788,2	1001,0	1638,0
	Gas	237,2	263,3	284,2	307,5	394,7	269,7	327,4	368,6	417,3	471,2
	Others	50,3	61,5	71,8	98,8	154,1	38,4	57,3	78,5	109,8	113,2
	Transport fuels	101,0	263,2	392,5	745,2	1983,0	301,6	538,8	891,4	1467,0	3187,0
LAC	Energy	407,7	586,5	779,6	1136,0	2166,0	242,1	431,7	622,8	884,8	1636,0
	Electricity	214,6	287,8	334,9	404,9	574,9	98,8	142,4	184,6	242,7	365,4
	Gas	131,2	145,6	151,9	153,4	173,0	69,3	107,2	126,2	144,0	164,9
	Others	9,5	9,7	8,0	7,5	8,0	21,2	26,3	27,7	23,0	19,9
	Transport fuels	52,1	142,7	283,7	567,1	1398,0	51,8	154,8	283,4	474,0	1085,0

Annex 6.

Model Selection for Energy Expenditure Regressions

A.6.1: Statistics of Equation 4 – Energy expenditure regressions

	Expenditures in					
	Energy	Domestic Energy	Electricity	Gas	Other	Transport
Model 1						
ln(expenditure)	.61***	.423***	.324***	.163***	.409***	.594***
Observations	185.794	185.794	164.668	143.591	22.550	46.140
Adjusted R2	0,67	0,59	0,63	0,55	0,40	0,56
rmse	0,64	0,56	0,60	0,42	0,90	0,61
bic	351.253	302.434	288.990	152.747	56.686	78.734
aic	351.131	302.312	288.870	152.628	56.590	78.630
F-stat	14.765	7.273	4.995	1.704	104	1.604
Model 2						
ln(expenditure)	.988***	1.36***	-.0883**	.877***	1.97***	.735***
ln(expenditure)2	-.0203***	-.0502***	.022***	-.0377***	-.0874***	-0,00724
Observations	185.794	185.794	164.668	143.591	22.550	46.140
Adjusted R2	0,67	0,59	0,63	0,55	0,40	0,56
rmse	0,64	0,56	0,60	0,42	0,90	0,61
bic	351.173	301.705	288.894	152.327	56.604	78.743
aic	351.041	301.573	288.764	152.198	56.499	78.629
F-stat	13.643	6.795	4.621	1.609	103	1.480
Model 3						
ln(expenditure)	4.15***	5.76***	-3.14***	5.79***	6.26***	2.94**
ln(expenditure)2	-.36***	-.522***	.348***	-.555***	-.564***	-.235*
ln(expenditure)3	.0121***	.0168***	-.0115***	.018***	.0175**	.00781*
Observations	185.794	185.794	164.668	143.591	22.550	46.140
Adjusted R2	0,67	0,59	0,63	0,55	0,40	0,56
rmse	0,64	0,56	0,60	0,42	0,90	0,61
bic	351.129	301.576	288.858	152.212	56.607	78.751
aic	350.987	301.434	288.718	152.074	56.495	78.628
F-stat	12.676	6.324	4.296	1.504	96	1.375

A.6.2: Statistics of equation 4 – Share of energy expenditure regressions

	Energy Share					
	Energy	Domestic Energy	Electricity	Gas	Other	Transport
Model 1						
ln(expenditure)	-2.57***	-2.9***	-2.12***	-1.79***	-.914***	-2.86***
Observations	185.794	185.794	164.668	143.591	22.550	46.140
Adjusted R2	0,33	0,38	0,40	0,64	0,36	0,29
rmse	4,71	2,81	2,02	1,23	2,03	4,40
bic	1.094.060	901.579	690.335	457.484	93.370	261.490
aic	1.093.938	901.458	690.215	457.366	93.274	261.385
F-stat	2.605	3.865	2.979	6.611	152	273
Model 2						
ln(expenditure)	4.64***	-2.7***	-3.59***	-12.5***	-0,564	-4.16***
ln(expenditure)2	-.387***	-0,0108	.0784***	.568***	-0,0196	.0662*
Observations	185.794	185.794	164.668	143.591	22.550	46.140
Adjusted R2	0,34	0,38	0,40	0,67	0,36	0,29
rmse	4,70	2,81	2,02	1,17	2,03	4,40
bic	1.093.453	901.590	690.228	445.281	93.379	261.497
aic	1.093.321	901.458	690.098	445.152	93.275	261.383
F-stat	2.458	3.568	2.761	7.568	141	253
Model 3						
ln(expenditure)	25.4***	55.7***	-11.4***	-9.94***	22.7***	6,54
ln(expenditure)2	-2.62***	-6.28***	.911***	.294**	-2.61***	-1,04
ln(expenditure)3	.0792***	.223***	-.0295***	.00958**	.0953***	0,0378
Observations	185.794	185.794	164.668	143.591	22.550	46.140
Adjusted R2	0,34	0,39	0,40	0,67	0,36	0,29
rmse	4,70	2,80	2,02	1,17	2,03	4,40
bic	1.093.421	900.613	690.213	445.288	93.351	261.506
aic	1.093.279	900.471	690.073	445.150	93.239	261.384
F-stat	2.286	3.398	2.566	7.028	133	235

IDB

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