Global Environmental Change 58 (2019) 101961

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Household dependence on solid cooking fuels in Peru: An analysis of environmental and socioeconomic conditions☆

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ARTICLE INFO

Keywords:
Air pollution
Fuel transition
Solid fuels
Energy choice

ABSTRACT

Solid fuel use is linked with adverse effects on the environment and human health. Yet, solid fuels remain an important energy source for households in developing countries. Even when country-level dependence on solid fuels is modest, there is often significant variation in within-country patterns of solid fuel use. This study examines a range of environmental and socioeconomic conditions to understand the relationship between them and household energy use within a country. While our results are derived from a study of regional patterns of solid fuel dependence in Peru, the contribution of this study is broad: variables that we include in our models of households' fuel choice decisions are likely to shape such decisions in most developing countries. Our findings indicate that environmental conditions, such as elevation and forest cover, are associated with solid fuel use. Socioeconomic factors, including urbanization, poverty and female literacy, are similarly important. In addition, we identify nuanced links between types of female employment and indigenous population, on the one hand, and solid fuel use, on the other.

1. Introduction

Energy access, for all households, is a fundamental component of development: the United Nations General Assembly included universal access to "affordable, reliable, sustainable and modern energy" as one of the 17 Sustainable Development Goals adopted in 2015. Dependence on solid fuels in low- and middle-income countries (LMICs) impedes this goal, creating a source of household air pollution that harms the health of women and children (Rafaj et al., 2018). In addition, reliance on firewood contributes to deforestation, reduces countries' ability to address climate change, and increases landslide and flood risks (Bhattacharjee and Behera, 2018). In LMICs, energy transitions from solid fuels to modern energy are challenging, especially among residents of rural and lower-income areas, which tend to have more limited access to clean energy sources (Uddin and Taplin, 2015; McLean et al., 2019).

The complexity of the fuel transition process and the wide variety of its implications mean that a study of solid fuel dependence contributes not only to our understanding of causes in fuel transition, but also to developing appropriate policies, which will have both environmental and health benefits, while reducing economic and social costs of fuel transition for more vulnerable social groups (Rao et al., 2013). Perera (2016) concludes that solid fuel use "inflicts a multitude of serious health and developmental harms in children through its emissions of toxic particles and gases and carbon dioxide (CO_2), a co-pollutant that is a major driver of climate change" (Perera, 2016, p. 141). One approach to addressing this problem is implementation of various engineering solutions, such as improved cookstoves (Puzzolo and Pope, 2017). A second approach is to create national programs (e.g., subsidy or consumer finance through loans) that incentivize the use of cleaner cooking fuels. Both technological and political solutions, however, face challenges in their efforts to transform energy practices. Scientists conclude that to address one of the causes of global environmental change (i.e., solid fuel consumption), we need to understand the relative importance of household conditions compared to environmental characteristics, both built and natural (Rosenthal et al., 2017).

Our research examines regional differences in energy usage patterns through analysis of subnational variation in solid fuel dependence in

☆ We thank Jou Fei Huang and Xi Cheng for their research assistance, and our anonymous reviewers for their comments and suggestions. Support for this research was provided by the Community for Global Health Equity at the State University of New York at Buffalo.

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https://doi.org/10.1016/j.gloenvcha.2019.101961
Received 4 January 2019; Received in revised form 10 July 2019; Accepted 5 August 2019
0959-3780/

Peru. Among LMICs, Peru provides an informative context for this type of analysis. Overall, the country is less dependent on solid fuels than many other LMICs. Specifically, just 26% of the country's households used solid fuels as their primary cooking fuels in 2017, which is less than in countries of Sub-Saharan Africa (80%), South-East Asia (58%), and the Western Pacific (31%) (IHME, 2018). However, solid fuel use varies by as much as 71% in neighboring Peruvian regions. Solid fuel dependence in the Lima region was 2.9% in 2012, on par with Europe (< 5%). This is also comparable to several regions in Colombia (Atlántico, Guaviare, Quindío, Vichada), and to Ecuador, where 3.2% of households rely on solid fuel use at the country level. In contrast, directly across the administrative border in Huancavelica, solid fuel dependence in 2012 was 81%, similar to Sub-Saharan Africa. Similar dependence levels are observed in several regions in Honduras (Intibucá, La Paz, and Lempira) and Guatemala (Alta Verapaz, Huehuetenango, El Quiché, Sololá) – all of which display dependence levels of more than 80%.

Despite the documented importance of solid fuel use for health and climate, to date, and to the best of our knowledge, no research provides a systematic analysis of determinants of this variability to explain vast disparities within the same country. A thorough understanding of variability in solid fuel use within Peru has far-reaching implications when it comes to uncovering within-country inequity in clean fuel access and a global understanding of successful and unsuccessful fuel transitions. We examine associations between energy use, on the one hand, and affordability, access, and need, on the other. In our conceptualization of access and need, we rely on several proxies, such as geographical location. We further investigate affordability through the role of female employment (vis-à-vis male employment) in energy use. Finally, we investigate the role of indigenous populations, whose fuel decisions depend on traditional and cultural requirements. While our variables have some limitations (e.g., we do not have data on decision-making), our analysis provides a contextualized region-level understanding of the relationship between environmental factors and household energy use within a country.

Our study makes two key contributions to the research on solid fuel dependence. First, we identify knowledge and evidence gaps regarding regional variation in patterns of solid fuel consumption in Peru. We then seek to fill these gaps by offering a systematic assessment of associations between a broad range of explanatory factors and solid fuel use. Our study also has the benefit of calculating the size of identified associations, which helps to compare the relative importance of different explanatory factors. Second, our results can provide useful guidelines for drawing up policies in developing countries with the goal of reducing solid fuel consumption. One approach to reducing solid fuel use is to implement policies making alternative sources of energy more accessible (e.g., through electrification, or providing alternative cookstoves). This approach directly addresses the problem of solid fuel dependence. Our research provides evidence that such direct strategies are beneficial: electrification has a negative association with solid fuel use. At the same time, we show that this is not the only viable approach – in fact, when governments implement policies in other critical areas, such as policies enhancing girls' access to education and providing skills required for high-skill occupations, such policies can help reduce solid fuel dependence as well. Given that LMICs' governments are significantly constrained in their resources and, hence, ability to implement multiple policies at the same time, it is helpful to have information about policy trade-offs. Our findings suggest that some policies generate multiple benefits: for instance, by improving education, governments are also contributing to the success of energy transition policies.

2. Research context: patterns and explanations of solid fuel use

This section provides a review of the literature that has examined factors shaping decisions about household energy sources in LMICs, with emphasis on Peru. In general, these factors relate to the external environment, both built and natural, and household characteristics. In almost all LMICs, electricity is not a significant energy source for cooking (Madubansi and Shackleton, 2007). One reason for this is that there is a threshold for building and maintaining electricity grids. Creating a sustained supply of electricity requires government investment and capacity. Second, electricity is often more expensive than other energy sources. Households in rural Peru do not use electricity for cooking, even if they have access, because it is more expensive than liquefied petroleum gas (LPG) and biomass (Meier, Tuntivate, Barnes, Bogash, and Farchy (2010, p. 16). Even in urban areas, only 2% of households use electricity for cooking (Peru Market Assessment Executive Summary, 2012, p. 23). Peru possesses one of the largest deposits of natural gas in South America, about half of which is exported. However, LPG is a preferred fuel from the government's perspective because it helps the country switch to cleaner, more sustainable energy and progress towards increasing energy access. LPG can be distributed to isolated regions with greater flexibility (e.g., LPG cylinders) than liquefied natural gas (LNG), which requires building and maintaining pipelines.

The energy ladder theory indicates that there is a gradual transition in energy consumption as income rises (DeFries and Pandey, 2010). Initially, households use wood or other forms of biomass that they collect. With increasing income, education, urbanization, and health awareness, households are expected to switch to modern energy sources that are cleaner, easier to use, more efficient and sustainable (Hosier and Dowd, 1987). However, this transition may be more difficult in some communities, especially for low-income households in isolated areas (van der Kroon et al., 2013). Price is important in determining households' energy choices, as well as concerns about families' ability to purchase newer fuels in the future (Troncoso and Soares da Silva, 2017). Therefore, residents may maintain traditional stoves after installing LPG stoves. Wolf, Mäusezahl, Verastegui, and Hartinger (2017) find that many in rural Peru use traditional and LPG stoves interchangeably. Only 5% of families in the Cajamarca, Cusco, and La Libertad regions use exclusively LPG stoves (Wolf et al., 2017, p. 2).

According to a 2012 Peru report from the Global Alliance for Clean Cookstoves, the price of an LPG cylinder is regionally variable: it is lower in regions where LPG is bottled, such as Lima, and higher in producing regions, such as Cusco (Peru Market Assessment Executive Summary, 2012, p. 24). There are also capital costs to fuel transitions (Edwards and Langpap, 2005) that reduce families' willingness to switch to alternative energy sources, especially in rural areas, where households often rely on barter exchanges (Masera et al., 2000). Since urban households regularly receive financial inflows and can make regular fuel payments, they are in a better position to purchase clean fuels (van der Kroon et al., 2013). In contrast, most low-income rural families rely on traditional or biomass fuels (kerosene, fuelwood, and agriculture residue) for lighting and cooking (Meier et al., 2010).

Institutional conditions add to cost burdens — purchasing and installing a gas stove may require a deposit for gas cylinders. Therefore, households may need a loan to switch cooking fuels. This means that credit market access is an important factor in the fuel transition process. Many Peruvian families encounter this problem, despite NGO efforts to improve credit access (Barnes et al., 1997). To reduce upfront costs tied to clean fuel transitions, the Peruvian government collaborated with oil companies to distribute free LPG stoves to low-income families from 2009 to 2011: the Ministry of Energy and Mining launched "Project Nina" and distributed around 40,000 LPG stoves and 64,000 improved wood-burning stoves to rural communities (Peru Market Assessment Executive Summary, 2012). However, compared to traditional stoves, LPG stoves are more expensive to use because they require a monthly expense to purchase fuel, whereas collected solid fuels are free (Masera et al., 2000). Although low-income families may receive subsidized LPG, it is not free and may cost 16 soles (around 6 USD) – a significant expense (Hollada et al., 2017). Households are also concerned about price instability (Coelho et al., 2018). Coelho et al. (2018) indicate that government subsidies can alleviate this concern and promote switching from wood to LPG. However, some families prefer to keep their traditional stoves in case of an abrupt subsidy cessation. Moreover, subsidies do not help to overcome another problem – limited energy distribution networks. LPG is distributed in tanks or cylinders; distribution requires well-maintained roads that are absent in some regions of Peru. Besides, LPG retailers are not evenly distributed throughout the country. Low-income households in isolated areas may find it challenging to purchase LPG cylinders or re-fill them, even with government vouchers. Consumers may have to walk long distances or use different modes of transportation, and carry home a heavy LPG cylinder (Pollard et al., 2018).

Existing research also indicates that women's practices, work, and education levels impact fuel choices. In Peru, like many other LMICs, women are responsible for fuel collection and food preparation; hence, fuel transitions often mean that women need to adjust. While education is not likely to affect specific cooking practices, studies find that a higher level of female education has a positive association with LPG stove use (Muneer, 2003). As education levels rise, the opportunity cost of using traditional fuels increases. Studies show that women and children are primary wood collectors, which is time consuming (Muneer, 2003). Women also have to allocate time to start and maintain a fire, cook meals, and clean after cooking because of soot produced by traditional stoves (Heltberg, 2004).

Education equips women with better understanding of long-term health risks of using biomass. Instead of following traditional practices, educated women tend to hold a more open attitude toward new technology and cultural changes. Malakar (2018) finds that people fear new types of fuels because of fire risks – and education can alleviate such fears. In addition, educated women are more likely to send their children to school, which reduces available labor for fuel collection and incentivizes transition to alternative fuels. Finally, communication barriers can be an obstacle in the process of fuel transition because communication is more likely between individuals with the same tribal, religious, and other affiliations, which can limit the flow of information about new energy sources. However, previous research suggests that women have stronger social connections with other women and, hence, are likely to overcome communication barriers and learn about cleaner fuels and proper use of modern stoves, making women more likely to switch (Kumar and Igdalsky, 2019).

Studies also point to environmental factors as determinants of regional variation in fuel use. Temperature plays a role in households' fuel choice: populations located at higher elevations and cooler regions prefer to use firewood for heating and cooking (Córdova-Aguilar, 1992; Gubler, 2017; Rhodes et al., 2014). After cooking, they leave stoves burning to heat their homes (Martínez-Negrete et al., 2013; Rhodes et al., 2014). At the same time, households may use LPG more frequently during rainy seasons, since more time is needed to start a fire using wood (Ruiz-Mercado and Masera, 2015). Longer rainy seasons also extend the time needed to dry wood, dung, or hay. Therefore, residents of areas with more rainfall may be more likely to switch to LPG.

Finally, existing research suggests that regions with higher percentages of indigenous population have a lower clean energy utilization rate. Three mechanisms explain this association. First, indigenous groups maintain kinship networks (Freire et al., 2015, p. 46). Large families mean more available labor to collect solid fuels, disincentivizing modern stove adoption (Heltberg, 2004; Rao and Reddy (2007). Second, traditional stoves have cultural value (Rhodes et al., 2014, p. 13). Additionally, wood collection provides opportunities for social networking and maintaining traditional ties (Malakar, 2018). Indigenous populations may also prefer the traditional taste of their cuisine, which may change with alternative fuels (Edwards and Langpap, 2005, p. 573). Third, studies find that communication problems may impede fuel transitions (Pollard et al., 2018). Consumers may not be willing to switch to newer fuels without information regarding costs, benefits, and safety (Ekouevi and Tuntivate, 2012, p. 38). This challenge can be more severe in Peruvian regions with a higher percentage of indigenous people, many of whom do not consider Spanish as their first language or may not speak Spanish at all, instead using Quechua, Aymara or Ashaninka. The 2017 Census in Peru shows that Spanish is the first language for 29.2% of Puno's population, 29.5% of Apurimac's population, and 36.7% of Ayacucho's population – regions with the largest shares of indigenous groups.

Table 1
Summary Statistics.

Variables	Mean	SD	Min	Max	Data Source
Solid fuel use	44.3	24.7	.4	86.6	DHS
Coastal	0.4	0.5	0	1	Constructed by authors
Capital	0.1	0.3	0	1	Constructed by authors
Forest cover (log)	11.0	2.4	5.8	15.2	AidData GeoQuery
Air temperature	16.6	6.5	7.4	27.2	AidData GeoQuery
Elevation	2.0	1.2	0.2	3.9	AidData GeoQuery
Distance to roads (log)	10.8	0.7	9.8	12.2	AidData GeoQuery
Regional population (log)	13.5	0.9	11.1	16.1	DHS
Rural population share	30.5	19.1	1.7	69.6	Census
Female literacy	91.6	6.1	73.5	99.1	DHS
Female employment	63.1	9.4	33.3	89	DHS
Electricity access	76.9	16.1	27.8	99.4	DHS
Mobile access	57.0	26.5	.9	94	DHS
Poverty	22.4	17.8	0	66	DHS
Indigenous population share	34.6	28.8	2.1	90.8	Census

3. Analysis of solid fuel use in Peru

We rely on three sources of data in our analysis of regional patterns of solid fuel consumption. The first is the Demographic and Health Surveys (DHS) by the United States Agency for International Development (USAID). The second is GeoQuery by AidData.org, a research lab at William & Mary's Global Research Institute, which collects and provides data on various aspects of international development (Goodman et al., 2016). The third is the 2017 Census conducted in Peru. Table 1 summarizes all variables and indicates the source of information for each. The unit of analysis is region-year. The dataset includes the following years: 2000, 2004, 2007, 2009, 2010, 2011, and 2012.

3.1. Dependent variable: solid fuel use

The household-level survey question is from the DHS: What type of fuel does your household mainly use for cooking? Responses are then aggregated at the region level. The Lima region and Lima Metropolitan Area have the lowest levels of solid fuel dependence in the country: in 2012, 2.9% and 8% of their populations used solid fuels for cooking, respectively. In contrast, Huancavelica depends on solid fuels more than any other part of the country: 81% of households relied primarily on solid fuels in 2012.

3.2. Independent variables

3.2.1. Characteristics of the external environment

3.2.1.1. Infrastructure

3.2.1.1.1. Capital. We coded a dummy variable, which equals 1 for the Lima region, and 0 for all other regions. This is a proxy for energy access and other benefits of proximity to the country's political and economic center. This is also where roughly a third of Peru's population resides. Therefore, we use the *Capital* dummy to control for multiple unique characteristics of this location.

3.2.1.1.2. Distance to roads. We proxy a region's infrastructural development by using the region's maximum distance to roads (calculated in meters and logged). The Center for International Earth Science Information Network serves as the data source: the variable is generated by using "a fishnet covering the globe, and centroids for each grid cell […] the grid cell size was either 0.5 or 1 degree" and selecting "a clearly identifiable route intersection the shortest distance from the centroid" (Center for International Earth Science Information Network (CIESIN, 2013: 2–3). Since each administrative unit is split into several grid cells, and hence multiple distance values are available, the dataset provides information on the minimum distance for each administrative unit, the average, and the maximum. We use the maximum value in our analyses. A dense network of roads may facilitate delivery of cleaner fuels to households, while remote areas may have no choice but rely on solid fuels available locally. The lowest distance to roads and, hence, a more developed transportation infrastructure, is in Apurimac, while Loreto has the highest distance.

3.2.1.2. Physical environment

3.2.1.2.1. Coastal. We construct a binary indicator, which equals 1 for regions located on the Pacific coast (11 regions), and 0 for landlocked regions (14 regions). Peruvian coastal regions have less dense vegetation because of deserts and mountains, whereas many non-coastal regions are in the rain forest zone. At the same time, the coast is also where much of the country's economic activity is concentrated, along with transportation infrastructure.

3.2.1.2.2. Elevation. This indicator reflects the region's global elevation (in thousand meters) from Shuttle Radar Topography Mission (SRTM) dataset (v4.1) at 500 m resolution. The region of Loreto has the lowest elevation (0.184), while Apurimac has the highest (3.855).

3.2.1.2.3. Air temperature. We use a measure of average annual air temperature (in degrees Celsius) to control for energy needs. In areas with lower temperatures, cooking fuel use should be higher because previous research shows that energy expenditure in humans grows with decreasing temperatures (Johnson et al., 2011, p. 545). Huancavelica has the lowest average annual temperature in Peru: 7.4C, whereas Ucayali has the highest: 27.2C. Note that elevation and air temperature are highly correlated: the bivariate correlation coefficient equals −0.798 and is statistically significant at 0.01.

3.2.1.2.4. Forest cover. To gauge households' access to one type of fuel, i.e., wood, we rely on European Space Agency's estimates of area size covered with forests. Forested areas in the region of Tacna with its desert climate are the smallest in the country (1.8 ha). The largest wooded area is the Amazon rain forest, where Loreto is located (29.8 Mha).

3.2.1.3. Population and poverty

3.2.1.3.1. Regional population. We include regions' population size (logged) to investigate whether providing cleaner fuels is more challenging in populous regions. Madre de Dios is the least populated region (157,000 people in 2012), while Lima is the most populous one (almost 9.9 million people in 2012).

3.2.1.3.2. Rural population. This indicator calculates the share of a region's total population, which resides in rural areas, based on information from the 2017 Census. The Lima region is the most urbanized area of the country, with less than 2% of rural residents. Huancavelica is on the opposite end of the urbanization spectrum, with 70% of rural population.

3.2.1.3.3. Indigenous population. To evaluate the role that cultural and traditional factors may play in solid fuel use, we create a measure of indigenous population as a share of a region's total population, based on the 2017 Census. The region of Puno has the highest concentration of indigenous population: 91% of residents belong to an indigenous group. The lowest concentration is in Tumbes: approximately 2% of residents identify as a member of an indigenous group.

3.2.1.3.4. Poverty. To gauge poverty, we rely on the percentage of each region's population in the lowest wealth quintile. There is significant amount of variation in poverty levels in Peru. The Lima Metropolitan Area has the lowest share of population in the least affluent quintile: zero percent in the early 2000s, and 0.1 percent in 2012. These values fall well below the average for the country's regions: 23 percent. On the opposite end of the poverty scale are Cajamarca and Huancavelica, where 61 and 66 percent of population, respectively, fell in the lowest wealth quintile in 2011.

3.2.2. Household characteristics

3.2.2.1. Women's education and employment

3.2.2.1.1. Female literacy. To evaluate the effect of education, specifically female education, on solid fuel dependence, we use data on the percentage of women (in the 15–49 age group) who are literate. The DHS manual defines literacy based on the following criteria: attendance of school beyond the secondary level, or ability to read at least a part of a sentence. General literacy levels in Peru are quite high, conditional on the fairly low standard set by the DHS definition: in 2012, the average literacy rate in Peru stood at 93%. Female literacy is the lowest in Huanuco (84%), and the highest in Ica and the Lima Metropolitan Area (99%).

3.2.2.1.2. Female employment. We investigate the relationship between women's economic opportunities and solid fuel dependence by including female employment rate in our analyses. This measure represents percentage of women (in the 15–49 age group) who have held jobs for at least a year. According to DHS data, 62 percent of women in Peru are employed, with the lowest rate of employment in Cajamarca (32%), and the highest rate in Huancavelica (89%). In addition, we collect data for female employment by occupation. Coding of occupation categories in the DHS data generally relies on the International Labor Organization's International Standard Classification of Occupations (ISCO). We use information on seven employment groups: (1) professional; (2) clerical; (3) services and sales; (4) skilled manual; (5) unskilled manual; (6) domestic; and (7) agricultural. The most common female occupations are services and sales (the average of 30 percent across all regions), and agriculture (28 percent). Unskilled manual work is the least popular occupation category (the average of just 2.4 percent for all regions).

3.2.2.2. Technology access

3.2.2.2.1. Mobile access. Peru's mobile network is quite well-developed and has been expanding very quickly. *Mobile access* captures the percentage of a region's households possessing a mobile telephone. In 2004, the median of this variable was just 8.7, while in 2012 it reached 79.5. Still, significant variation in mobile access exists across different regions. In 2012, just 54.8% of Loreto's households had mobile phones (the minimum), in contrast to Arequipa with 94% of households with mobile access (the maximum).

3.2.2.2.2. Electricity access. This variable represents the percentage of households in each region with access to electricity. The median of this variable increased significantly during the period under study: from 67.5% in 2004 to 86.6% in 2012. At the same time, substantial disparities remain: the lowest share of households with access to electricity is in Amazonas (64%), and the Lima Metropolitan Area has the highest share (99.4%).

4. Methods

The estimation technique we use for all models is linear regression with panel-corrected standard errors, which are adjusted for panel-specific first-order autocorrelation (AR1) processes. The choice of the technique is appropriate given that we use pooled time-series data: Beck and Katz (1995) suggest that in this case, a proper approach should correct for autocorrelation and estimate panel-corrected standard errors to address heteroskedasticity as well as contemporaneous correlation in the error processes. We account for autocorrelation and

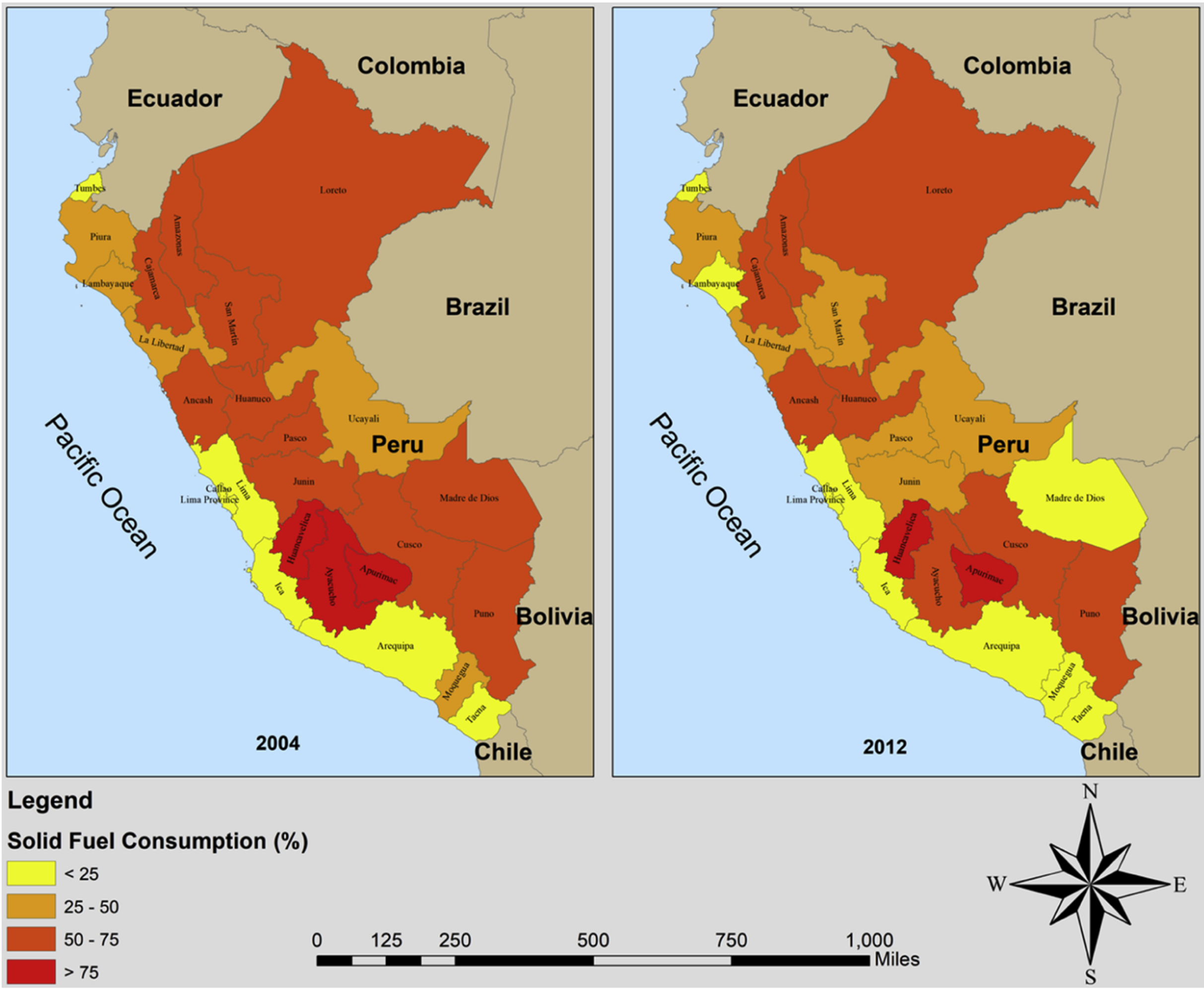


Fig. 1. Solid Fuel Consumption in Peru by Region (in 2004 and 2012).

address the slow-moving nature of fuel transition by including a lagged dependent variable in our model specifications. We control for heteroskedasticity by calculating panel-corrected standard errors.

5. Results

Before turning to our statistical results, we use two maps to highlight patterns of solid fuel use across Peru's regions and their change over time, specifically from 2004 to 2012. Fig. 1 illustrates varying levels of solid fuel dependence in different parts of the country. The 2004 panel of Fig. 1 shows, for instance, that there can be vast gaps in solid fuel consumption levels between neighboring regions, such as Ancash and the Lima region. A comparison of two panels of Fig. 1 also suggests that overall Peru is moving away from its reliance on solid fuels for cooking. However, some regions maintain their dependence. For example, Cajamarca remains in the high-dependence group in the 2012 panel of the map, indicating no change from the 2004 panel, while the Amazonas region reduces its dependence and drops out of the high-dependence group in the 2012 panel.

Table 2 reports the first set of results, which are based on different specifications. In Models 1–3, the dependent variable is solid fuel use. In Models 4–6, we replace it with deviation in solid fuel use from the country level. The former models help us address the question: what factors are associated with solid fuel dependence in various regions? The latter models allow us to consider what factors are linked to regions' greater (or lower) dependence on solid fuels, compared to the entire country.

Several external environmental characteristics have statistically significant relationship with solid fuel use. Specifically, we find that the region where the country's capital is located (i.e., the Lima region) benefits from its proximity to the political center of Peru: solid fuel consumption in the region is lower than in other regions. The predicted level of solid fuel use for the capital region is 38 percent, whereas for other regions it is 45 percent, based on results in Model 3. At the same time, coastal regions tend to have higher predicted solid fuel consumption: 47 percent, compared to 44 percent for non-coastal regions.

Two other geographic factors yield statistically significant results in Table 2. Elevation and forest cover have a positive association with solid fuel use. When all regressors are set at their means, the predicted level of solid fuel consumption is 44.8 percent. If we increase either elevation or forest cover by one standard deviation above their means, predicted solid fuel consumption goes up by 2 percentage points in each case, which indicates that the two variables have the same substantive impact on predicted levels of solid fuel dependence. Panels *a* and *b* of Fig. 2 illustrate regional variation in elevation and forest cover.

Our models identify demographic factors that have significant associations with regional solid fuel dependence. The size of rural population and poverty levels are linked to higher dependence levels, while female literacy has the opposite effect. To compare the magnitude of these findings, we first calculate predicted solid fuel use when all variables are set at their means in Model 3 (44.8%), and then increase each of the three significant demographic regressors by one standard deviation above their means and evaluate changes in predicted solid fuel dependence. In the case of rural population increase, the resulting

Table 2
Models of Solid Cooking Fuel Use in Peru.

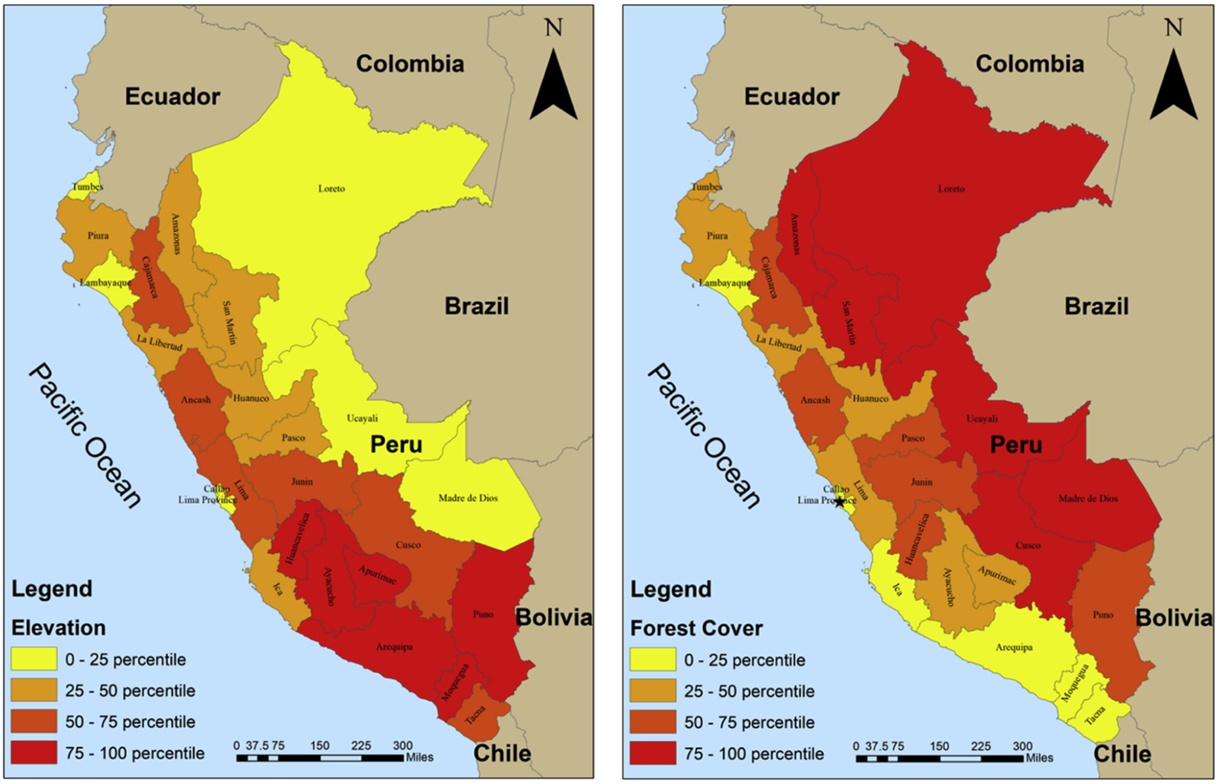
	DV: Level of solid fuel use			DV: Deviation in solid fuel use from country level		
	Model 1 (baseline)	Model 2 (with lagged DV)	Model 3 (with lagged DV & additional controls)	Model 4 (baseline)	Model 5 (with lagged DV)	Model 6 (with lagged DV & additional controls)
Capital	−18.17**	−5.41**	−7.39**	−15.55**	−5.57**	−7.15**
	(1.76)	(1.95)	(2.14)	(1.36)	(2.07)	(2.17)
Forest cover	2.82**	0.80**	0.85**	2.21**	0.64**	0.70**
	(0.25)	(0.30)	(0.24)	(0.20)	(0.28)	(0.26)
Elevation	3.64**	1.15	1.76**	3.67**	1.37*	1.70**
	(0.77)	(0.70)	(0.78)	(0.78)	(0.72)	(0.84)
Distance to roads	0.86	−0.53	−0.47	1.51	−0.80	−0.34
	(1.08)	(0.86)	(1.18)	(1.27)	(0.71)	(1.09)
Rural population	0.37**	0.12**	0.13**			
	(0.05)	(0.06)	(0.06)			
Female literacy	−0.47**	−0.24**	−0.22**			
	(0.14)	(0.12)	(0.10)			
Female employment	0.07	0.04	0.08			
	(0.08)	(0.04)	(0.05)			
Electricity access	−0.28**	−0.12*	−0.13*			
	(0.06)	(0.07)	(0.07)			
Mobile access	−0.07**	−0.03	−0.03			
	(0.03)	(0.02)	(0.02)			
Poverty	0.09	0.07	0.08**			
	(0.06)	(0.04)	(0.04)			
Deviation in rural population				0.35**	0.09*	0.11*
				(0.04)	(0.05)	(0.06)
Deviation in female literacy				−0.35**	−0.18*	−0.16*
				(0.13)	(0.10)	(0.09)
Deviation in female employment				0.07	0.03	0.06
				(0.07)	(0.04)	(0.05)
Deviation in electricity access				−0.28**	−0.12*	−0.13**
				(0.06)	(0.06)	(0.06)
Deviation in mobile access				−0.21**	−0.18**	−0.18**
				(0.07)	(0.05)	(0.05)
Deviation in poverty				0.13**	0.10**	0.10**
				(0.06)	(0.04)	(0.04)
Coastal			2.68**			2.84**
			(1.25)			(1.19)
Air temperature			0.15			0.08
			(0.09)			(0.10)
Regional population			0.68			0.56
			(0.49)			(0.47)
Lagged DV		0.64**	0.65**		0.59**	0.60**
		(0.09)	(0.08)		(0.09)	(0.09)
Constant	49.63**	35.59**	15.57	−45.31**	−0.58	−17.15
	(21.07)	(17.82)	(16.85)	(14.77)	(7.88)	(12.44)
Observations	144	144	144	144	144	144
R-squared	0.98	0.99	0.98	0.97	0.98	0.98

Linear regression with panel-corrected standard errors in parentheses (adjusted for panel-specific AR1 processes). Time period: 2000–2012.
* $p < 0.10$.
** $p < 0.05$.

value of predicted solid fuel use is 47.4; in the case of poverty, it is 46.4; and in the case of female literacy, it is 43.7. Therefore, the substantive impact of the rural population variable is larger than the impact of the other two measures. Panels *a* and *b* of Fig. 3 illustrate regional variation in rural population and female literacy.

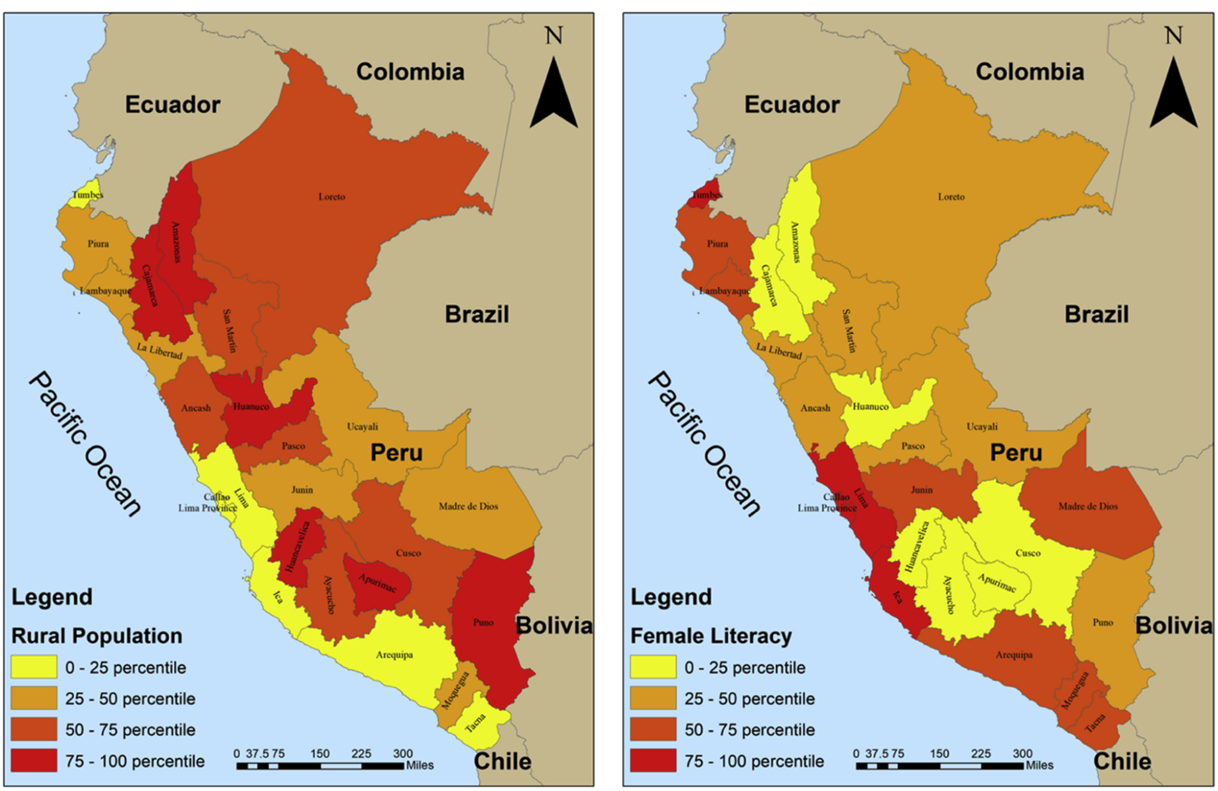
In addition, coefficients on two household technology access variables reach statistical significance at conventional levels. Both mobile and electricity access are linked to lower solid fuel use. These findings are consistent with our expectation that infrastructural improvements facilitate households' access to cleaner fuels. While the result for mobile access is not particularly robust in Models 1–3, as it loses its statistical significance in Models 2–3, this measure expressed as deviation from the country level shows a more robust link to regional solid fuel use, measured as deviation from the country level. Model 3 estimates suggest that one standard deviation increase in electricity access results in 3 percentage points reduction in predicted solid fuel use, all else being fixed at the mean. To get a better sense of associations between mobile and electricity access, on the one hand, and solid fuel use, on the other, we turn to a robustness check based on regional differences from country levels. Specifically, we use estimates in Model 6 of Table 2 and calculate changes in predicted levels of solid fuel dependence when we increase mobile and electricity access by one standard deviation above their means. When all regressors are set at their means, the predicted solid fuel use value is 9.2. When we increase one of each access measure at a time, the predicted value goes down to 6.8 for mobile access and 7.4 for electricity access. This means that regions that move from average to better-than-average infrastructure development are predicted to see a decline in solid fuel use, which brings them closer to the country average.

Finally, the lagged dependent variable has a positive and significant association with solid fuel use, as expected. This indicates a substantial level of path dependence in regional energy patterns: past fuel consumption strongly determines current fuel consumption. At the same time, there are several explanatory variables, which do not appear to have significant links to solid fuel dependence. Coefficients on distance to roads, air temperature, the size of regional population and female



(a) Elevation (b) Forest cover

Fig. 2. Elevation and Forest Cover by Region (Peru; 2012).



(a) Rural population (b) Female literacy

Fig. 3. Rural Population and Female Literacy by Region (Peru; 2012).

employment consistently fail to reach statistical significance across all models reported in Table 2. Two measurement issues can account for these non-findings: lack of within-region variation for two variables (distance to roads and air temperature), and correlation between lagged population and female employment, on the one hand, and the coast dummy, on the other. Difference of means tests show that coastal areas are more populous and have lower female employment. If we drop the coast dummy from our models, coefficients on both regional population and female employment reach statistical significance: more populous regions and areas with greater female employment rates tend to use more solid fuel. Therefore, we attribute non-findings for these two variables to the effect of including the coast dummy.

We can now use these estimates to derive predicted solid fuel use in two regions of Peru to evaluate the predictive power of our models. We choose two regions that share a border and differ significantly in their solid fuel dependence levels: Ica and Huancavelica. When we calculate predicted solid fuel use by setting all explanatory variables to values corresponding to Ica in 2012, based on estimates derived from Model 3 in Table 2, predicted use equals 7.8 with the 95% confidence interval of (6.5; 9.0). The actual value of Ica's solid fuel dependence is 8.2. We then repeat this process for the region of Huancavelica. The predicted solid fuel use value is 79.5 with the 95% confidence interval of (77.3; 81.6). The actual value is 81. In both cases, our model yields predicted values that have a close correspondence to actual values.

To illustrate the substantive significance of our findings, we generate marginal effects plots based on our estimates for results, which are significant at the 0.05 level. Fig. 4 is based on Model 2 in Table 2. The predicted value of 0 on the Y axis means that a given region uses no solid fuels; the value of 100 means that a region uses only solid fuels as the primary cooking fuel. When we change forest cover (panel *b*) and rural population (panel *c*) from their minimum values to their maximum values, predicted solid fuel dependence rises from 38 to 48.3 percent, and from 41.3 to 49.7 percent, respectively. Similarly, when we change female literacy (panel *d*) from the minimum to the maximum, predicted solid fuel dependence declines from 49.4 to 43.2 percent, while the shift from the non-capital to capital status (panel *a*) leads to the drop from 45.2 to 39.8 percent in predicted solid fuel use. Together, these predicted solid fuel use plots highlight the substantive implications of our statistical results.

5.1. The role of female and male employment

None of the models in Table 2 indicate that there is a significant association between female employment and solid fuel use. However, previous research suggests that women's work status may be linked to households' ability and willingness to buy more (or less) of different types of fuel (Sehjpal et al., 2014). In our dataset, we find that the bivariate correlation coefficient for female employment and solid fuel use is positive (.38) and significant at .05, which suggests that, when more women generate income for their households, solid fuel dependence deepens. This is consistent with previous studies on the effect of income: greater economic resources may encourage households to buy more solid fuels, rather than switch to cleaner fuels, especially in rural regions (Heltberg, 2003).

To delve deeper into the relationship between female employment and solid fuel use, we collected additional data from the DHS database: specifically, we added information on women's occupation types and then re-ran the specification in Model 3 of Table 2. Table 3 reports results with various occupation types. The first model includes all occupations in the same specification, while the remaining models are robustness checks, which include one occupation variable at a time. Results from these robustness checks are very similar to results in Model 1, with one exception: the clerical occupation has a negative and significant association with solid fuel use in Model 3, but the coefficient is not significant in the main model (i.e., Model 1).

Consistent with the bivariate correlation coefficient between female employment and solid fuel use, female employment has a positive and significant association with solid fuel dependence in Model 1, as well as

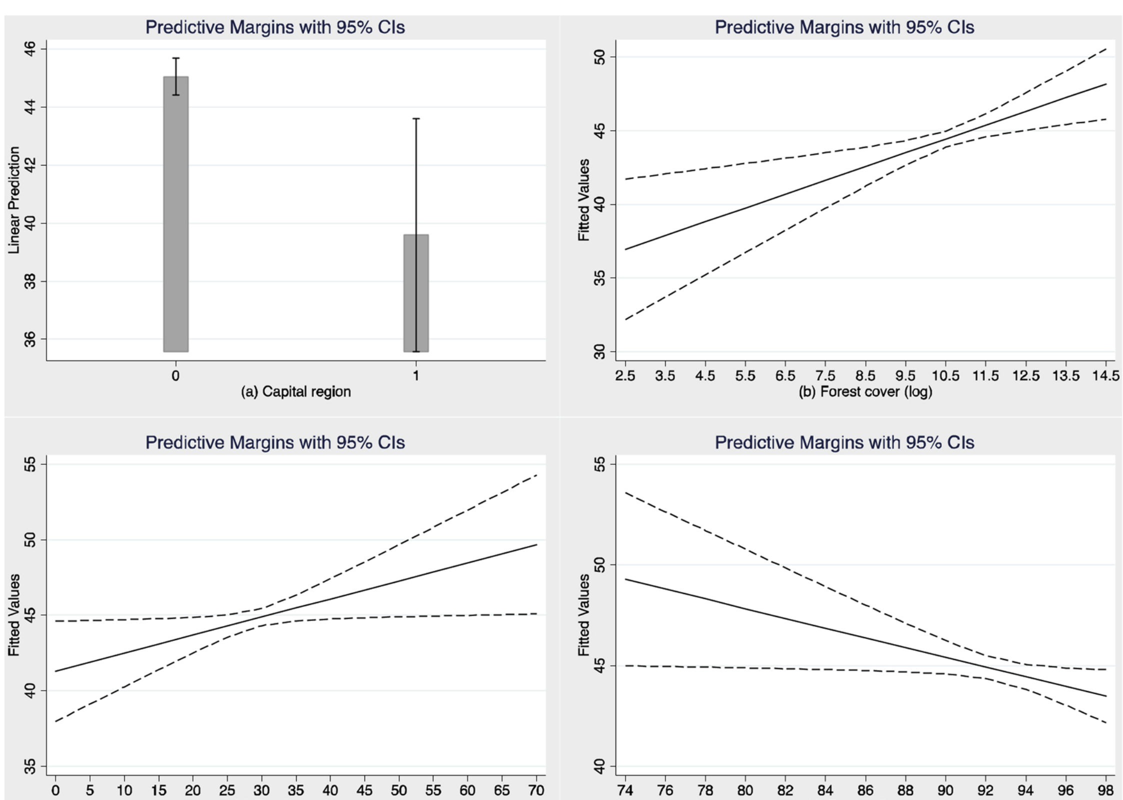


Fig. 4. Marginal Effects of Capital Region, Forest Cover, Rural Population, and Female Literacy on Solid Fuel Use (Based on Model 2 in Table 2).

Table 3
Models of Solid Cooking Fuel Use in Peru (by Female Occupation).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Female employment	0.13**	0.14**	0.16**	0.16**	0.13**	0.17**	0.20**	0.17**
	(0.06)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Professional	−0.25**	−0.11*						
	(0.12)	(0.07)						
Clerical	−0.16		−0.17**					
	(0.21)		(0.08)					
Services	−0.07			−0.01				
	(0.05)			(0.02)				
Skilled manual	−0.46**				−0.19*			
	(0.13)				(0.11)			
Unskilled manual	0.05					0.11		
	(0.23)					(0.26)		
Domestic	0.76**						0.27**	
	(0.11)						(0.08)	
Agricultural	−0.03							−0.03
	(0.03)							(0.04)
Coastal	1.02	4.68**	4.59**	4.25**	4.02**	4.36**	2.45**	3.72**
	(1.27)	(1.61)	(1.66)	(1.50)	(1.57)	(1.48)	(1.20)	(1.62)
Capital	−8.28**	−6.39**	−4.99**	−5.64**	−9.07**	−5.94**	−7.64**	−6.05**
	(1.95)	(2.39)	(2.19)	(2.03)	(2.21)	(2.16)	(1.75)	(2.27)
Regional population	1.13**	0.22	0.03	0.20	0.78	0.27	0.91**	0.20
	(0.39)	(0.69)	(0.72)	(0.64)	(0.54)	(0.61)	(0.37)	(0.72)
Rural population	0.13**	0.12	0.12	0.13*	0.11*	0.13*	0.16**	0.14*
	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)
Female literacy	−0.11	−0.21*	−0.21*	−0.21**	−0.19*	−0.22**	−0.16*	−0.24**
	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.09)	(0.11)
Electricity access	−0.12	−0.19**	−0.18**	−0.17**	−0.19**	−0.18**	−0.13**	−0.18**
	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)	(0.08)
Mobile access	−0.05**	−0.04*	−0.04*	−0.03**	−0.05**	−0.04**	−0.04**	−0.04*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Poverty	0.05	0.05	0.05	0.04	0.05	0.04	0.07	0.04
	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)
Forest cover	0.50*	1.05**	1.00**	0.98**	1.04**	1.00**	0.63**	0.95**
	(0.29)	(0.36)	(0.36)	(0.34)	(0.33)	(0.35)	(0.28)	(0.37)
Air temperature	−0.25**	0.04	0.05	0.06	0.03	0.06	0.03	0.06
	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.12)	(0.09)	(0.11)
Elevation	0.77*	1.32**	0.98*	0.91*	1.48**	1.01*	0.59	0.98*
	(0.43)	(0.57)	(0.52)	(0.54)	(0.65)	(0.57)	(0.50)	(0.59)
Distance to roads	1.35	0.26	0.31	−0.03	0.08	0.09	−0.14	−0.14
	(1.34)	(1.36)	(1.44)	(1.44)	(1.61)	(1.55)	(1.36)	(1.40)
Lagged DV	0.67**	0.63**	0.65**	0.65**	0.61**	0.64**	0.67**	0.65**
	(0.07)	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)	(0.08)	(0.09)
Constant	−9.27	16.56	16.17	16.68	11.12	14.32	−0.97	22.13
	(14.77)	(21.28)	(21.60)	(22.01)	(21.31)	(22.53)	(17.96)	(22.14)
Observations	120	120	120	120	120	120	120	120
R-squared	0.99	0.99	0.99	0.98	0.98	0.98	0.99	0.99

Linear regression with panel-corrected standard errors in parentheses (adjusted for panel-specific AR1 processes). Time period: 2000–2012.
* $p < 0.10$.

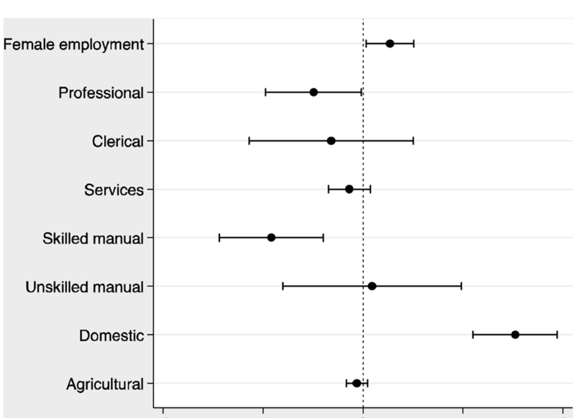


Fig. 5. Marginal Effects of Various Categories of Female Employment on Solid Fuel Use (Based on Model 1 in Table 3).

seven robustness checks. This indicates that, in contrast to Lewis and Pattanayak (2012), we find that greater economic resources resulting from women joining the workforce enable households to increase the amount of solid fuel that they consume. At the same time, only one occupation type is linked to greater solid fuel dependence: i.e., domestic and household jobs. The coefficient on this occupation variable is positive and statistically significant at conventional levels. Two other occupation types – professional and skilled manual occupations – have the opposite (negative) relationship with solid fuel use. Other occupations do not have a statistically significant association with solid fuel dependence. Two explanations are plausible for these associations. First, women in professional and skilled manual jobs may be earning higher wages and, hence, they may be in a better position to pay for cleaner fuel alternatives, while domestic and household workers are in the opposite situation. Second, professional and skilled manual occupations, on the one hand, and domestic and household occupations, on the other hand, may expose women to different types of social networks. In the former case, more educated and better paid women may learn about benefits of cleaner cooking fuels and opt to switch to gas or electricity. In the latter case, less educated and poorly paid women may

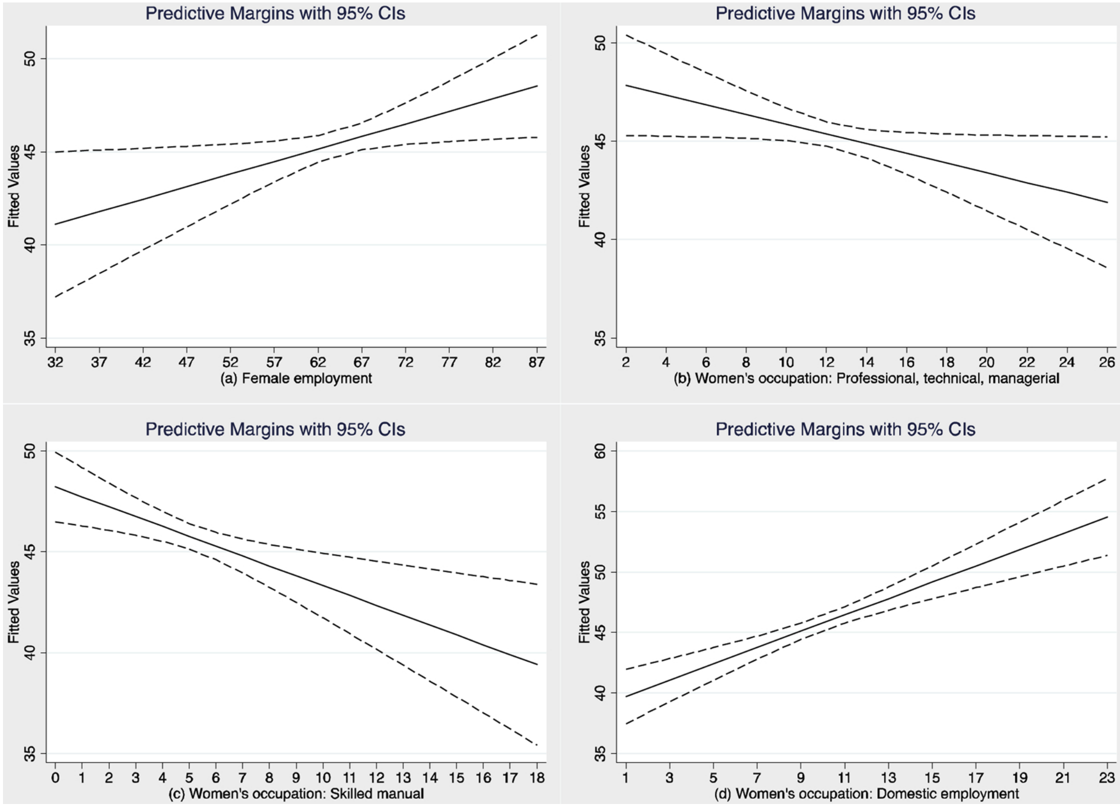


Fig. 6. Marginal Effects of Female Employment, and Occupations in Services, Skilled Manual and Domestic Categories on Solid Fuel Use (Based on Model 1 in Table 3).

Table 4
Summary Statistics for Female Occupation Variables.

Variable	Mean	SD	Min	Max
Female employment	61.7	10.2	32.2	89
Professional employment	12.0	5.1	2.4	25.9
Clerical employment	4.8	2.8	.5	14.8
Services employment	30.0	10.3	6	55.1
Skilled manual employment	5.0	3.3	0	18.3
Unskilled manual employment	2.4	3.2	0	26.4
Domestic employment	10.2	4.4	1.6	24
Agricultural employment	28.1	19.5	.1	75.6

be reinforcing each other's ideas about traditional methods of cooking and, hence, may be using any additional income to purchase more solid fuel, rather than cleaner alternatives.

We plot marginal effects based on results in Model 1 of Table 3. First, Fig. 5 shows which occupations have statistically significant links to solid fuel dependence. Next, Fig. 6 illustrates the magnitude of identified effects. For regions with low levels of female employment, such as La Libertad with the rate of just 39.5% in 2012, the predicted value of solid fuel dependence is 42.1 percent. However, in regions where female employment reaches high levels, such as Puno in 2012 (85.5% of women had jobs), predicted solid fuel consumption goes up to 48.3 percent (Fig. 6 panel *a*). Employment in domestic and household jobs (panel *d*) has an even stronger association with solid fuel dependence: when we change values of the domestic occupation variable from its minimum (1.6) to its maximum (24), predicted solid fuel use rises from 39.4 to 56.5 percent, all else being fixed at the mean. The opposite relationship emerges for professional (panel *b*) and skilled manual occupations (panel *c*). When we change these variables from their minimum values to their maximum values, the corresponding decline in predicted solid fuel use equals 5.8 and 8.4% points, respectively. As Table 4, which summarizes female occupation variables, shows, professional employment is the third largest employment category in Peruvian regions, providing jobs to 12 percent of working women, on average. Domestic employment is the fourth category, which accounts for 10% of employed women across various regions, on average. Two largest occupational groups, i.e., services and agriculture, do not appear to have any significant links to solid fuel use patterns.

How are male occupations correlated with solid fuel use? The DHS dataset provides information on various types of male occupations in Peru for one year only (1996); hence, we are limited in our ability to analyze the relationship between male occupations and solid fuel use. However, we can tabulate summary statistics and calculate bivariate correlation coefficients to understand how different (or similar) male and female occupation patterns are. We are specifically interested in one category, which is positively and significantly associated with increased solid fuel use in Table 3 – i.e., domestic employment. Table 5 shows that this is the least popular occupation for men. Therefore, male occupations tend to be in areas that either have no association with solid fuel use in Table 3, or have a negative association. These results certainly do not constitute a formal test; nevertheless, they indicate that male occupation types may not be strongly correlated with solid fuel

Table 5
Comparison of Male and Female Occupations (in 1996).

	Mean for women	Mean for men	Male/female bivariate correlation (significance level)
Professional	12.30	13.00	0.19 (0.33)
Clerical	6.59	4.41	0.63 (0.00)
Services	33.84	12.48	0.56 (0.00)
Skilled manual	0.54	7.01	0.22 (0.26)
Unskilled manual	8.42	24.36	−0.06 (0.78)
Domestic	11.40	1.95	0.33 (0.08)
Agricultural	26.65	36.38	0.80 (0.00)

Fig. 7. Indigenous Population Share by Region (Peru 2017).

dependence.

5.2. The role of indigenous population

The final set of results focuses on links between the size of a region's indigenous population and solid fuel use in the region. We obtained data from Peru's 2017 Census, which asked individuals to identify themselves based on "their customs and their ancestors." For each region we add up the numbers for the general categories available in the Census (e.g., Native or indigenous to the Amazon), as well as specific groups (e.g., Quechua). Fig. 7 demonstrates regional variation in indigenous population. We construct a continuous variable, *Indigenous population*, to represent the share of a region's population, which belongs to one of indigenous groups. The mean of the variable is 33, which is close to the value for the region of Ancash (34), with the minimum of 2 (Tumbes), and the maximum of 91 (Puno).

The size of indigenous population is highly correlated with several explanatory variables already included in our models. Specifically, indigenous groups tend to be more highly concentrated away from coastal regions, and in areas with higher elevation and lower average annual temperatures. In addition, regions with larger indigenous populations tend to be more rural and have lower rates of female literacy and higher rates of female employment. Table A1 in Appendix A summarizes this information.

Three models reported in Table 6 investigate the relationship between indigenous population and solid fuel dependence. We first estimate a bivariate linear model (Model 1), which suggests that there is a positive and significant association between the two variables. In Model 2, the coefficient on the indigenous population variable becomes smaller, but remains positive and statistically significant (although the level of significance is .1 in this case) if we control for all other regressors included in Model 3 in Table 2. Finally, we add *Indigenous population²* to our specification in Model 3. This new variable has a positive and statistically significant coefficient; however, the coefficient on the indigenous population variable itself loses its significance.

Table 6
Models of Solid Cooking Fuel Use in Peru (Controlling for *Indigenous Population*).

	Model 1	Model 2	Model 3
	(bivariate)	(multivariate)	(non-linear)
Indigenous population	0.38**	0.06*	−0.10
	(0.02)	(0.03)	(0.07)
Indigenous population²			0.00**
			(0.00)
Coastal		3.46**	3.88**
		(1.55)	(1.85)
Capital		−6.52**	−5.85**
		(2.19)	(2.04)
Forest cover		0.91**	0.88**
		(0.25)	(0.26)
Air temperature		0.10	0.20**
		(0.09)	(0.09)
Elevation		0.73	2.43**
		(0.69)	(0.62)
Distance to roads		−0.41	1.03
		(1.11)	(1.17)
Regional population		0.91**	0.37
		(0.44)	(0.42)
Rural population		0.17**	0.15**
		(0.06)	(0.05)
Female literacy		−0.20*	−0.27**
		(0.10)	(0.13)
Female employment		0.02	0.01
		(0.06)	(0.06)
Electricity access		−0.15**	−0.13*
		(0.07)	(0.07)
Mobile access		−0.03	−0.04**
		(0.02)	(0.02)
Poverty		0.07*	0.08**
		(0.04)	(0.04)
Solid fuel use (lagged)		0.62**	0.59**
		(0.07)	(0.08)
Constant	40.60**	15.75	12.67
	(2.76)	(17.04)	(17.07)
Observations	168	144	144
R-squared	0.96	0.99	0.99

Linear regression with panel-corrected standard errors in parentheses (adjusted for panel-specific AR1 processes). Time period: 2000–2012.
* $p < 0.10$.
** $p < 0.05$.

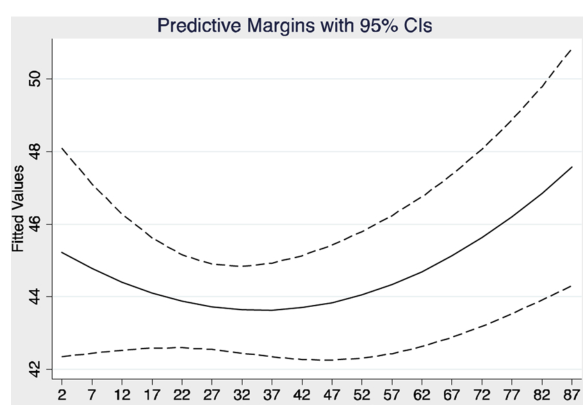


Fig. 8. Marginal Effects of Indigenous Population on Solid Fuel Use (Based on Model 3 in Table 6).

To visualize the shape of the relationship between indigenous population and solid fuel, we create a marginal effects plot. Fig. 8 shows that, there is essentially no change in solid fuel consumption as the size of indigenous population rises from the lowest levels to roughly a third of regional population. However, for higher values of indigenous population, there is a positive link between the share of indigenous population and solid fuel dependence. In our dataset, we find that in regions with large indigenous groups, such as Huancavelica or Cusco, the average value of the solid fuel use variable is 73.8, whereas in regions where indigenous population is less than half of total regional population have the average value of 38.3 percent. Of course, due to high correlation between the size of indigenous groups and other variables in our models, these averages are very noisy. Once we control for other variables, our predicted solid fuel use values are more revealing. Specifically, we find that, when indigenous population is 40% of the total, predicted solid fuel dependence equals 43.7%. In contrast, in regions with 90% of indigenous population, the predicted solid fuel use value is 48%. This difference cannot be explained by poverty, geographic characteristics or any other variables included in our models; therefore, we can link it to the relative size of indigenous groups.

6. Conclusions

Our study shows that a combination of external and household factors explains the variation in solid fuel use across a country. In other words, infrastructure development and access alone do not offer a complete explanation; neither do socioeconomic factors. Furthermore, our results highlight the fact that LMICs are not internally homogeneous in terms of their natural environment, infrastructure, and population. Therefore, region-level studies are critical for stakeholders interested in promoting sustainable changes in households' energy choices.

To analyze households' dependence on solid cooking fuels, we focus on Peru given its overall decrease in solid fuel use over time, and significant cross-regional variation in solid fuel dependence. Our results show that energy price/affordability and access are important but the type of female employment is an interesting factor. Women employed as domestic workers increase solid fuel consumption. Similarly, indigenous groups opt for solid fuel use for reasons other than poverty, climate, or literacy. Socialization and culture are plausible drivers of these relationships. Our study supports Rosenthal et al. (2017) in stating that the context (household and the external environment) needs to be understood to identify and deploy sustainable practices. Specifically, efforts to reduce solid fuel dependence should expand to include women and indigenous people in some areas.

One direction of future research needs to consider the incremental nature of fuel transitions: existing studies show that growing income levels do not result in immediate fuel transitions. Instead, households use increasing incomes to expand the range of fuels they use, which is known as fuel stacking (IEA, 2006): newer energy sources (such as electricity) are limited to specific tasks (e.g., heating water), while energy-consuming activities (such as cooking) still depend on traditional fuels. Therefore, more research is necessary to capture the slow-moving nature of solid fuel transitions and assess how much cooking contributes to fuel stacking.

From the standpoint of studying fuel transition and adopting policies to promote cleaner fuels, our study provides a cautionary note. Aggregatecountry-level information can disguise significant within-country differences. In the case of Peru, some regions, such as Lima, Ica and Tumbes, have mostly moved away from solid fuels: in this aspect, they are comparable to Europe, and their populations benefit from less household air pollution as a result. In contrast, other Peruvian regions resemble Sub-Saharan Africa: Apurimac, Cajamarca and Huancavelica depend heavily on solid fuels, and the air pollution problem is most severe for these regions' residents. Therefore, national and international efforts to promote cleaner fuels need to identify regions with the highest solid fuel dependence rates and target these regions with clean energy programs to have the greatest environmental and health impact.

Appendix A

Table A1
Correlation Matrix for Indigenous Population Share and Other Regressors.

Variable	Bivariate correlation coefficient (p-value)
Coastal	−.46*
	(.03)
Capital	−.13
	(.56)
Forest cover	.18
	(.39)
Air temperature	−.47*
	(.02)
Elevation	.77*
	(.00)
Distance to roads	−.02
	(.92)
Regional population	−.19
	(.37)
Rural population	.49*
	(.01)
Female literacy	−.57*
	(.00)
Female employment	.78*
	(.00)
Electricity access	−.23
	(.29)
Mobile access	−.33
	(.12)
Poverty	.39
	(.06)

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