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LPG fuel subsidies in Latin America and the use of solid fuels to cook

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ABSTRACT

The use of solid fuels (USF) for cooking is a key environmental health risk factor, affecting more than 2.8 billion people globally. The Sustainable /Development Goal seven (SDG7) aspires to ensure access to affordable, reliable, sustainable and modern energy for all by 2030. This will require transition toward modern cooking fuels such as Liquefied Petroleum Gas (LPG) and electricity. In Latin American and the Caribbean (LAC), 90 million people still rely on solid fuels for cooking. Access and price have been identified as the main factors that limit substitution of solid fuels by clean fuels.

In this paper, we present an exploratory analysis of the effects of subsidy policies for LPG in reducing USF in LAC countries when controlling for indicators of socioeconomic development and urbanization. In LAC, subsidies to LPG have substantially contributed to accelerate the transition from USF to clean fuels for cooking. Targeted subsidies should be considered as a policy option to implement the SDG7 on clean energy. Making clean energy accessible to all has the co-benefits of preventing diseases and premature deaths. Understanding the transition processes from USF to cleaner fuels made by LAC countries can better inform policy making in other regions.

1. Introduction

An estimated 1.3 billion people in the world lack access to electricity and more than 2.8 billion still rely on solid fuels such as firewood and charcoal for cooking and heating (OECD/IEA, 2006). In 2010, household air pollution from solid fuels was the third leading risk factor for global disease burden after high blood pressure and tobacco smoking (including second-hand smoke), and contributed to 7.3% of the global burden of disease (WHO, 2014a). The World Health Organization (WHO) estimated 4.3 million deaths in the world in 2012 as a result of the use of solid fuels (USF) for cooking and heating, with 82,000 in Latin America and the Caribbean (LAC) (WHO, 2014a). Health problems linked to household air pollution from USF include acute lower respiratory infections in children under five, and ischemic heart disease, stroke, chronic obstructive pulmonary disease and lung cancer in adults (Lim et al., 2012). Smoke from USF in households is a risk factor for low birth weight, perinatal mortality, asthma, cataracts, tuberculosis, and other adverse pregnancy outcomes, as well as cardiovascular disease (WHO, 2014b). Women and children in developing countries are the most exposed to smoke from USF (Cecelski and Matinga, 2014).

In November 2014, the WHO published its guidelines for indoor air quality, which include goals for reducing emissions of carbon monoxide (CO) to a maximum of 7 mg/m^3(24-hr average), and fine particulate matter ($PM_{2.5}$) to a maximum of 10 μg/m^3(annual average) (WHO, 2014b). The guidelines are based on the assessment of the health consequences of exposure to $PM_{2.5}$ and CO, and on the maximum permissible levels of these compounds in the air inside homes for a healthy environment (WHO, 2014b). The WHO Guidelines for Indoor Air Quality – Household Fuel Combustion warn of the risks of USF and sets goals to reduce emissions of harmful pollutants from open fires and stoves (for cooking and heating), as well as from lighting devices, for residential use. The need to improve household access to cleaner energy sources is underlined in its recommendations, which focus on reducing emissions of pollutants and on the importance of proper ventilation, while recognizing the need for intermediate measures adapted to rural and lower income households that depend on solid fuels.

Though the reasons underlying USF are complex, it has been shown to be highly associated with poverty and the lack of access to clean fuels. Access to clean fuels is difficult to address, given that individuals may not have the financial resources to buy Liquefied Petroleum Gas (LPG) or electricity, even when available in their communities. For this reason, most solutions proposed in poor areas have been focused on

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"making the available clean" (i.e. to burn biomass cleanly in improved biomass stoves), rather than on "making the clean available" (Smith and Sagar, 2014). On account of a better combustion, improved biomass stoves[1] have higher efficiencies a lower emissions of kitchen smoke, while still relying on solid fuels that are accessible and generally free. These new improved biomass stoves vary enormously, but none have yet been shown to sufficiently reduce exposure to $PM_{2.5}$ to comply with the WHO's Guidelines for Indoor Air Quality (Smith and Sagar, 2014). Research on exposure-response shows that the use of LPG leads to concentrations of $PM_{2.5}$ below the critical level of 10 μg per m^3, whereas concentrations measurements in homes with improved biomass stoves have shown an annual average of 170 μg per m^3 (Johnson and Chiang, 2015; WHO, 2014b). Even the Philips stove, the most advanced biomass stove in the Global Alliance for Clean Cookstoves (GACC) catalogue, reduces $PM_{2.5}$ concentration by only 66% (Muralidharan et al., 2015). This highlights the importance of ensuring access to clean fuels and not just improving the combustion and efficiency of biomass stoves.

In LAC 90 million people (15% of the total population) (WHO, 2015) rely on solid fuels for cooking and heating. Improving the access to clean fuels will require a multi-pronged and stepwise approach that considers the energy resources available in each country, and that takes into account that solid biomass fuels will be used as long as cash income is irregular, access to clean fuels is difficult, and biomass fuels are virtually free. In LAC, that has a relatively low consumption of polluting fuels as compared to Africa (84%) and South-East Asia (65%)[2] (WHO, 2016), LPG may be a viable solution, given its widespread use throughout the Region. This is particularly true where LPG is available, where biomass fuels need to be purchased (therefore people are already spending money in fuel), and where incomes are higher and more reliable (Kojima et al., 2011). The International Energy Agency estimates that more than 40% of households that will gain access to modern energy by 2030 will do so by switching to LPG (Kojima, 2013a). In October 2013, Sustainable Energy for All (SE4All) and the World LPG Association (WLPGA) announced the goal to transition one billion people from traditional fuels to LPG. A multi-stakeholder partnership has been created to build on best practices and sustainable business models in order to overcome the multitude of policy, market regulation, business environment, and local financing bottlenecks inhibiting the ability of governments and the private sector to meet the need for LPG. Before that, in 2012, WLPGA launched the "Cooking for Life" campaign to communicate the health benefits of switching communities from wood, charcoal, dung and other traditional fuels to LPG (Cecelski and Matinga, 2014).

Even though we acknowledge that natural gas and electricity are also clean fuels for cooking, and that electricity is a more sustainable solution in the long term, in this exploratory analysis we focus on the transition from solid fuels to LPG, because most LAC countries have undergone this transition successfully, and because lessons learned from this process may be useful in future analyses of opportunities and barriers for the use of clean fuels in other countries of the world.

2. LPG uptake in LAC

In the LAC region, more than 70% of the population already uses LPG to cook (OLADE, 2014). LPG is a clean-burning, efficient, versatile and portable fuel, produced as a by-product of natural gas extraction and crude oil refining. LPG has a higher calorific value, produces less air pollutants per meal and has a conversion efficiency up to five times higher than traditional fuels, including kerosene, wood, charcoal and coal. LPG combustion produces less climate pollutants than solid biomass fuels even when the latter are renewably harvested, due to the emissions of black carbon from biomass combustion (Smith et al., 2005), which make up nearly two-thirds of the $PM_{2.5}$ particles from household biomass stoves (Venkataraman et al., 2005). Although much shorter lived than greenhouse gases, black carbon particles travel far enough to have a significant effect on climate change at the regional and global levels (Bond et al., 2013).

Many factors determine LPG use: family income, price, availability and reliability of LPG supply, prices of other fuels, purchase costs of LPG cylinders and stoves, regulation (notably with regards to the handling of LPG cylinders), familiarity with cooking with LPG, awareness about the harm caused by smoke from solid fuels, and cultural preferences (Kojima, 2013a). Kojima's studies on the response of users to relative prices indicate that firewood prices would need to increase considerably before a household would consider replacing firewood for LPG for economic reasons. In Mexico, a study carried out by the authors (to be published) in February 2017 in two rural communities of Chiapas showed that 59% of the households already pay in average 370 pesos (US$ 20) per month to buy firewood. The cost of an LPG cylinder is 300 pesos (USD 16) and people that use LPG exclusively in these communities buy a cylinder every three or four weeks. When asked why they do not use LPG to cook all their meals, 96% argued that they cannot afford it. When asked if they would use it if the cost of the cylinder was 50 pesos, 82% said they would use it, but 14% said maybe and 4% said no, showing that they consider other factors besides the price, such as the difficulty to make tortillas with a regular LPG stove.

The energy needs of a household go beyond cooking and include space and water heating, lighting, and drying food and clothes. The uptake of a new cooking fuel will not occur unless the new technology can effectively perform all necessary tasks sought by the user in an affordable way (Kowsari and Zerriffi, 2011; van der Kroon et al., 2013; Andadari et al., 2014; Thurber et al., 2014). Clean cookstoves and fuels are well-adopted by users if three main dimensions are effectively addressed: affordability, motivation, and a minimum level of engagement (Rai and McDonald, 2009). However, clean fuels are expensive, involve a significant change in user habits, and in general are not highly-valued initially. Besides, motivation is low, since usually clean technologies cannot perform the same tasks performed by the traditional stove. As such, the adoption of clean fuels is difficult and it is important that efforts are made to create compelling reasons for consumers to tackle these challenges (Slaski and Thurber, 2009).

LPG supply involves significant challenges, and the LPG industry and distribution model has an impact on the LPG uptake. Some studies have shown that LPG use tends to decrease in countries that lack LPG home delivery services (Rajakutty et al., 2002). In Haiti, the lack of a regulatory framework has been identified as a barrier to the uptake of LPG (ESMAP, 2007), and in Guatemala the monopoly in the distribution of LPG makes it very difficult to motivate entrepreneurs to improve their service (Lascurain, 2016).

Energy access is a multi-dimensional phenomenon: Beyond the presence of a connection or supply, it is related with other factor such as the quality of the supply, its affordability, the government's energy policies and regulations, and the reliability of the service (Jain et al., 2015).

Reaching the goal of SE4All and WLPGA will require overcoming the aforementioned barriers, of which price is the primary barrier. Increasing the payment capacity of the population of biomass users is always an effective, albeit long-term strategy. In the shorter term a more viable strategy that has already been widely used in LAC is to provide subsidies to the poorest population.

2.1. Subsidies: are they effective?

A subsidy is a form of public financial aid extended to an economic sector, generally with the aim of promoting economic and social policy. Fuel subsidies have been used to foster access to energy for the poor,

[1] "Improved biomass stove" refers to any stove that uses solid biomass and that has been designed to improve the performance vis-à-vis an open fire or traditional stove in terms of efficiency or emissions.

[2] Figures correspond to WHO regions, and include kerosene.

but experience shows that, unless they are targeted, these subsidies tend to disproportionally help the middle and upper classes that have higher consumption and access to clean fuels (ESMAP, 2003; Whitley and van der Burg, 2015).

Fuel subsidies are also expensive; fuel subsidies in Venezuela, for example, cost the government 7% of its Gross Domestic Product (GDP) in 2012 (IMF, 2015).[3] Their use may be diverted to non-household applications such as vehicles, restaurants and other businesses, for which the fuel subsidy was not intended. Even when efforts are made to ensure that only the poorest households have access to subsidized LPG, it is difficult to prevent them from selling it to others, often in a black market, for needed cash rather than using it for their own cooking (Smith et al., 2005). Because the political costs of organizing a subsidy reform are very high, fuel subsidies tend to get locked in once they are introduced (Kojima, 2013a). In El Salvador, for instance, the loss of multiple seats in Congress suffered by the Farabundo Martí National Liberation Front after the reforms to the LPG fuel subsidy was partly attributed to the change in LPG fuel subsidy policies (Calvo-Gonzalez et al., 2015).

Direct, targeted cash transfers represent an alternative to help the poor cope with high prices of LPG. Cash transfers can be included as part of an integrated, comprehensive poverty alleviation program. Another alternative is to offer a fuel subsidy in a targeted way. Examples of targeted LPG fuel subsidies exist in El Salvador (with an electronic card that can only be used for this purpose) and in Peru (with LPG coupons given to those with very low electricity consumption) (Kojima, 2013b; MINEC, 2014; Toft et al., 2016).

Since the purchase cost of LPG cylinders is a barrier for the adoption of LPG among poor households that lack the cash to make an upfront payment, one possibility is to make small cylinders available, as has been done in Indonesia to substitute kerosene (Toft et al., 2016). In addition to having a lower purchase and refill cost, small cylinders are easier to transport, something relevant for residential customers that need to take the cylinders to retail shops for refill. Small cylinders, however, make LPG more expensive on a unit basis and pose a greater challenge to cylinder maintenance, repair and replacement (Kojima, 2013a). The government could, therefore, use cross-subsidization, imposing the same unit price independently of quantities sold (Kojima, 2013b). In Senegal, subsidies to support the dissemination of 3 kg and 6 kg LPG cylinders enabled lower to middle class households to adopt LPG. The LPG promotion program led to a remarkable boom in LPG consumption, which grew from less than 2000 t in 1974 to 15,000 t in 1987 and nearly 100,000 t in 2012. Nearly 85% of households in Dakar and 66% of those in other main urban areas now own LPG stoves (Ekouevi and Tuntivate, 2012). The subsidy was withdrawn in the 2000s (Laan et al., 2010). In Nairobi, Kenya, Pima Gas is testing a model that provides refills for one kg of gas at dispensaries close to customers, to serve the “kadogo” low income economy (Mulupi, 2012).

Another type of subsidy consists of helping with the start-up costs (stove, cylinder, installation), either by giving them for free, lowering the purchase price or offering the option of payment in installments. This last option is being tried in Ecuador where the government is introducing induction stoves and the payment is made through the electricity bill in 12 monthly installments. The stove can be purchased from any retail store and the import of induction stoves is not subject to tariffs (MEER, 2015). Although more targeted than price subsidies and easier to implement for governments, this strategy is generally of little help to the poor because the poor do not have the financial means to pay for the regular use of LPG and other clean fuels unless these subsidies are coupled with fuel subsidies, or unless the prices of alternative fuels are even higher, as in Haiti and in some Guatemalan urban settings (Lascurain, 2016; Kojima, 2013a). In Ecuador, the government is also giving a time-bound subsidy to electricity for those that opt for the induction stove.

In light of the advantages and disadvantages of various subsidy options discussed above, the question is generally not whether to use subsidies, but rather how they should be used, to what extent, at what cost, for whom and with what kind of exit strategy (Feldman, 2009).

3. The situation in Latin America

In LAC, USF for cooking occurs mainly in rural areas and has been gradually replaced in most countries by cleaner fuels, mainly LPG and to a lesser extent natural gas and electricity in urban areas. However, biomass consumption is still substantial in urban areas in Haiti, Guatemala, Nicaragua, Honduras, Paraguay and Peru (WHO, 2015). Fig. 1 shows how the percentage of the population using biomass for cooking has changed in the Region in countries with more than 3 million people. We have chosen to exclude of the analysis the countries with less than 3 million people, because of limited information available, and in general, low USF.

Rates of USF change differed notably among countries in the Region. In the most developed countries (see HDI in Table 1), the largest changes occurred between 1990 and 2000, including Argentina, Chile, Costa Rica, Uruguay and Venezuela. Some countries underwent substantial decreases in the percentage of USF over the 23-year timespan; that is the case of the Dominican Republic, Ecuador, Peru and El Salvador (more than 25%). This rate changed very little in other countries, such as for Guatemala and Haiti. Finally, the decrease in SFU in some countries only mirrors the increase in urban population, which is clearly the case of Mexico, Panama and Paraguay.[4]

Four factors have been found to have a mayor influence in the transition from solid fuels to clean fuels: urbanization, development, access to clean fuels and family income (Puzzolo et al., 2013). However, the relationship and interplay among these variables is complex and factors like subsidies can modify their relative importance.

Table 1 shows the demographic statistics of LAC countries with more than 3 million people for 2013. Sorting countries by levels of urbanization, it is clear that Argentina, Chile, Uruguay, and to some extent Venezuela, have witnessed an accelerated urbanization process as compared with the rest of the Region. This urbanization has been driven mainly by economic development, as can be appreciated by the GDP of those same countries. Mexico's GDP, on the other hand, would predict a greater degree of development than is shown by its Human Development Index (HDI) or rate of urbanization.

The sixth column is called change, and is the result of considering how much the % of USF has changed between 2013 and 1990 in a given country, how much has the % of population living in urban areas for the same country and the same period changed, and then subtracting the % of people that changed from rural areas to urban areas, from the change in USF in the same period. For example, from Fig. 1 we can see that Bolivia had 45% of solid fuels users in 1990 and 23% in 2013. The % of USF's change is 22% (45–23%) for that period. In 1990, Bolivia had 56% of urban population and 68% in 2013. The % of urban population change was 12% (68–56%) for that period. To measure the change in USF that it is not driven by urbanization alone, we have subtracted the change in % of urban population from the change in % of USF population (22–12%). This gives 10%, which is the result shown on column 6. We acknowledge that not all people moving from rural areas to urban areas are necessarily changing from solid to clean fuels, but urbanization in LAC is one of the main drivers to the adoption of clean fuels, and we considered important to have this column to show

[3] This figure includes LPG, gasoline and other oil products, but not electricity.

[4] Mexico's urban population increased by 8% from 1990 to 2013, USF reduction for the same period was 10%. Panama's urban population increased by 12% from 1990 to 2013, USF reduction for the same period was 10%. Paraguay's urban population increased by 10% from 1990 to 2013, USF reduction for the same period was 12%. WHO, observatory data base consulted March 2016

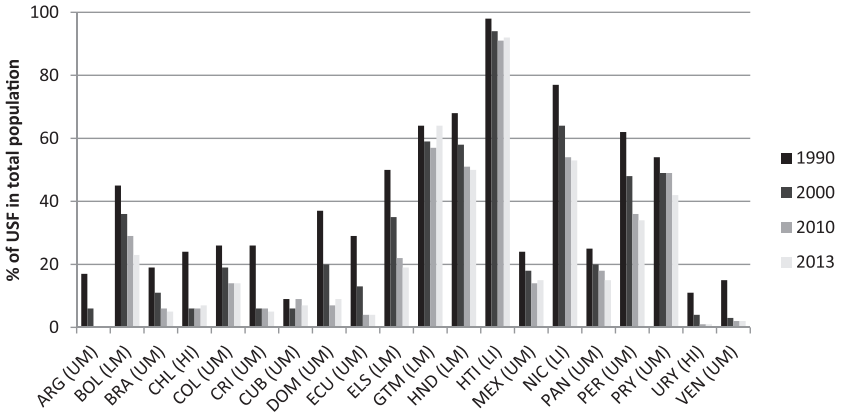

Fig. 1. % USF in some American countries, 1990, 2000, 2010 and 2013.
Source: WHO Household Energy Database (WHO, 2015). HI: High Income, UM: Upper middle income, LM: Lower middle income, LI: Low Income countries, World Bank classification.

Table 1
Demographics for some countries in the Americas.
Sources: WHO Observatory Data Base for 2013, USF: Solid Fuel Users. Energy Index: Equivalent oil barrels per capita. HDI: Human Development Index. GDP is per capita, PPP (constant 2005 international $). All data is for 2013, except for % of Indigenous Population (2010).

Country	Population (Millions)	% Urban pop	% USF	% Urban USF	Change ([% USF 2013 -%USF 1990] - [% urban pop 1990 - % urban pop 2013])	% Access to LPG or Natural Gas[a]	% Access Elec.[a]	Energy Index[a]	HDI	GDP/ capita USD	% Pop. Living under $ 1.9	% Indigenous Pop[b]	Year to reach 75% Urban pop.
Argentina	41.446	92	< 5	No data	12	95	95	10.13	0.808	14,363	1.75	2.4	1965
Bolivia	10.671	68	23	< 5	10	80	82	4.16	0.667	4350	7.7	62.2	No yet
Brazil	200.362	85	5	< 5	3	88	99	8.42	0.744	10,056	4.87	0.5	1992
Chile	17.62	89	7	No data	12	No data	98	11.37	0.822	13,596	0.92	11	1969
Costa Rica	4.872	75	5	< 5	0	No data	99	5.56	0.763	10,377	1.68	2.4	2013
Colombia	48.321	76	14	< 5	4	86	96	3.89	0.711	8479	6.12	3.4	2013
Cuba	11.266	77	7	< 5	0	No data	98	6.57	0.815	9056	No data	No data	2000
Dom Rep	10.404	77	9	< 5	6	80	94	4.18	0.7	8387	2.32	No data	2011
Ecuador	15.738	63	< 5	< 5	17	96	97	5.54	0.711	7201	4.43	7	No yet
El Salvador	6.34	66	19	6	14	74	94	3.31	0.662	5981	3.25	0.2	No yet
Guatemala	15.468	51	64	31	0	50	89	4.35	0.628	4292	11.53	41	No yet
Haiti	10.317	56	92	86	0	3	28	2.14	0.471	996	53.9	No data	No yet
Honduras	8.098	54	50	21	5	39	89	4.2	0.617	3519	18.93	7	No yet
Mexico	122.332	79	15	6	2	80	98	7.38	0.756	12,441	2.68	15.1	2002
Nicaragua	6.08	58	53	27	18	42	76	2.64	0.614	2613	10.83	8.9	No yet
Panama	3.864	66	15	< 5	0	No data	91	6.98	0.765	12,206	2.86	12.3	No yet
Paraguay	6.802	59	42	21	2	50	99	4.75	0.676	4648	2.19	1.8	No yet
Peru	30.376	78	34	13	19	63	90	3.87	0.737	8556	3.7	24	2005
Uruguay	3.407	95	< 5	No data	1	94	99.6	8.36	0.79	12,655	0.34	2.4	1945
Venezuela	30.405	89	< 5	< 5	10	No data	99.7	11.58	0.764	10,973	No data	2.7	1975

[a] OLADE (2014).
[b] CEPAL (2013).

the differences between countries in the reduction of the % of USF if we left behind the urbanization factor. This shows that in some countries like Mexico and Panama, the only change in USF is likely a product of urbanization, and not a change in the policies or access to clean fuels for the rural population. This is particularly true for those countries that have only rural USF.

The analysis of the data shows some interesting facts. Bolivia and Guatemala share a similar GDP and have large indigenous population. However, Bolivia has advanced substantially toward USF reduction, and Guatemala has not. El Salvador and Paraguay also have many similarities in terms of population size, HDI, and low percentage of indigenous population. However, El Salvador has achieved a significant decrease in the number of people relying on solid fuels, while Paraguay has not. Mexico has one of the highest GDPs in the Region and a high energy index, which often suggests good access to energy as is the case of many oil-producing countries. Nonetheless, this has not been translated into a USF reduction exceeding the urbanization rate of the country.

All countries that currently have less than 5% USF according to WHO estimates for 2013 reached the urbanization rate benchmark of 75% before the year 2000. The only exception is Ecuador, which has 2% USF, but only 63% of urban population in 2013.

Besides the differences in GDP and urbanization between countries, there are very relevant differences in terms of their institutional capacity and of how they visualize the problem of the use of biomass in traditional stoves. This in turn determines the solutions, if any, implemented by the countries, namely their energy access policies.

A summary of some LPG fuel subsidy policies in LAC countries that exemplify the different strategies followed in the region is shown on Table 2.

Table 2
Natural gas and LPG pricing policies in some LAC countries.
Source: IMF (2015) unless other source is given.

Country	Description of the program	Comments
Argentina ARG Upper Middle Income	Argentina started to eliminate subsidies in its energy tariff at the beginning of the 1990s, when 87% of population already lived in cities. The price of natural gas has not changed since 2002, and a fund was created to subsidize residential LPG for low-income households and natural gas expansion. Only those with access to natural gas received the subsidy (IMF, 2015). As for LPG, an agreement between the government and producers in 2008 set the prices of LPG for residential use low. This remains the same, and in fact has fallen steadily due to currency depreciation (Kojima, 2016).	More than 98% of people have access to clean fuels. USF is very low. The subsidy to natural gas is very regressive (Whitley and van der Burg, 2015). In 2013, the government made a commitment to limit the subsidy, and in 2015, the eligibility for the subsidy was restricted to low-income households with no connection to natural gas
Bolivia BOL Low Middle Income	LPG prices have not changed since 2005. Bolivia imports some petroleum products, but exports natural gas; fuel subsidies recorded in the budget rose along with the rise in international energy prices to represent 3% of GDP in 2013. The country's authorities attempted to remove fuel subsidies in December 2010, but the proposal was withdrawn after widespread protests of the population. National authorities are building plants to separate LPG from natural gas aiming at self-sufficiency in the sector (OLADE, 2012).	USF decreased from 36% in 2005 to 23% in 2013 (WHO, 2014). Urbanization for the same period rose by 6%. Subsidies for natural and LPG gas allowed 39% of the rural, and almost the entire urban population to switch from USF to LPG (WHO, 2014).
Brazil BRA Upper Middle Income	From 1950–2001, the Brazilian government utilized subsidies to control the market price of LPG (Smith et al., 2005). In May 2001, end-user prices were liberalized, the use of LGP decreased and the USF increased (Coelho and Goldemberg, 2013). At the same time, the government introduced an *Auxilio-Gas* ("gas assistance") program to enable qualifying low-income households to purchase LPG. Qualifying families were those with incomes less than half the minimum wage. The total program cost in 2002 was about half that of price of the subsidy. In 2002, a differential pricing policy was established for LPG cylinders, with one price for cylinders of 13 kg or less, and another for other sizes. Assistance to enable the poor to use LPG is provided as part of *Bolsa Familia*r, the government's social welfare program, in the form of LPG vouchers (Kojima, 2013a).	By 2000, Brazil had only 11% USF (WHO, 2014; Coelho and Goldemberg, 2013). With the information available, it was not possible to disentangle the impact of urbanization and development from the subsidy policies that allowed access to cheap LPG before 2000. The social welfare program may have contributed to the sustained reduction in the % USF, as by 2013, only 5% of the total population used wood to cook (28% of the rural population) (WHO, 2014). Because of Brazil's size, this still represents over 10 million USF
Dominican Republic DOR Upper Middle Income	During 2005–2008, the Dominican Republic launched a reform aimed at progressively eliminating subsidies to gasoline, diesel and LPG. Part of those savings was used to give targeted subsidies in the form of cash transfers to poor households to offset the increased cost of monthly consumption of LPG and public transportation. In 2008, the LPG subsidy was replaced with a social protection scheme whereby 800,000 *bonogas* cards were issued to poor families, entitling them to a monthly reduction of RD$228 (about US$6) for LPG purchase (Kojima, 2013a).	There has been a significant reduction in USF, from 37% in 1990 to 7% in 2010. Between 2010 and 2013, USF increased 2% (WHO, 2014). It is difficult to know if this is due to the sensitivity of the survey or to the increase in fuel prices, as the subsidy is not enough to buy a full cylinder and is not dependent on LPG price.
Ecuador ECU Upper Middle Income	Since 1970, Ecuador has provided subsidies for 15 kg LPG cylinders. Since 2001, a 15 kg cylinder has cost USD$1.6, compared to an average international price of USD$15 (OLODADE, 2013). Previous attempts to remove the subsidy have failed. However, authorities have announced that the LPG subsidy will end in order to replace commonly used propane stoves with high-efficiency induction electric stoves. Consumers will be able to purchase the stoves at an average cost of USD$300–400, taking advantage of special financing scheme. The government will also give an electricity subsidy of 100kWh per month. This is complemented by an ambitious program to increase the use of renewable energy in the electric grid to 80% (MEER, 2015)	Ecuador has less than 5% USF (WHO, 2014). This is particularly relevant considering 37% of its population is rural and 7% is indigenous. In 2015, the LPG subsidy represented 0.5% of the country's GDP (World Bank country profile). In 2006, it was estimated that 41% of LPG sold in Ecuador was not used for residential purposes and 22% was smuggled into Colombia and Peru, where fuel prices are much higher [OLADE (2007)].
El Salvador ELS Low Middle Income	Since 1974, the government fixed the price of 12 kg LPG cylinders at subsidized rates. The subsidy was large (only 35–40% of recovery prices were charged), untargeted and created smuggling problems. From 2011, the government started to give the subsidy directly to consumers, either through the electricity bill for small consumers or a special card for businesses and households without electricity. Given that the cash transfer was fixed, but the price of LPG was allowed to float, this new policy exposed households to volatility in the price of LPG. At the same time, households using more than one cylinder per month only received the equivalent of a single cylinder subsidy. Because the payment was not linked to the purchase of LPG, households could use the money for other needs and return to solid fuel use. In 2013–2014, the government tightened the subsidy by requiring advanced registration and presentation of a special permit at the time of sale. The new payment system paid subsidies directly to LPG vendors when beneficiaries purchased LPG at the same time as providing ID and entering a personal identification number in a special, program-specific mobile phone. LPG subsidies accounted for about 0.6% of El Salvador's GDP in 2013 (Toft et al., 2016; Calvo Gonzalez *et al*., 2015).	It is very likely that the LPG subsidies have helped El Salvador reduce USF to 19%, noting that 34% of its population is rural. There is contextual evidence showing a reduction in LPG consumption by 15.4% following the reform in the subsidy, but no increase in USF. This was accompanied by 7.1% increase in the consumption on LPG in neighboring Guatemala, raising questions of possible prior smuggling of subsidized LPG to the neighboring country (OLADE, 2013). The current subsidy policies (since 2013) are not designed to displace the use of firewood; only people who already use LPG are eligible for the benefit. This subsidy, although more targeted than before, still covers around 75% of the population.
Mexico MEX Upper Middle Income	According to the Mexican law, domestic prices should follow an international reference point, though prices are set by the Mexican government in practice. Overall, domestic LPG prices have been	In 1999, Mexico implemented reforms to reduce subsidies, replacing energy subsidies with targeted cash transfers for lower-income households through the expanded program "*Oportunidades*". This

(continued on next page)

Table 2 *(continued)*

Country	Description of the program	Comments
	above the international benchmark, despite the fact that Mexico is an oil-producing country and PEMEX, the State-run oil company, refers to the existence of an LPG subsidy on its website. In 2007, the government introduced an energy component to the existing anti-poverty program, *Oportunidades*; and introduced additional cash transfers in 2008 (Whitley and van der Burg, 2015).	has helped to improve the targeting performance of social transfers. However, the cash transfer program did not have provisions to guarantee that the money was used to buy LPG.
Panama PAN Upper Middle Income	There is no pre-tax subsidy; LPG is subsidized via State budget. LPG subsidy in 2013 was around 11%. This is a universal subsidy and does not reach the poorest population (Yepes, 2011).	The transition to LPG may have been driven primarily by development and urbanization, as the subsidy is too small.
Peru PER Upper Middle Income	Peru has adjusted excise taxes to smooth out prices, and maintains a stabilization fund to prevent full domestic pass-through from changes in international market prices. The fund has generated large fiscal costs, which peaked in 2008 at over 1.4% of Peru's GDP, including both direct costs and lost revenue (Vagliasindi, 2013). In recent years, the authorities have progressively narrowed the range of products that are subject to these bands. Since 2012, price bands closer to market prices have only been maintained on diesel and LPG. In 2013, the "Fondo de Inclusión Social Energético" (FISE) was created, promoting LPG stoves by providing the stove, accessories and a discount voucher to buy LPG (around USD$6) monthly.	USF in Peru is higher than expected, considering urbanization and the portion of the population living below the poverty line (see Fig. 2). The number of FISE recipients was estimated at more than 710,000 households (Toft et al., 2016). An evaluation of current programs has shown that stacking is predominant (80%), primarily because the LPG price is considered expensive, even with the direct subsidy (UNOPS, 2014).
Venezuela VEN Upper Middle Income	Venezuela is a major exporter, and possesses one of the world's largest oil and natural gas reserves. Driven by the country's choice of economic development, fuel price is highly subsidized and has not changed since 2003, being the cheapest in LAC. Fuel subsidies have accounted for 7% of GDP in recent years has also led to overconsumption, energy inefficiency, and smuggling to neighboring countries.	Venezuela is highly urbanized, but the changes in SFU surpass the rates of urbanization and development. Subsidy to LPG is very likely to have played a major role on this sustained full shift to cleaner fuels. Nowadays the country has less than 5% USF.

The LPG fuel subsidy policies in these countries could be a reasonable explanation for the observed differences in USF. A difficulty when analyzing the impact of LPG fuel subsidy policies is that they need to be contextualized, and may not be comparable, differing both in the design of the policy as in the target population coverage. The LPG fuel subsidies in Bolivia may have provided access to this fuel to most of the population, despite cultural and economic barriers, which have shown to constrain the adoption of clean fuels in other countries (Troncoso et al., 2007; Ruiz-Mercado and Masera, 2015). Likewise, LPG fuel subsidies may help explain low USF in El Salvador, compared to its neighboring countries. Subsidies vary significantly between countries. For example, in 2013 the cost per kg of LPG with subsidy was USD$0.65 in the Dominican Republic, USD$0.6 in Brazil, USD $0.44 in El Salvador,[5] USD$0.33 in Bolivia, USD$0.13 in Ecuador and USD$0.07 in Venezuela (OLADE, 2012; Kojima, 2013b). The outcomes of these subsidies also differ. Many countries in the Region, including Guatemala, Mexico and Peru, have led national programs to distribute improved biomass stoves. These programs may help explain why these same countries are not switching to clean fuels as quickly as expected. In Mexico, despite the fact that most of the population has physical access to LPG, it has been documented that some people stop using LPG once they have an improved biomass stove (Masera et al., 2005; Berrueta et al., 2007). From a health perspective, this is a leap backwards. On the other hand, countries that have had few or no improved biomass stove programs, like Ecuador, Venezuela and El Salvador, but have opted to provide subsidies to LPG, have made progress in terms of access to clean fuels at a faster rate than expected.

Subsidies have been particularly effective in switching urban USF towards LPG. Bolivia has less than 5% urban USF. In comparison, Mexico has 6% and Peru, a neighboring country with many cultural similarities but twice the GDP than Bolivia, has 13% of urban USF (WHO, 2015). The Dominican Republic witnessed a substantial reduction in USF between 1990 and 2005 when a subsidy to LPG was in place. In 2008, the country changed its subsidy policy to cash transfers to the poor, and USF had a relapse in 2011–2013 when the international price of LPG increased (see Fig. 1). This difference is not statistically significant, but highlights the price sensitivity of the LPG market and the weakness of this type of subsidy. Fig. 2 shows the relationship between USF multiplied by an urbanization factor (USF x % Urbanization/100), and the country's GDP. Haiti was not included as it has very atypical values. The urbanization factor was considered to acknowledge differences in urbanization between countries.

It can be noted that countries that are giving a subsidy to LPG are under the line, with Ecuador as the most remarkable case. Argentina and Uruguay also have very low USF, as expected. All countries above the line have higher USF than expected. Guatemala, Peru and Mexico are among the worst cases. Chile's USF is also higher than expected, due to the use of firewood for heating in cold regions. This may also be influenced by the country's large indigenous population, which was 11% in 2010 (CEPAL, 2013).

Fig. 3 shows the difference between the actual prevalence of biomass use and a statistical model that predicts USF based on rurality and poverty (vertical axis) and the fraction of the population in rural areas (horizontal axis). Venezuela and Cuba are not included in the analysis due to lack of data on extreme poverty from these countries.

Countries above the zero line have biomass consumption higher than what would be predicted by its poverty and rurality indicators. Those below the line have a lower consumption of biomass than expected. Ecuador (blue dot) is 28% below the line and outside the confidence intervals, meaning that the model predicts that the percentage of biomass users in Ecuador should be 28% higher. On the other hand, Peru has 22% more USF than predicted.

Interestingly, all countries below the line have some sort of LPG fuel subsidy with the exception of Costa Rica and Honduras, where electricity is used more frequently for cooking than LPG. In addition, the number and percentage of people living in extreme poverty in Honduras is twice as large as what the country's GDP would predict, which may suggest why it appears below the line in this analysis.

[5] In Brazil, Dominican Republic and El Salvador the price of LPG per kg was 1.57, 1.16 and 1.01 respectively, the subsidy is in the form of a cash transfer in Brazil and Dominican Republic, and a special card in El Salvador.

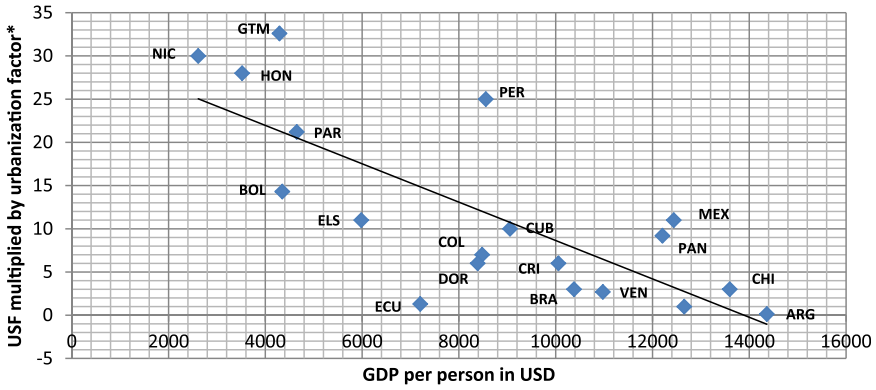

Fig. 2. Relation between USF and GDP. *The % of population using solid fuels was multiplied by the proportion of population living in urban areas. This permits considering the impact of development in the USF, that it is one of the main drivers to change. For instance, Mexico and Panama have the same % of USF, but Panama is more rural. Therefore, it is closer to the expected rate than Mexico, that should have less USF given its urban population.

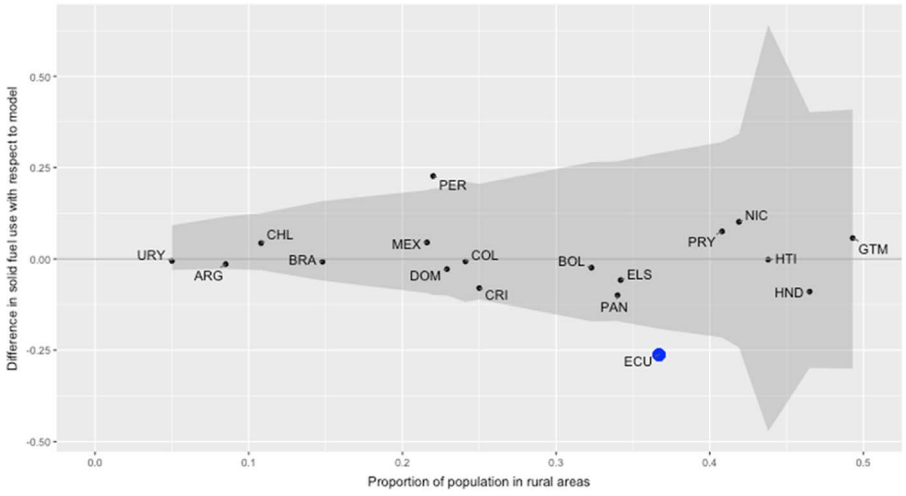

Fig. 3. Predictive model on the use of solid fuels based on the percentage of the population living in rural areas and the percentage of the population living under the poverty line. Figure prepared by Javier Lascurain. Poverty is standardized considering differences in cost of life between countries. The model uses normalized data from all 18 countries to predict the use of solid fuels for a given level of poverty and urbanization with a 90% confidence (grey area). If a country is on the 0 line, there is no difference between the prediction and the reality. There are other factors at play besides poverty and rurality, namely, the *unexplained source of variability*. The grey area shows what would be an acceptable level of unexplained variability. The poverty line as defined by the World Bank as a daily income of US $1.9.

The arguments presented on this paper support the idea that LPG fuel subsidies have helped to improve access to this clean and modern fuel. Ecuador and Venezuela have managed to give access to LPG to almost all their population. Those two countries are the ones with the lowest LPG prices, and their subsidies are a huge economic burden for these countries, representing 7% of their GDP (including other fuels) (IMF, 2015). Universal subsidies may disproportionally benefit the middle and upper classes that have a higher consumption of LPG. In the case of Bolivia, universal subsidies have reached the poor in urban cities but not those in rural areas, showing that despite the huge economic burden for the country (6.1% of the GDP, including other fuels) (IMF, 2015), the subsidy is not reaching the poorest. Many countries are seeking strategies to reform universal subsidies to better target the poorest population, as is the case of El Salvador. India opted for a voluntary program called “give it up” that asks middle class LPG consumers to give up their LPG fuel subsidy (US$16 per year), which is transferred to a poor family. As of April 2016, 10 million people had adhered to the program (The Economic Times, 2016).

4. Conclusions and policy implications

Our analysis shows that price is the single most important adoption factor for the use LPG as fuel for cooking in LAC, even surpassing cultural barriers, as can be seen in Ecuador and Bolivia. Fuel subsidies vary significantly between countries and must be considered in the light of other factors, including access to biomass. Countries with the largest subsidies are those where subsidies have a universal reach. In these cases, substantial amounts benefit the upper classes, as they are the ones with better access to and higher consumption of LPG. However, some subsidies reach the poor, particularly in Venezuela and Ecuador, and in the urban areas of Bolivia.

We can speculate that a higher LPG fuel subsidy, directed only to the poor, could be more effective in the transition to clean technologies for cooking. It is therefore strategic to reduce the number of people receiving subsidies and to more effectively target the poorest.

The main challenge for implementing targeted subsidies is to ensure that it reaches the intended beneficiaries, and to limit the leakage towards other needs or other groups (e.g. through the black market). For example, El Salvador is giving a targeted subsidy using a special electronic card that targets more than 75% of the population. Another possibility is to use cash transfers through poverty alleviation programs (which usually have robust systems to ensure that they reach the target beneficiaries). This has been implemented in Brazil and the Dominican Republic with good results.

While none of these schemes are perfect, each country should analyze its options, considering both the importance of transitioning to clean energy and the sustainability of the solutions. Policies that address inequities in the distribution of resources as a means to health

equity should be emphasized. Moreover, it is important that subsidy policies include mechanisms to target also those that do not currently use LPG.

Goal 7 of the Sustainable Development Goals states the need to ensure access to affordable, reliable, sustainable and modern energy for all by 2030 (UN, 2015). Achieving this goal in LAC is feasible, considering that less than 90 million people, concentrated mainly in 10 countries, use solid fuels for cooking and heating. However, solutions for supporting the transition in other countries, like Haiti, to clean energy, will require more in-depth analyses. To speed up and scale up this transition, a better understanding of the factors that enable changes is needed in each country.

The analysis presented in this paper is exploratory and has clear limitations. Ideally, to relate the decline in the USF with LPG fuel subsidies, it would be necessary to have information on the price and percentage of LPG fuel subsidy in each country per year, as well as data on the decline of USF in the same period in the population with access to LPG. Unfortunately, we do not have this level of detail in the data. This is because data collection varies enormously between countries and is not based on harmonized questions, making it impossible to know what criteria for classification of USF is used. To improve the analysis of the transition to cleaner fuel, it is necessary to first improve and standardize data collection between countries.

Detailed cost-benefit analyses are also necessary. For example, it would be interesting to assess the cost-benefit of the program in El Salvador. The country has made remarkable progress in the last years, but it is worth exploring if a more targeted subsidy would accelerate the transition of the poorest segment of the society.

Many factors need to be considered before claiming that affordability is the only problem that needs to be solved. Economic incentives to buy clean fuels should be combined with awareness campaigns and promotion strategies, such as introducing smaller cylinders in the market. Realization of the occurrence of stacking should not deter efforts to promote clean fuels and technologies as the best option to promote good health. Even when stacking diminishes the benefits of using clean technologies and fuels, it is important to consider that adoption is a process. For example, a home that is already using a clean fuel or technology is more likely to use it more frequently if circumstances improve. It is also more likely that the next generation will choose a clean solution if available (Troncoso et al., 2013). Energy needs and cooking practices can change as people access a higher level of development; for example, in urban Central America, most people no longer make tortillas but buy them, which reduces energy needs. Governments, donors and international agencies need to collaborate and send a clear message to stop promoting only intermediate solutions, like improved biomass stoves. Instead, options for the transition should be diversified and clearly communicated, always promoting a portfolio of possibilities, highlighting the importance of a transition towards the exclusive use of clean fuels.

An important factor in the adoption of a new technology or fuel is the ability to manage the risks, perceived and real. These include the time invested in learning to use the new technology, the possibility that it does not fit traditional cooking practices, concerns with safety, and the potential financial challenges of managing payments for the fuel using a different time schedule. Unless the economic situation of the poor improves substantially, subsidies and cash transfers will be needed to reduce these risks, and effectively provide the poor with access to clean technologies and fuels.

Finally, although stacking is frequent, it is not the norm. It is important to learn from the many households that move to clean fuels in one step. How are they resolving their energy needs without reverting to solid fuels? What are the factors behind a successful adoption and sustained use of clean solutions? These lessons are critical to better promote sustainable changes.

Disclaimer

The author is a staff member of the Pan American Health Organization. The author alone is responsible for the views expressed in this publication, and they do not necessarily represent the decisions or policies of the Pan American Health Organization.

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