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Sajid M. Chaudhry, Muhammad Shafiullah

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Does culture affect energy poverty? Evidence from a cross-country analysis

Sajid M. Chaudhry[1], Muhammad Shafiullah[2,*]
[1]Economics, Finance & Entrepreneurship Group, Aston Business School, Aston University, United Kingdom
Email: s.m.chaudhry@outlook.com
[2]School of Economics, University of Nottingham, Malaysia, Jalan Broga, 43500 Semenyih, Selangor, Malaysia
Email: Muhammad.Shafiullah@nottingham.edu.my

Abstract

We investigate the impact of cultural dimension on energy poverty—a topic hitherto overlooked in the literature—employing panel fixed effects, logistic, and heteroskedasticity identified endogenous variable regression estimators. The panel framework incorporates 103 countries over a period of 1971-2018. Using five different proxies representing the cultural dimensions and other demographic and macroeconomic control variables, the empirical analyses reveal that power distance and masculinity (as opposed to femininity) worsen the conditions of energy poverty while individualism (as opposed to collectivism) and long/short-term orientation (i.e., pragmatism vs. traditionalism/conservatism) tend to lessen the probability of energy deprivation. We find the effect of uncertainty avoidance on energy poverty ambiguous. Our research findings have profound policy implications in reducing not just energy poverty but also eradicating poverty in general. In light of our results, we suggest policy reforms and global initiatives that are gender sensitive, incorporate the multidimensional impact of culture on national behavior particularly aiming at reversing the cultural acceptance of a higher degree of unequally distributed power, and create a more inclusive society with pragmatism, leading to the achievement of the sustainable development goals of the 2030 Agenda.

Keywords: Energy poverty; energy poor; culture; cultural dimensions.
JEL Classifications: Q4; A13; Z1.

1 Introduction

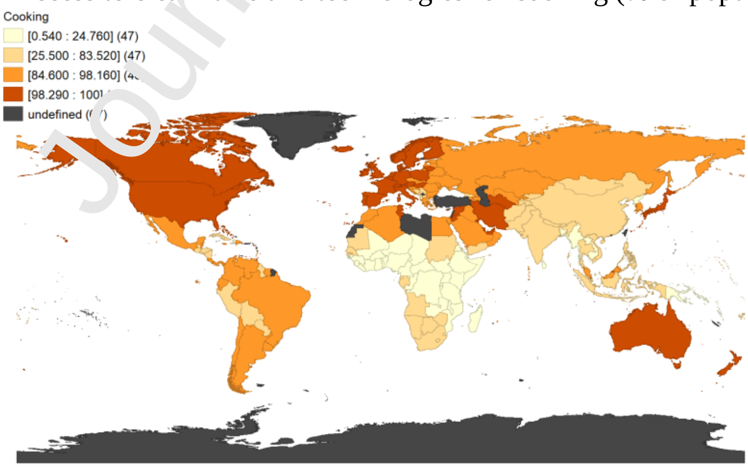
Recently energy poverty has gained importance on academic, political and policy makers' agenda because of climate change and rising energy prices. However, among the major three transformations namely energy security, climate change and energy poverty, energy poverty has been given the least attention (Gonzalez-Eguino, 2015). Furthermore, energy poverty is not only a developing country issue but also a serious concern in developed countries. Bonatz et al. (2019, p. 817), for instance, argue that "[e]nergy poverty in developing countries is primarily a problem of

* Corresponding author.

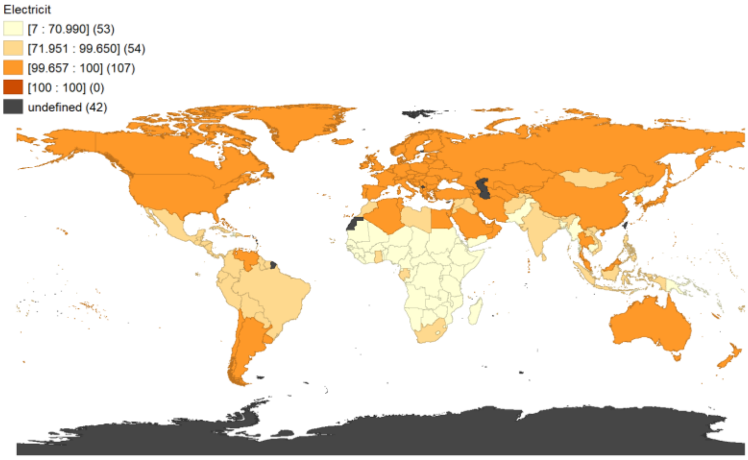
adequate physical access to clean and modern energy; whereas energy poverty in developed countries is an issue of affordability and energy efficiency.” To provide a snapshot of the extent of the problem of energy poverty globally, around 770 million people in 2019 and more than 2.6 billion people in 2018 lacked access to electricity and clean cooking facilities, respectively (IEA, 2020a).

The condition is more acute in developing countries with the three most deprived regions across developing countries: South Asia, sub-Saharan Africa, and East Asia. For example, according to IEA (2020a) around 580 million people in the sub-Saharan Africa lacked access to electricity in 2019 and only 17% of the population had clean cooking access in 2018, with the numbers expected to rise in 2020 due to the COVID-19 pandemic, “reversing several years of progress” (IEA, 2020b) in the region in terms of reducing energy poverty. Figure 1 shows the global energy (poverty) landscape for 2014—the latest year which contains the greatest number of observations for all three energy indicators—access to clean fuels and technologies for cooking (% of population), access to electricity (% of population), and energy use (kg of oil equivalent to per capita). Across all indicators, the condition of energy poverty is more severe in developing countries as noted above.

(a) Access to clean fuels and technologies for cooking (% of population)



(b) Access to electricity (% of population)



(c) Energy use (kg of oil equivalent per capita)

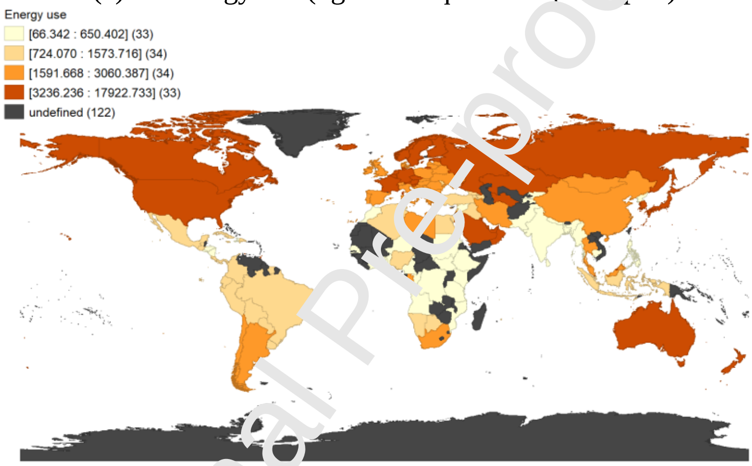


Figure 1: Global energy (poverty) landscape, 2014

Source: World Bank (2020).

The role of cultural dimensions has been studied as an important determinant of a range of issues within the topics in economics.[†] However, not much attention has been paid to culture as a determinant of energy poverty – a lack of access to modern energy services, for instance, failure of households to access electricity or clean cooking facilities[‡]. Although the main determinants of energy poverty are said to be energy efficiency, income, and energy prices (see, for example, Boardman, 2010; Heindl & Schuessler, 2015; Hills, 2011; Okushima, 2017; Thomson et al., 2017b),

[†] See, for example, Gorodnichenko & Roland (2011), Giannetti & Yafeh, (2012), Klasing (2013), Kleimeier & Chaudhry (2015).

[‡] A comprehensive definition of energy poverty is provided by Reddy (2000) which defines it as “the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development.”

it can be caused by a complex combination of factors including different aspects of cultural dimensions. González-Eguino (2015) points out that development aid projects may fail to provide better and adequate access to energy services if they simply try to replicate the use of the same technologies in different locations without considering the cultural features of each area and community.

Churchill & Smyth (2020) argue that in a multicultural society, as in Australia, the negative effects of ethnic diversity on energy poverty function through social institutions such as trust and therefore relevant policies are required to foster social capital and trust, ensuring social inclusion, to lessen the adverse effects of ethnic diversity. They show that trust is the channel through which ethnic diversity acts as an important determinant of energy poverty. In short, the significance of energy poverty in affecting human and economic development is now widely acknowledged and axiomatic in the literature. This article contributes to the related literature on the determinants of energy poverty by investigating the impact of cultural dimension. To the best of our knowledge, we are the first to study cultural dimensions as determinants of energy poverty and as such answer the following question: Does culture affect energy poverty?

The importance of culture in economics can be recognized by the fact that the Noble Laureate Douglass North (North, 2005) terms culture as an economic outcome and Greif (2006) argues that it is culture that differentiates two societies with similar policies but with different levels of investment. In our study, we use Hofstede's (2001) cultural dimensions of Power Distance, Individualism, Uncertainty Avoidance, Masculinity, and Long-Term Orientation[§], as these are considered to be having the most influence than any other measures of cultural dimensions because of their uniqueness in terms of "clarity, parsimony and resonance" (Smith et al., 2002; Kirkman et al., 2006; Tang & Koveos, 2008).

[§] The sixth cultural dimension of Indulgence is not included because of lack of data.

Our findings are novel and interesting. Using annual data from an unbalanced panel of 103 countries over a period from 1971 to 2018, we find that the power distance and masculinity (as opposed to femininity) deteriorate the conditions of energy poverty. On the other hand, individualism (as opposed to collectivism) and long/short-term orientation (i.e., pragmatism vs. traditionalism/conservatism) tend to have a positive effect on the probability of energy deprivation. The effect of uncertainty avoidance on energy poverty remains ambiguous according to our findings.

The novelty of this article is twofold. First, to the best of our knowledge, our investigation is the first to study the impact of cultural dimensions on energy poverty. Current study relates to Churchill & Smyth (2020) and Churchill (2020) who study cultural and social dimension such as trust and ethnic diversity. Churchill & Smyth (2020) show positive association between ethnic diversity and energy poverty and Churchill (2020) shows a positive relationship between ethnic diversity and transport poverty. These studies argue that trust is the channel through which ethnic diversity influences energy poverty. Our study differs from these studies as we use direct measures of culture such as Power Distance, Individualism, Uncertainty Avoidance, Masculinity, and Long/Short-term Orientation developed by Hofstede (2001). With the use of these cultural dimensions, our article provides a comprehensive empirical analysis on the effects of culture on energy poverty. Second, we use a relatively large dataset incorporating both developed and developing countries, hence, we provide global evidence on the impact of culture on energy poverty. Our research findings are robust to different specification, methodology and endogeneity, and have profound policy implications in terms of not just reducing energy poverty but also poverty in general, helping countries target policy reforms in order to achieve the Sustainable Development Goals—SDG 1 and 7 in particular—of the 2030 Agenda.

The rest of the article is structured as the following: Section 2 describes the mechanisms by which culture affects energy poverty and presents a review of the related literature, Section 3 explains the empirical model used for estimations, and describes the data and other methodologies used, Section 4 reports and discusses the empirical results, and finally, Section 5 provides a discussion of policy implications and concluding remarks.

2 Literature Review

2.1 Mechanism of Cultural Influence

An emerging body of literature identifies national culture, generally Hofstede's (2001) measures of cultural dimensions, as having a considerable influence on both the national- and individual/household/firm-levels decision-making processes regarding debt-financing, equity, cash holding, risk taking, education & economic outcomes, climate change & action/mitigation, environmental performance & sustainability, etc. (e.g., Husted, 2005; Peng & Lin, 2009; Ciocirlan & Pettersson, 2012; Fan et al., 2012; Arosa et al., 2014; Li et al., 2013; Chen et al., 2015; Haq et al., 2018; Shao et al., 2021, inter alia). National culture affects social contract as well as individual and/or household approach to finance and risk, essential considerations in decisions regarding energy use (deprivation), access to safe and clean energy.

In addition to affecting funding decisions, national cultures have been argued (as well as observed) to shape attitudes, institutions, and policies towards energy and the environment (Husted, 2005; Peng & Lin, 2009; Ciocirlan & Pettersson, 2012; Churchill & Smyth, 2020). We argue that the channel through which the national culture affects energy poverty is attitude and preferences. Specifically, these are the attitude and preferences that shape policy makers' mindset to lead to a certain policy set. We explain below the mechanism of each cultural dimension and its expected impact on energy poverty.

Power distance accounts for the extent of hierarchy and concentration of power and wealth in society. Societies with a higher level of power distance exhibit stratification and inequality as well as reduced social trust. Reduced social trust is prohibitive in securing (long-term) funding/loans from financial institutions as transaction costs rise (Aggarwal & Goodell, 2009; Haq et al., 2018; Churchill

& Smyth, 2020). As such, greater power distance within a national culture limits the individual's/firm's/household's ability to obtain funds for consumption and/or investment. A culture with greater power distance also exhibits greater internal power struggles and lower level of education, which provide less scope for debate and evidence-based policy making on public goods (and bads) (Husted, 2005; Peng & Lin, 2009). These, in turn, are expected to lower the individual, household, and/or national energy consumption possibility and access to improved energy technologies. Power distance is, thus, expected *a priori* to aggravate energy poverty situation in a national economy.

The prevalence of uncertainty avoidance manifests in residents' aversion to ambiguity or risk in economic, social, and political interactions. A higher level of uncertainty avoidance also results in more short-term focus—with agents holding more cash, short-term debt (as opposed to long-term debt), and lower personal debt (Zheng et al., 2012; Arosa et al., 2014). These are expected to affect individual and household ability to finance energy consumption and/or access to technology. However, the short-term emphasis in decision making may involve a tradeoff in energy consumption and access. While energy consumption may be boosted by short-term decision-making, its long-term prospect is likely to stagnate due to avoidance of uncertainty and costs/risks associated with investment for the unknown future: such as constructing new energy power plants, committing to alternative/clean energy sources, etc.

Moreover, national cultures with a greater tendency to avoid uncertainty are prone to maintaining the status quo while discouraging citizen empowerment and public discourse. This eventuates in limiting institutional capacity to formulate appropriate and timely policies, which reflect the will of the people regarding energy and environmental concerns (Husted, 2005). This short- and long-term tradeoff as well as weakened institutional capacity in uncertainty avoidance render an ambiguous *a priori* effect on energy poverty.

Individualistic cultures emphasize the individual's as well as their immediate family's welfare, freedom, and achievement as opposed to that of the tightly knit 'ingroup' in collectivist ones (Li et al., 2013). Residents in individualistic national cultures are generally more self-confident and [overly-] optimistic about the future (Van den Steen, 2004; Haq et al., 2018). Consequently, individuals from such cultures tend to downplay risks—especially in relation to borrowing and opting for debt over equity. This means that individualistic societies will favor maximizing individual welfare by financing and/or improving energy consumption as well as uptake of newer, and perhaps, riskier alternative energy sources. This is indeed observed empirically as societal prevalence of individualism (vs. collectivism) fosters greater acceptance of alternative sources of energy such as nuclear power and renewables (Xia et al., 2019; Ang et al., 2020).

Individual merit is also valued more in such cultures, which encourage greater human capital accumulation (Peng & Lin, 2009). Moreover, individualistic national cultures enable the individual to voice their opinions—fostering a diverse array of interest-group initiatives, including that relating to energy and environmental matters (Husted, 2005). An informed and vocal population is more capable of influencing institutions and policy to respond to issues concerning them. Thus, an individualistic country is likely to exhibit lower levels of energy poverty than their collectivist counterparts, *a priori*.

Masculine national cultures concentrate on achievement, heroism, assertiveness, and material rewards for success (attributes that are considered masculine) as opposed to cooperation, modesty, caring for the weak, and quality of life (relationship-oriented attributes that are considered feminine). To put it simply, masculine cultures are 'tough' whereas feminine ones are 'tender' (Hofstede Insights, 2020). In essence, the prominence of masculinity in the household, as well as nationally, hampers funding decisions regarding energy use and access to clean cooking technologies that disproportionately affect the quality of life its weak members (especially women and girls)—see for example, Pachauri & Rao (2013), Sadath & Acharya (2017), etc. Empirical observation—such as

Pachauri & Spreng (2011, p. 7502)—finds that with greater gender equality, the [predominantly male] household head is less enthusiastic about any energy decision that alleviates female household members' suffering.

In addition, Hofstede (2001) and Husted (2005) argue that institutions in masculinity dominated economies incentivize material goals (e.g., economic growth) rather than quality of life improvements (e.g., adoption of clean energy, environmental sustainability, etc.). A greater reign of masculinity also disincentivizes educational outcomes, especially for females (Peng & Lin, 2009). As such, more masculine national cultures are expected *a priori* to exacerbate energy deprivation.

Finally, societies with a long-term orientation tend to emphasize a protracted outlook and the importance of adapting to present and future challenges (Arosa et al., 2014). Such national cultures incentivize actions that are more 'pragmatic' (i.e., involving thrift, hard work, and persistence) rather than opportunistic or myopic actions (that may be traditional or conservative) (Zheng et al., 2012; Hofstede & Minkov, 2010; Hofstede Insights, 2020). The financial economics literature observes managers from such national cultures tend to pursue on long term survival of their firm and avoid short term borrowing (Haq et al., 2018). Institutions in long-term oriented societies incentivize 'learning, honesty, adaptiveness, accountability, and self-discipline' and on practicality rather than ideology.

There is also greater preference for environmental sustainability/climate action by authorities and residents from these cultures (Hofstede & Minkov, 2010). These have implications for energy usage for individual/household/firm as alleviating energy deprivation requires reallocation of resources—such as incurring long-term debt and other risks associated with new energy sources, patience/perseverance, and adaptation of long-held institutions, policies, and behaviors to improve energy and environmental sustainability (Denton et al., 2003). Like that of uncertainty avoidance, considerable tradeoffs between short- and long-term costs and benefits are expected regarding the tradeoffs between pragmatism and traditionalism/conservatism when solving energy deprivation problems.

2.2 Energy Poverty

There is abundant literature on energy poverty and one of the challenges that researchers face is how to define energy poverty. Generally, it has been defined as the intersection of energy efficiency, income, and energy prices. However, the crux of the matter lies in the affordability of energy (Boardman, 2010; Thomson et al., 2016; Thomson et al., 2017b). In addressing the debates on the definitions, driving forces and extent of domestic energy deprivation across developed and developing countries, Bouzarovski & Petrova (2015) argue in favor of taking an approach which requires understanding of both energy services and energy vulnerability factors, thus helping policy makers to focus on the geographic aspects of domestic energy deprivation. The authors point out that the inability to have adequate energy services is a key problem instead of fuel, energy efficiency, and affordability—the issues most scientific and policy discussions pay attention to.

Energy poverty is said to have implications for social wellbeing (Biermann, 2016; Churchill et al., 2020) health and productivity (Gonzalez-Eguino, 2015; Thomson et al., 2017b; Rodriguez-Alvarez et al., 2019), environment (Reddy, 2000; Gonzalez-Eguino, 2015; Sovacool, 2012), and the economic development (Sachs & Waner, 2001; Gonzalez-Eguino, 2015). Similarly, the importance of ethnic diversity and culture associated with ethnic groups in explaining economic productivity, various dimensions of poverty, and other socioeconomic drawbacks is well recognized in the literature. For example, Akay et al. (2017), Alesina et al. (1999), Alesina et al. (2003), Churchill, (2017), Churchill & Laryea (2019), Dincer (2011), Easterly & Levine (1997) study the impact of ethnic diversity on social, economic, and political outcomes. Ottaviano & Peri (2006) note a net positive effect of cultural diversity on the productivity of natives of the United States. The study reveals that U.S.-born citizens living in 160 metropolitan areas where the share of foreign-born increased between 1970 and 1990, experienced a significant increase in their wages and in the rental price of their housing.

More specifically in relation to our investigation, Churchill & Smyth (2020) examine the impact of ethnic diversity on household energy poverty in Australia—a major immigrant receiving country in the world. Their findings suggest that ethnic diversity is positively associated with energy poverty with one standard deviation increase in ethnic diversity associated with around 0.103-0.422 standard deviation increase in energy poverty, depending on how energy poverty is measured. The authors argue that trust is an important channel through which ethnic diversity operates to influence energy poverty, since ethnic diversity diminishes trust leading to social frictions and ultimately having an adverse effect on energy poverty. In a similar vein, Churchill (2020) looks into ethnic diversity as a determinant of transport poverty in Australia using same dataset and research method to draw a similar conclusion that trust is an influencing factor through which ethnic diversity has an adverse effect on transport poverty. Similarly, Disli et al. (2016) reveals the existence of the Environmental Kuznets Curve (EKC) and shows that culture significantly affects the income-emission relationship. Based on the findings of the effects of the six cultural dimensions on EKC, the study draws two sets of conclusions: (i) masculinity, power distance and indulgence move the EKC upward and shift the income turning point to the left; and (ii) individualism, uncertainty, and long-term orientation move the EKC downward while shifting the income turning point to the right.

Taken together, the above discussion shows that incorporating the cultural dimensions into research related to poverty and development help provide new insights that help understand various issues for instance the difference in energy policies between the developed and developing countries, and provide new reference and guidance for future policymaking.

3 Data, Model and Methodology

3.1 Data

In this study, we use a global dataset of 103 countries over a period starting from 1971 to 2018. We use two sources to collect our data: the data for calculation of energy poverty and other explanatory variables are collected from the World Bank Databank[**] and the data on culture measures are collected from Geert Hofstede's website.[††] Table 1 provides the summary statistics of the variables implemented in the empirical analysis. Among the energy poverty indicator variables, $Enpov1$ has the greatest number of observations, followed by $Enpov3$ and $Enpov2$. The standard deviation of $Enpov1$ in contrast to its mean is substantially higher than for the other two energy poverty measures. Within the cultural dimensions, Long/Short-term Orientation has the lowest number of observations while the remaining four have the same number of observations. The ratio of standard deviation to the respective mean would be highest for Individualism (vs. Collectivism) and lowest for Power Distance. This indicates that the variation of cultural dimensions across countries is relatively low. Considering the rest of the control variables, Consumer price index, Current account balance, and Research and development expenditure have coefficient of variation higher than 100% while the other variables have relatively low values of the latter. These variables are generally in percentages—except for Log of GDP per capita—and fluctuate between 0 and 100—except for Current account balance and Manufacturing, value added. This indicates that the control variables vary moderately, except for the abovementioned. In **Error! Reference source not found.** (**Error! Reference source not found.**), we provide a list of countries together with their number of observations and mean of the variables used in our study. We can see variation across countries but our core variables of interest Power Distance, Uncertainty Avoidance, Individualism (vs. Collectivism) and Masculinity (vs. Femininity) are available for the whole data period (1971-2018) for more than 75% of the countries.

[**] https://databank.worldbank.org/source/world-development-indicators
[††] https://geerthofstede.com/research-and-vsm/dimension-data-matrix/

Table 1: Summary statistics

Variable	No. of observations (1)	Mean (2)	Standard deviation (3)	Minimum (4)	Maximum (5)
Enpov1	3,976	0.241	0.428	0	1
Enpov2	1,700	0.424	0.494	0	1
Enpov3	2,579	0.469	0.499	0	1
Age dependency ratio, old	4,450	12.79	7.487	3.004	46.17
Consumer price index	3,957	63.76	61.779	0	2740
Current account balance	3,538	-2.24	6.877	-49.65	4E+01
Log of GDP per capita	4,250	8.556	1.481	5.101	11.63
Labor force participation rate	2,930	68.58	9.482	41.53	91.50
Manufacturing, value added	3,481	15.67	8.984	0	192.00
Research and development expenditure	1,519	1.027	0.948	0.005	4.95
Power Distance	4,354	63.32	20.658	11	104
Uncertainty Avoidance	4,354	63.66	23.088	8	112
Individualism (vs. Collectivism)	4,354	38.42	22.151	6	91
Masculinity (vs. Femininity)	4,354	48.10	19.069	5	110
Long/Short-term Orientation	3,922	43.38	21.764	7	87.91

Hofstede is the originator of computing cultural dimensions based on the cultural attitude held by people and created four cultural dimensions consisting of Power Distance, Individualism, Uncertainty Avoidance, and Masculinity in 1980 (Hofstede, 1980). This exercise was based on employee surveys collected at IBM offices in 50 countries between 1967 and 1973. The author later included Long Term Orientation and Indulgence as the fifth and sixth dimensions using the World Value Surveys (Hofstede et al., 2010). Hofstede's framework of cultural dimensions is the most popular and commands the most influence in business and economics research (Tang & Koveos, 2008).

The cultural dimensions' proxies implemented in our study are that of the Six Dimensions (6D) Model by Geert Hofstede (Hofstede Insights, 2020). The 6D Model measures national culture using six measures: Power Distance Index, Individualism vs. Collectivism, Masculinity vs. Femininity, Uncertainty Avoidance Index, Long Term Orientation vs. Short Term Normative Orientation, and Indulgence vs. Restraint. In our empirical analysis, we avail the first five measures of cultural dimensions and overlook the sixth one—Indulgence vs. Restraint—due to lack of sufficient data. The five cultural dimensions are included together in the empirical estimation equation(s). We then follow the prior literature—e.g., Zheng et al. (2012), Arosa et al. (2014), Kanagaretnam et al. (2014), Haq et al. (2018), inter alia—and substitute each of the above five Hofstede cultural dimensions into model equation (4) individually (see Sections 3.4 and 4.1 for details).

The Power Distance Index of Hofstede indicates the magnitude of unequal power distribution with higher respect for rank within a national culture. The higher number shows greater unequal power distribution. For example, Australia has a mean Power Distance Index of 38 over 1971-2018 data period compared to Albania that has a mean Power Distance Index of 90 over 1971-2018 data period as can be seen from **Error! Reference source not found.** in **Error! Reference source not found.**. This means that there is a very high acceptability of inequality and power differences in Albania compared to Australia. If Australia moves from 38 to 39, this will signify that Australian culture acceptance for unequal power distribution has increased. Power Distance is expected to aggravate energy poverty as higher inequality in distribution of power in the culture will adversely affect distribution of resources including energy.

Individualism vs. Collectivism measures the cultural focus on the welfare of the individual and their immediate family in contrast to collective welfare of tightly knit 'ingroup'. A higher value of this dimension highlights the cultural preference for the individual vis-à-vis the 'ingroup'. Going with our example of Australia and Albania, the mean value of Australia is 90 compared to only 20 in case of Albania indicating that Australian culture is much more individualistic compared to Albania.

The Masculinity vs. Femininity dimension records the culture's inclination towards masculine traits—i.e., achievement, heroism, assertiveness, and material rewards for success—versus feminine traits—i.e., cooperation, modesty, caring for the weak, and quality of life. This is often colloquially referred to as "tough versus tender" cultures (Hofstede Insights, 2020). A higher value in the Masculinity vs. Femininity dimension signifies a lower emphasis on cooperation, caring for the weak, and quality of life, which in turn is expected to worsen deprivation of energy resources.

Australia has a mean value of 61 compared to a mean value of 80 for Albania for Masculinity vs. Femininity indicating that Albanian culture is more inclined towards achievement, heroism, assertiveness and material rewards for success compared to Albania.

Uncertainty Avoidance Index denotes the cultural aversion to uncertainty or risk. A higher value of this dimension indicates a higher degree of rigidity of behavior and beliefs and neophobia. Continuing with our selected countries of Australia and Albania, we can see from **Error! Reference source not found.** (**Error! Reference source not found.**) that the mean value of Uncertainty Avoidance is 51 in case of Australia and 70 in case of Albania. This numbers show that Albanian culture shows higher degree of rigidity of behavior and a one unit decrease in the number will decrease the degree of rigidity of behavior for Albanians. The effect of Uncertainty Avoidance on energy poverty is likely to be mixed as there are long- and short-run tradeoffs. Cultural aversion to short-turn costs/risks—such as adopting new energy production and consumption technologies—may have greater long-run costs/risks regarding deprivation of energy use.

Lastly, the Long Term Orientation vs. Short Term Normative Orientation registers the culture's emphasis on 'long-held traditions' versus 'pragmatic solutions' to tackling the present and future challenges (Hofstede Insights, 2020). A higher value of Long-/Short-term Orientation implies the culture's preference for pragmatism over traditionalism/conservatism. Australia has a mean value of 21.16 compared to a mean value of 61 in case of Albania showing that Albanian culture has greater preference for more pragmatism compared to Australia.

3.2 Measuring Energy Poverty

We define three different proxies for measuring energy poverty that are broadly consistent with the literature in terms of objective and subjective measures (Biermann, 2016; Robinson et al., 2018; Churchill et al., 2020). These proxies are binary (dummy) variables, and we use data from the World Bank (2020) World Development Indicators to generate these indicator variables. The first one—

aptly abbreviated as $Enpov1$—considers countries whose energy consumption, measured in terms of kilograms (kg) of oil equivalent per capita, is in the bottom quartile in a particular year, as illustrated in equation (1).

$$Enpov1 = \begin{cases} 1 \text{ if (Energy use)} \leq 25\text{th percentile} \\ 0 \quad \text{otherwise} \end{cases} \tag{1}$$

This definition is consistent with the argument that the households that have to spend higher proportion of their income because of high relative energy prices are termed as energy poor and this is considered to be an objective way of capturing energy poverty (Thomson et al., 2017a; 2017b; Churchill & Smyth, 2020).

The second measure of energy poverty ($Enpov2$) is based on household access to clean fuels and technologies for cooking as a percentage of the country's population. A particular country is energy poor if the household access to clean fuels and technologies for cooking is below the global median—in terms of percentage of its population—in a given year, and vice-versa (equation 2).

$$Enpov2 = \begin{cases} 1 \text{ if (Access to clean fuels and technologies for cooking)} \leq 50\text{th percentile} \\ 0 \quad \text{otherwise} \end{cases} \tag{2}$$

This measure of energy poverty is based on the absence of a fundamental energy provision in line with Sen (1999) and Reddy (2000) who argue that energy poverty is not about achieving a certain level of energy but rather is the lack of something or lack of choice of something. Acemoglu & Robinson (2012) call lack of access to a fundamental source of energy as a lack of genuine development.

The final energy poverty indicator ($Enpov3$) used in this study is based on a country's access to electricity as a share of its population and defined as equation (3). For a particular year, the country is energy poor if the percentage of its population with access to electricity is lower than the global median.

$$Enpov3 = \begin{cases} 1 \text{ if (Access to electricity)} \leq 50\text{th percentile} \\ 0 \quad \text{otherwise} \end{cases} \tag{3}$$

Similar to second measure of energy poverty, our third measure of energy poverty is motivated by the absence of access for fundamental energy provision but instead of micro household level, we define energy poverty at a broader level. We use a country's access to electricity per capita to see how the country as a whole is doing. We use this definition at the national level because our main determinant of energy poverty is also measured at the national level, i.e., Hofstede's national culture measure.

3.3 Measuring the Control Variables

As for the control variables, the selection is based on the determinants of energy poverty and data availability and includes: Age dependency ratio, old (% of working-age population); Consumer price index (2010 = 100); Current account balance (% of GDP); GDP per capita (constant 2010 US$); Labor force participation rate, total (% of total population ages 15-64); Manufacturing, value added (% of GDP); and Research and development (R&D) expenditure (% of GDP). The above control variables are all sourced from the World Bank (2020) World Development Indicators. The GDP per capita is the only control variable that is not in percentages, and, as such, we take a natural logarithmic transformation to allow for a diminishing marginal effect as well as to stabilize the large variations.

The finalized dataset is an unbalanced panel of 103 countries—the list of which can be found in **Error! Reference source not found.** (**Error! Reference source not found.**)—over a period starting from 1971 to 2018[‡‡]. As explained in the introduction, income, energy efficiency and energy prices are the main determinants of energy poverty (Boardman, 2010; Heindl & Schuessler, 2015; Hills, 2011; Okushima, 2017). Hence, we control for these in our econometric model along-with other control variables used in the literature. We proxy income with GDP per capita as countries with higher GDP per capita are less likely to be energy poor. If the GDP per capita is higher of a country, the country is expected to be energy efficient as households can afford to live in dwellings that are new and are well insulated (Mattioli et al., 2017), therefore, GDP per capita can be used as proxy for energy efficiency as well. We use the broader price indicator, Consumer price index as proxy for energy prices. It captures not only energy prices but also other prices that depend on energy prices.

With regard to other controls, we use Age dependency ratio following Churchill & Smyth (2020). Furthermore, economic growth and population are also considered to be important determinants of energy poverty (see for example, Peng & Lin, 2009; Gonzalez-Eguino, 2015; Husted, 2016). Therefore, we include GDP per capita as a proxy for economic growth and labor force participation rate as proxy for the working population.

3.4 Model and Methodology

We specify a panel fixed effects equation (4) in which energy poverty is a function of cultural dimension(s) and other control variables. Here, the i and t subscripts represent the country and year of the observation, respectively, γ_i represents the country fixed effects, and ε_{it} is the idiosyncratic regression error assumed to be independently and identically distributed (i.i.d.).

[‡‡] For most countries in this sample, data on energy use end in 2014.

$$
\begin{aligned}
(\text{Energy poverty})_{it} &= \beta_0 + \beta_1(\text{Age dependency ratio, old})_{it} \\
&+ \beta_2(\text{Consumer price index})_{it} + \beta_3(\text{Current account balance})_{it} \\
&+ \beta_4(\text{Log of GDP per capita})_{it} + \beta_5(\text{Labor force participation rate})_{it} \\
&+ \beta_6(\text{Manufacturing, value added})_{it} + \beta_7(\text{R\&D expenditure})_{it} \\
&+ \beta_8(\text{Cultural dimension})_{it} + \gamma_i + \varepsilon_{it}
\end{aligned}
\tag{4}
$$

Since the energy poverty proxies (i.e., the dependent variables) are binary and noncontinuous, the estimates of the linear fixed effects equation (4) may be biased. As a result, we opt for a panel logistic regression incorporating fixed effects, in equation (5). The logistic method overcomes the limitations of the fixed effects estimator by identifying a model, which can predict the probability of a binary outcome—i.e., being energy poor or not (Hoffman, 2019). In the logistic regression, the binary outcome is predicted by computing a natural logarithm of the odds ratio—the ratio of the probability of a country being energy poor in a particular year $\big(P(\text{Energy poverty})\big)$ to the probability that it is not $\big(1 - P(\text{Energy poverty})\big)$—or the logit of the binary (or categorical) dependent variable ($Energy\ poverty$): i.e., $\log\left(\frac{P(\text{Energy poverty})}{1-P(\text{Energy poverty})}\right)$. The logit of (Energy poverty) is then modelled on the right hand side variables of model equation (4), generating equation (5), and estimated using maximum likelihood estimation (MLE):

$$
\begin{aligned}
\log\left(\frac{P(\text{Energy poverty})}{1 - P(\text{Energy poverty})}\right)_{it} &= \beta_0 + \beta_1(\text{Age dependency ratio, old})_{it} \\
&+ \beta_2(\text{Consumer price index})_{it} + \beta_3(\text{Current account balance})_{it} \\
&+ \beta_4(\text{Log of GDP per capita})_{it} + \beta_5(\text{Labor force participation rate})_{it} \\
&+ \beta_6(\text{Manufacturing, value added})_{it} + \beta_7(\text{R\&D expenditure})_{it} \\
&+ \beta_8(\text{Cultural dimension})_{it} + \gamma_i + \varepsilon_{it}
\end{aligned}
\tag{5}
$$

The estimated coefficients of equation (5) provide the log-odds of (Energy poverty) with respect to a unit increase in the regressor being considered. The log-odds estimates can be used to compute the marginal effects—which demonstrate the change in probability of the outcome variable (Energy poverty in this case) in response to a unit change in a particular regressor, *ceteris paribus*. The use of MLE in estimating logit regressions is advantageous as it allows the researcher flexibility to incorporate data that is not normal in distribution and samples with dissimilar covariance matrices (DiGangi & Hefner, 2013; Hoffman, 2019).

Countries which with low GDP per capita, labor force participation (including low women's empowerment), etc. are more likely to exhibit greater power distance and masculinity. As a result, the cultural dimensions may be endogenously determined within the model—i.e., correlated with the error term (Ullah et al., 2018). It is important to perform endogeneity tests and implement appropriate estimators for a remedy. The Generalized Method of Moments (GMM) analysis is a useful estimation method that overcomes (dynamic) endogeneity bias in the model estimates for panel data. Conventional endogenous variable regression estimators, such as the two- and three-stage least squares (2SLS and 3SLS) methods, require at least one instrumental variable for the endogenous variable. Identification of appropriate instruments is invariably subject to much debate among researchers—especially in a cross-country context—and a big obstacle in empirical exercises involving endogeneity. The GMM method is advantageous over 2SLS and 3SLS methods as it uses lags of dependent variables as instruments (Ullah et al., 2018).

The Lewbel (2012) method uses heteroskedasticity in the data to identify—a solution initially proposed by Rigobon (2003)—the structural parameters of the model with the endogenous regressor(s). The instruments can be internal—generated from the control variables and lagged dependent variable as in GMM—or external—as identified in 2SLS/3SLS. The Lewbel (2012) approach improves upon GMM and 2SLS by combining the traits of both to derive an efficient estimator that works with multiple endogenous and/or mismeasured regressors. Given the difficulty in identifying an instrumental variable that is correlated with culture and uncorrelated with the error term for all 103 sample countries, we apply the Lewbel (2012) heteroskedasticity identified endogenous variable regression model for a panel framework to equation (4), incorporating only internal instruments. This technique implemented with only internal instruments is known to perform as well as conventional endogenous variable regression estimators with identified external instruments. The Lewbel (2012) estimator has been used in energy poverty analysis by recent literature such as Farrell & Fry (2021), Munyanyi et al. (2021), Zhang et al. (2021), inter alia.

The Lewbel (2012) approach involves, at first, the identification of a linear triangular model:

$$Y_1 = X'\beta_{10} + Y_2\gamma_{10} + \varepsilon_1 \tag{6}$$

$$Y_2 = X'\beta_{20} + \varepsilon_2 \tag{7}$$

here, X is a vector of observed exogeneous regressors, Y_1 is the model regressand, and Y_2 is the endogenous regressor. Identification of this system of equations does not require imposing equality restrictions on β_{10} or the assumption of uncorrelated error terms ε_1 and ε_2. The GMM approach may be used on the triangular model by specifying the vector S containing elements of Y and X, as well as that of Z—which may be equal to X or a subset of it—that X does not already contain. By letting $\mu = E(Z)$ and $\theta = \{\gamma_1, \beta_1, \beta_2, \mu\}$, we can derive the following vector valued functions:

$$\begin{gathered} Q_1(\theta, S) = X(Y_1 - X'\beta_1 - Y_2\gamma_1), \\ Q_2(\theta, S) = X(Y_2 - X'\beta_2), \\ Q_3(\theta, S) = Z - \mu, \\ Q_4(\theta, S) = (Z - \mu)(Y_1 - X'\beta_1 - Y_2\gamma_1) \times (Y_2 - X'\beta_2) \end{gathered} \tag{8}$$

The four vectors of equation (8) are stacked into one long vector to arrive at $Q(\theta, S)$. Considering $S = \{S_1, \dots, S_n\}$ for n as the number of observations, a regular Hansen (1982) GMM estimator can be identified as,

$$\hat{\theta} = \arg\min_{\theta\in\Theta} \sum_{i=1}^{n} Q(\theta, S_i)'\Omega_n^{-1} \sum_{i=1}^{n} Q(\theta, S_i) \tag{9}$$

where Ω_n is a positive definite sequence. Estimation of β_{20} using linear regression equation (7) yields the residuals $\hat{\varepsilon}_{2i}$. The residuals are then used to generate $(Z - \bar{Z})\hat{\varepsilon}_2$ ($\bar{Z}$ is the sample mean of Z), which are used as instruments in conjunction with X to estimate equation (6). The ordinary linear 2SLS estimators are given by equation (10):

$$\hat{\beta}_2 = \overline{XX'}^{-1}\overline{XY_2},\ \hat{\varepsilon}_2 = Y_2 - X'\hat{\beta}_2,$$
$$\begin{pmatrix}\hat{\beta}_1\\ \hat{\gamma}_1\end{pmatrix} = \left(\widehat{\Psi}_{\mathrm{ZX}}'\widehat{\Psi}_{\mathrm{ZZ}}^{-1}\widehat{\Psi}_{\mathrm{ZX}}\right)^{-1}\widehat{\Psi}_{\mathrm{ZX}}'\widehat{\Psi}_{\mathrm{ZZ}}^{-1}\left(\frac{\overline{XY_1}}{(Z-\bar{Z})\hat{\varepsilon}_2, Y_1}\right) \tag{10}$$

here, sample averages are indicated by the overbars, the sample average of the expectation Ψ_{ZX} is $\widehat{\Psi}_{\mathrm{ZX}}$, and the consistent estimator of $\widehat{\Psi}_{\mathrm{ZZ}}^{-1}$ is $\widehat{\Psi}$ in an ordinary 2SLS regression. Ψ_{ZX} and Ψ_{ZZ} are two matrices that are defined as:

$$\Psi_{\mathrm{ZX}} = E\left[\begin{pmatrix}X\\ [Z - E(Z)]\varepsilon_2\end{pmatrix}\begin{pmatrix}X\\ Y_2\end{pmatrix}'\right],$$
$$\Psi_{\mathrm{ZZ}} = E\left[\begin{pmatrix}X\\ [Z - E(Z)]\varepsilon_2\end{pmatrix}\begin{pmatrix}X\\ [Z - E(Z)]\varepsilon_2\end{pmatrix}'\right] \tag{11}$$

in addition, Ψ is any positive definite matrix whose dimensions resemble that of Ψ_{ZZ}. In terms of the limiting distributions, $\hat{\beta}_2$ follows that of a regular ordinary least squares method while $\hat{\beta}_1$ and

$\hat{\gamma}_1$ follow that of ordinary 2SLS. However, the possible error in estimating the instruments $(Z - \bar{Z})\hat{\varepsilon}_2$ may require to be accounted for.

4 Empirical Estimation Results

4.1 Estimation results and discussion

First, we consider all the cultural dimension measures together in their respective energy poverty equations for estimation. The cultural dimension of individualism (vs. collectivism) cannot be added to this regression due to power distance and individualism being highly correlated—with a coefficient of -0.6429. This is expected *a priori* as the measurement of power distance relies on inequality while that of individualism relies on Gross National Income (GNI) per capita (Hofstede et al., 2010). The Kuznets curve hypothesis posits a (nonlinear) relationship between inequality and per capita income and is likely behind the strong correlation between power distance and individualism.

Table 2 presents the estimated coefficients from the fixed effects, logit (log-odds ratios)[§§], and the Lewbel (2012) models considering the four cultural dimensions. The coefficient of power distance is positive across all three estimators—except for the logit model with $Enpov1$ as the dependent variable (column (4)). The power distance coefficients are statistically significant in columns (1)-(3), (5), and (8). The marginal effect of a unit increase in power distance is a 0.0726 percentage point increase in probability of energy poverty. As such, an increase in power distance appears to worsen (increase) energy poverty. The coefficients on uncertainty avoidance on energy poverty is negative in columns (1) to (4) and positive in the remaining five columns of Table 2. The positive coefficients are significant in columns (1)-(3) while the positive coefficients are significant in columns (5)-(9). In the logit regression, a 1-unit increase in uncertainty avoidance leads to between 0.0575 and 0.126 percentage point increase in the probability of energy poverty. Due to a

[§§] The marginal effects of the cultural dimensions are provided below the coefficients. The marginal effects of the control are not reported to maintain conciseness of Table 2.

number of significant negative as well as positive coefficients, the effect of uncertainty avoidance on national energy poverty appears 'uncertain'.

The six statistically significant coefficients of masculinity (vs. femininity) are positive (columns (1), (3), (5), (6), (8), and (9), Table 2). The probability of energy poverty is raised by some 0.0359 and 0.290 due to 1-unit increase in masculinity. A more masculine culture, thus, tends to aggravate (increase) energy poverty. The coefficients of long/short-term orientation are negative except in column (7). The negative coefficient in column (4), however, is not statistically significant while all others are. A unit increase in long/short-term orientation reduces the probability of energy by between 0.0521 and 0.154. Accordingly, a culture with a more long-term orientation is expected to exhibit lower rates of energy poverty.

It is important to note that the estimated results from Table 2 suffer from severe multicollinearity. This does not come at a surprise since construction/definition of the cultural dimensions is based loosely on their constituent components' observed co-movements rather than 'iron links' (Hofstede et al., 2010). Hofstede and Minkov (2010) find the long/short-term orientation dimension to be 'strongly correlated' with GNI—the latter of which forms the basis for the individualism dimension. Hofstede et al. (2010) also notes that the 'IBM dimensions' and long/short-term orientation are highly correlated. As such, the mutual exclusivity of each of the cultural dimensions is questionable from both methodological and practical perspectives. In such a situation, it is important to tread in line with the extant empirical literature that uses the Hofstede cultural dimensions—e.g., Zheng et al. (2012), Arosa et al. (2014), Kanagaretnam et al. (2014), Haq et al. (2018), inter alia—and model each cultural dimension separately to avoid multicollinearity and/or overlapping inferences. As a result, the detailed interpretation and justification of estimated results are only provided below.

Table 2: Effect of (four) cultural dimensions on energy poverty

	Regressand								
	Fixed effects			Logit [a]			Lewbel (2012)		
Regressors	$Enpov1$ (1)	$Enpov2$ (2)	$Enpov3$ (3)	$Enpov1$ (4)	$Enpov2$ (5)	$Enpov3$ (6)	$Enpov1$ (7)	$Enpov2$ (8)	$Enpov3$ (9)
Age dependency ratio, old	0.00458**	0.00128	0.0114***	-0.912	-119.6***	-0.764***	-0.00759***	-0.00151	-0.0256***
	(0.00232)	(0.00244)	(0.00281)	(1.173)	(0.0842)	(0.138)	(0.00158)	(0.00204)	(0.00228)
Consumer price index	-0.00125***	-0.000972**	-0.00211***	-0.0106	-32.07***	-0.0418***	0.000438	0.000556	-0.00235***
	(0.000440)	(0.000397)	(0.000423)	(0.0321)	(0.0146)	(0.0142)	(0.000345)	(0.000618)	(0.000432)
Current account balance	0.00307***	-0.000762	-0.00150	0.196*	25.44***	-0.100***	-0.000105	-0.00399***	0.00265*
	(0.000889)	(0.00123)	(0.00186)	(0.109)	(0.0900)	(0.0338)	(0.000826)	(0.00139)	(0.00153)
Log of GDP per capita	-0.139***	-0.175**	-0.182***	-13.05***	-1,270***	-0.079*	-0.0402***	-0.209***	-0.0844***
	(0.0394)	(0.0720)	(0.0616)	(1.614)	(0.982)	(0.350)	(0.00742)	(0.0102)	(0.00947)
Labor force participation rate	0.00139	0.00925***	0.00226	0.176	116.6***	0.163***	0.00437***	0.0243***	0.0212***
	(0.00398)	(0.00317)	(0.00323)	(0.326)	(0.0353)	(0.0362)	(0.00108)	(0.001000)	(0.00109)
Manufacturing, value added	-0.00564**	0.00138	0.00255	-0.0609	59.66***	-0.00826	-0.00132	0.0104***	0.00299*
	(0.00266)	(0.00220)	(0.00286)	(0.155)	(0.108)	(0.0281)	(0.000809)	(0.00176)	(0.00175)
R&D expenditure	0.0267*	0.0468***	-0.0636***	-0.748	-875.6***	-4.150***	0.0417***	0.0268*	-0.0450**
	(0.0137)	(0.0134)	(0.0237)	(13.80)	(1.620)	(0.897)	(0.0129)	(0.0161)	(0.0189)
Power Distance	0.0154*	0.0298*	0.0511***	-0.106	52.94***	0.0180	0.000495	0.00249***	-0.00118
	(0.00852)	(0.0152)	(0.0129)	(0.178)	(0.0299)	(0.0222)	(0.000449)	(0.000836)	(0.000844)
Uncertainty Avoidance	-0.0338**	-0.145***	-0.231***	-0.00191	42.10***	0.0548***	0.00185***	0.00334***	0.00656***
	(0.0144)	(0.0639)	(0.0480)	(0.0121)	(0.0304)	(0.0146)	(0.000488)	(0.000688)	(0.000827)
Masculinity	0.0227***	0.0338	0.0710***	-0.186	26.47***	0.126***	-0.000605	0.000927*	0.00230***
	(0.00616)	(0.0221)	(0.0165)	(0.291)	(0.0778)	(0.0257)	(0.000368)	(0.000550)	(0.000541)
Long/Short-term Orientation	-0.0162***	-0.117**	-0.199***	-0.0631	-38.35***	-0.0673***	0.00113**	-0.00329***	-0.00420***
	(0.00487)	(0.0527)	(0.0396)	(0.129)	(0.0304)	(0.0146)	(0.000461)	(0.000901)	(0.000858)
Marginal effects (power distance)	-	-	-	-0.000528	0.000726	0.000412	-	-	-
				(0.000971)	(0.000903)	(0.000494)			

Marginal effects (uncertainty avoidance)	-	-	-	-9.47e-06	0.000575	0.00126***	-	-	-
				(0.0000599)	(0.000717)	(0.000298)			
Marginal effects (Masculinity)	-	-	-	-0.000921	0.000359	0.00290***	-	-	-
				(0.00128)	(0.000448)	(0.000480)			
Marginal effects (long/short-term orientation)	-	-	-	-0.000313	-0.000521	-0.00154***	-	-	-
				(0.000617)	(0.000651)	(0.000216)			
Observations	1,069	1,009	1,258	1,069	1,009	1,258	1,069	1,009	1,258
Number of countries	87	91	93	87	91	93	87	91	93
R^2 (within)	0.825	0.923	0.827	-	-	-	0.181	0.515	0.555
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Parentheses provide heteroskedasticity robust standard errors, except for marginal effects.
[a] Log likelihood calculated using adaptive Gauss-Hermite quadrature.
***, **, & * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively.

Table 3 exhibits the estimated results of power distance, excluding the other cultural dimensions, on the three different measures of energy poverty. The coefficients are positive and statistically significant, considering the level of α at 1 and 5 percent, in the panel fixed effects, logistic, and Lewbel (2012) regression models. The magnitude of these positive coefficients of power distance ranges between 0.00402 and 45.21. The marginal effects of the estimated logit coefficients of power distance indicate that a 1-unit increase in power distance results in an increase in energy poverty probability of between 0.160 and 0.755 percentage points. The interpretation of an energy poverty-worsening effect of power distance is simple and intuitive—the greater the cultural value of inequality of power, the increased odds of energy deprivation in the society. A more uneven power structure is expected intuitively to aggravate inequity in distribution of and/or access to resources, particularly energy. This is a novel finding of our paper but appears to agree with studies that find institutional quality and democracy (and perhaps a reduction in inequality) to improve energy consumption and efficiency (Ahlborg et al., 2015; Sun et al., 2019).

Table 3: Effect of power distance on energy poverty

Regressors	Regressand								
	Fixed effects			Logit [a]			Lewbel (2012)		
	$Enpov1$ (1)	$Enpov2$ (2)	$Enpov3$ (3)	$Enpov1$ (4)	$Enpov2$ (5)	$Enpov3$ (6)	$Enpov1$ (7)	$Enpov2$ (8)	$Enpov3$ (9)
Age dependency ratio, old	0.00440*	0.00144	0.0113***	-1.562**	-59.51***	-0.432***	-0.00637***	-0.00880***	-0.0293***
	(0.00227)	(0.00243)	(0.00277)	(0.646)	(0.0873)	(0.0700)	(0.00154)	(0.00222)	(0.00299)
Consumer price index	-0.00120***	-0.000939**	-0.00219***	-0.0808***	-19.18***	-0.0501***	0.000431	0.00122	-0.00210**
	(0.000403)	(0.000382)	(0.000410)	(0.0233)	(0.0123)	(0.0139)	(0.000603)	(0.000767)	(0.000892)
Current account balance	0.00296***	-0.000788	-0.00126	0.164***	-4.395***	-0.0876***	-0.00197	-0.00779***	-0.00423
	(0.000850)	(0.00119)	(0.00181)	(0.0517)	(0.0621)	(0.0327)	(0.00145)	(0.00194)	(0.00302)
Log of GDP per capita	-0.134***	-0.160**	-0.182***	-4.484***	-1,031***	-0.432**	-0.0763***	-0.155***	-0.0422**
	(0.0366)	(0.0688)	(0.0602)	(1.451)	(1.013)	(0.200)	(0.0113)	(0.0133)	(0.0168)
Labor force participation rate	0.00196	0.00850***	0.000429	0.536***	95.97***	0.139***	0.00949***	0.0196***	0.0138***
	(0.00382)	(0.00300)	(0.00321)	(0.144)	(0.0686)	(0.0342)	(0.00162)	(0.00161)	(0.00264)
Manufacturing, value added	-0.00615**	0.000446	0.00355	0.271	38.67***	0.00892	-0.00184	0.00619***	-0.000628
	(0.00260)	(0.00211)	(0.00283)	(0.179)	(0.0729)	(0.0375)	(0.00255)	(0.00207)	(0.00295)
R&D expenditure	0.0242*	0.0437***	-0.0556**	-3.088	290.4***	-5.663***	0.0561*	0.0157	0.0283
	(0.0131)	(0.0126)	(0.0238)	(2.283)	(2.026)	(0.935)	(0.0327)	(0.0279)	(0.0496)
Power Distance	0.0121***	0.0213***	0.0323***	0.163**	45.21***	0.0600***	0.00273	0.00402**	0.00700**
	(0.00440)	(0.00657)	(0.00588)	(0.0687)	(0.0339)	(0.0113)	(0.00192)	(0.00171)	(0.00299)
Marginal effects (Power Distance)	-	-	-	0.00160***	0.00755**	0.00183***	-	-	-
				(0.000246)	(0.00325)	(0.000306)			
Observations	1,145	1,081	1,346	1,145	1,081	1,346	1,145	1,081	1,346
Number of	96	100	102	96	100	102	96	100	102

countries									
R^2 (within)	0.846	0.948	0.884	-	-	-	0.279	0.583	0.583
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Parentheses provide heteroskedasticity robust standard errors, except for marginal effects.
[a] Log likelihood calculated using nonadaptive Gauss-Hermite quadrature.
***, **, & * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively.

The estimated impact of uncertainty avoidance is found to be mixed, in Table 4. The estimated coefficients of uncertainty avoidance are positive in the fixed effects regression. In contrast, the log-odds from the logistic regressions are negative in two instances—for $Enpov1$ and $Enpov2$ as the regressand—and positive once—for $Enpov3$, while the estimated Lewbel (2012) coefficients are all negative. Only two of the negative coefficients—$Enpov1$ for logit and $Enpov3$ for Lewbel (2012)—is statistically significant at the usual levels of α (see columns (4) and (9), Table 4). The values of these coefficients range between -0.121 and 0.0491. The computed marginal effects of uncertainty avoidance have the same signs as the log-odds in the logit regression. The marginal effects show an increase in uncertainty avoidance by 1-point reduces the probability of $Enpov1$ by 0.0495 percentage point and increases that of $Enpov3$ by 0.128 percentage point.

Despite having more positive coefficients, we argue that the effect of uncertainty avoidance on energy poverty measures is rather 'uncertain', especially based on the estimated logit and Lewbel (2012) results. This is likely due to the long- and short-run tradeoffs involved in avoiding uncertainty. Cultures and institutions that are eager to avoid costs/risks of uncertainty in the short-run—such as that of building new energy power plants, committing to alternative/clean energy sources, etc.—may be trading in higher costs/risks in the long-run and vice-versa. This phenomenon may be more apparent in the logit and Lewbel (2012) regression estimates, where uncertainty avoidance reduces energy poverty based on energy use (short-run deprivation) but increases energy poverty as measured by access to electricity (long-run deprivation).

Table 4: Effect of uncertainty avoidance on energy poverty

	Regressand								
	Fixed effects			Logit [a]			Lewbel (2012)		
Regressors	$Enpov1$ (1)	$Enpov2$ (2)	$Enpov3$ (3)	$Enpov1$ (4)	$Enpov2$ (5)	$Enpov3$ (6)	$Enpov1$ (7)	$Enpov2$ (8)	$Enpov3$ (9)
Age dependency ratio, old	0.00440*	0.00144	0.0113***	-0.307*	0.0535	-0.817***	-0.000826	0.00312	-0.00883
	(0.00227)	(0.00243)	(0.00277)	(0.159)	(0.363)	(0.232)	(0.00261)	(0.00267)	(0.00612)
Consumer price index	-0.00120***	-0.000939**	-0.00219***	0.0351*	-0.0829	-0.0452***	8.78e-05	0.000256	-0.00180**
	(0.000403)	(0.000382)	(0.000410)	(0.0191)	(0.0964)	(0.0152)	(0.000384)	(0.000630)	(0.000752)
Current account balance	0.00296***	-0.000788	-0.00126	0.212***	0.0251	-0.0[illegible]59*	0.00435**	-0.000987	-0.00443
	(0.000850)	(0.00119)	(0.00181)	(0.0439)	(0.142)	(0.0[illegible]57)	(0.00176)	(0.00211)	(0.00448)
Log of GDP per capita	-0.134***	-0.160**	-0.182***	-20.53***	-15.7[illegible]	[illegible].457	-0.153***	-0.285***	-0.173***
	(0.0366)	(0.0688)	(0.0602)	(3.829)	(14.[illegible])	(0.558)	(0.0146)	(0.0140)	(0.0268)
Labor force participation rate	0.00196	0.00850***	0.000429	-0.0699	[illegible].439	0.236***	0.00214	0.00758***	-0.00512
	(0.00382)	(0.00300)	(0.00321)	(0.[illegible]514)	(0.477)	(0.0750)	(0.00229)	(0.00209)	(0.00389)
Manufacturing, value added	-0.00615**	0.000446	0.00355	-0.[illegible]0449	0.0950	0.0799	-0.00597***	0.00443**	-0.00447
	(0.00260)	(0.00211)	(0.00283)	(0.192)	(0.317)	(0.106)	(0.00147)	(0.00212)	(0.00411)
R&D expenditure	0.0242*	0.0437***	-0.0[illegible]56[illegible]*	0.770	-0.416	-5.531***	0.0654***	0.0427***	-0.0520
	(0.0131)	(0.0126)	(0.[illegible]238)	(2.049)	(3.716)	(1.117)	(0.0138)	(0.0162)	(0.0372)
Uncertainty Avoidance	.00966**	0.0287***	[illegible]40***	-0.121***	-0.141	0.0491*	-0.000119	-0.00144	-0.0107**
	(0.00426)	(0.0073[illegible])	(0.00694)	(0.0266)	(0.144)	(0.0290)	(0.00205)	(0.00173)	(0.00423)
Marginal effects (Uncertainty Avoidance)	-	-	-	-0.000495***	-0.00177*	0.00128**	-	-	-
				(0.0000897)	(0.00103)	(0.000633)			
Observations	1,145	1,081	1,346	1,145	1,081	1,346	1,145	1,081	1,346
Number of countries	96	100	102	96	100	102	96	100	102
R^2 (within)	0.832	0.929	0.837	-	-	-	0.366	0.540	0.255
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Parentheses provide heteroskedasticity robust standard errors, except for marginal effects.
[a] Log likelihood calculated using nonadaptive Gauss-Hermite quadrature.
***, **, & * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively.

Table 5 shows that individualism, in contrast to collectivism, has an energy poverty-improving (reducing) effect in all three versions of the fixed effects and logistic regressions (columns (1) to (6)), and in two versions of the Lewbel (2012) regressions (columns (7) and (8)). The only positive coefficient (in column (9)) is statistically insignificant at the usual significance levels. The values of these coefficients vary between -38.56 and -0.00530. The marginal effects calculated from the logistic regression have the same sign as the log-odds estimates and indicate a reduction in the energy poverty probability of between 0.0746 and 0.539 percentage points in response to a 1-unit rise of individualism.

These findings are in line with their *a priori* expectations as individualistic cultures tend to stress more on the individual welfare—deprivation of energy in this instance—rather than the collective one. By minimizing the individual's energy deprivation, energy poverty at the aggregate (societal) level can be minimized—a concept that can be interpreted to be in the same thread as Adam Smith (Hume, 2003). Moreover, societal prevalence of individualism (vs. collectivism) has been observed to foster greater acceptance of alternative sources of energy such as nuclear power and renewables (Xia et al., 2019; Ang et al., 2020).

Table 5: Effect of individualism (vs. collectivism) on energy poverty

	Regressand								
	Fixed effects			Logit [a]			Lewbel (2012)		
Regressors	$Enpov1$ (1)	$Enpov2$ (2)	$Enpov3$ (3)	$Enpov1$ (4)	$Enpov2$ (5)	$Enpov3$ (6)	$Enpov1$ (7)	$Enpov2$ (8)	$Enpov3$ (9)
Age dependency ratio, old	0.00440*	0.00144	0.0113***	-4.502***	9.960***	-0.703***	-0.00351	-0.00455*	-0.0327***
	(0.00227)	(0.00243)	(0.00277)	(1.362)	(0.237)	(0.134)	(0.00215)	(0.00249)	(0.00322)
Consumer price index	-0.00120***	-0.000939**	-0.00219***	-0.00119	-9.722***	-0.0450***	-0.000382	0.00127	-0.000987
	(0.000403)	(0.000382)	(0.000410)	(0.0106)	(0.0221)	(0.0169)	(0.000651)	(0.000793)	(0.000717)
Current account balance	0.00296***	-0.000788	-0.00126	0.456***	0.299	-0.0314	-0.00267	-0.00957***	-0.00455*
	(0.00085	(0.00119)	(0.00181)	(0.0964)	(0.301)	(0.0370)	(0.00166)	(0.00205)	(0.00267

	0)						)		)
Log of GDP per capita	-0.134***	-0.160**	-0.182***	-41.97***	-1,080***	-2.883***	-0.0393**	-0.123***	-0.0432*
	(0.0366)	(0.0688)	(0.0602)	(11.21)	(1.706)	(0.573)	(0.0166)	(0.0179)	(0.0229)
Labor force participation rate	0.00196	0.00850***	0.000429	0.731***	40.99***	-0.0652**	0.0111***	0.0213***	0.0165***
	(0.00382)	(0.00300)	(0.00321)	(0.264)	(0.131)	(0.0259)	(0.00145)	(0.00130)	(0.00172)
Manufacturing, value added	-0.00615**	0.000446	0.00355	0.0263	41.58***	-0.126***	-0.00356	0.00765***	0.00810**
	(0.00260)	(0.00211)	(0.00283)	(0.0622)	(0.124)	(0.0444)	(0.00242)	(0.00251)	(0.00360)
R&D expenditure	0.0242*	0.0437***	-0.0556**	7.201***	-47.58***	-1.083	0.0460	-0.0252	-0.135***
	(0.0131)	(0.0126)	(0.0238)	(2.434)	(5.934)	(0.664	(0.0287)	(0.0216)	(0.0307)
Individualism	-0.0129**	-0.0169***	-0.0259***	-0.312***	-38.56***	-0.0872***	-0.00531*	-0.00530**	0.00529
	(0.00569)	(0.00432)	(0.00408)	(0.0830)	(0.0[illegible]69)	(0.0204)	(0.00289)	(0.00223)	(0.00326)
Marginal effects (Individualism)	-	-	-	-0.000746***	-0.00539	-0.00207***	-	-	-
				(0.000154)	(0.00667)	(0.000465)			
Observations	1,145	1,081	1,346	1,145	1,081	1,346	1,145	1,081	1,346
Number of countries	96	100	102	96	100	102	96	100	102
R^2 (within)	0.832	0.929	0.8[illegible]7	-	-	-	0.114	0.544	0.547
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Parentheses provide heteroskedasticity robust standard errors, except for marginal effects.
[a] Log likelihood calculated using nonadaptive Gauss-Hermite quadrature.
***, **, & * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively.

In

Table 6, we present the estimated effects of masculinity (vs. femininity) on energy poverty. The estimated coefficients of masculinity are positive in eight models—except when considering $Enpov1$ as the regressand in the logistic regression (column (4)), where it is negative. Only the positive coefficients of masculinity are statistically significant at the standard significance levels. The implication is profound as a culture leaning more towards masculinity was expected, *a priori*, to be more energy poor. The significant coefficients of masculinity on energy poverty are measured between 0.00118 and 0.137. In the logit model, the marginal effects imply that a 1-point increase in masculinity aggravates the probability of energy poverty within a range of 0.225 and 0.349 percentage points.

This finding is akin to that of recent studies which conclude that women's empowerment, including labor force participation, improves the quality and quality of energy consumption in households, especially in developing economies (e.g., Burke & Dundas, 2015; Rahut et al., 2017; Hou et al., 2017; Yasmin & Grundmann, 2020). This, by extension, can be used to argue that when a culture emphasizes masculinity over femininity, household/firm energy use decisions are hampered, and energy deprivation is aggravated. This is because a more masculine culture assigns less importance to cooperation, caring for the weak, and quality of life (Hofstede Insights, 2020). Reiterating this impact of gender inequality, Pachauri & Spreng (2011, p. 7502) note that "[i]n cultures where women have no rights at all, the head of the household may not be inclined to agree to have anything introduced [to reduce energy poverty], which would ease the woman's toil." Our findings provide a clear evidence in support of such claim.

Table 6: Effect of masculinity (vs. femininity) on energy poverty

	Regressand								
	Fixed effects			Logit [a]			Lewbel (2012)		
Regressors	$Enpov1$ (1)	$Enpov2$ (2)	$Enpov3$ (3)	$Enpov1$ (4)	$Enpov2$ (5)	$Enpov3$ (6)	$Enpov1$ (7)	$Enpov2$ (8)	$Enpov3$ (9)
Age dependency ratio, old	0.00440*	0.00144	0.0113***	-1.326***	-0.245**	-0.771***	-1.03e-05	0.00449**	-0.0222***
	(0.00227)	(0.00243)	(0.00277)	(0.301)	(0.0954)	(0.136)	(0.00191)	(0.00195)	(0.00147)
Consumer price index	-0.00120***	-0.000939**	-0.00219***	-0.0759***	-0.0632	-0.0562***	-1.02e-06	0.000163	-0.00216***
	(0.000403)	(0.000382)	(0.000410)	(0.0150)	(0.0622)	(0.0151)	(0.000589)	(0.000599)	(0.000359)
Current account balance	0.00296***	-0.000788	-0.00126	0.0563	0.0160	-0.0900***	0.00453**	-0.000794	0.00563***
	(0.000850)	(0.00119)	(0.00181)	(0.119)	(0.0466)	(0.0335)	(0.00200)	(0.00196)	(0.00153)
Log of GDP per capita	-0.134***	-0.160**	-0.182***	-4.215**	-1.327	-0.0637	-0.173***	-0.306***	-0.133***

				*					
	(0.0366)	(0.0688)	(0.0602)	(0.931)	(1.650)	(0.140)	(0.0222)	(0.0131)	(0.0115)
Labor force participation rate	0.00196	0.00850***	0.000429	0.526***	0.187*	0.200***	0.00176	0.00767***	0.00296**
	(0.00382)	(0.00300)	(0.00321)	(0.109)	(0.111)	(0.0432)	(0.00232)	(0.00192)	(0.00138)
Manufacturing, value added	-0.00615**	0.000446	0.00355	0.380***	0.206**	0.0716***	-0.00672***	0.00683***	-0.00688***
	(0.00260)	(0.00211)	(0.00283)	(0.112)	(0.0921)	(0.0208)	(0.00242)	(0.00213)	(0.00151)
R&D expenditure	0.0242*	0.0437***	-0.0556**	-0.150	-7.524**	-6.000***	0.0803***	0.0454***	-0.0190*
	(0.0131)	(0.0126)	(0.0238)	(1.269)	(3.432)	(0.899)	(0.0190)	(0.0135)	(0.0106)
Masculinity	0.0136***	0.0882***	0.134***	-0.0532	0.137***	0.0800***	0.00245**	0.00169**	0.00118*
	(0.00495)	(0.0273)	(0.0244)	(0.0387)	(0.0373)	(0.0156)	(0.00102)	(0.000765)	(0.000701)
Marginal effects (Masculinity)	-	-	-	-0.000339	0.00349***	0.00225***	-	-	-
				(0.000215)	(0.00119)	(0.000270)			
Observations	1,145	1,081	1,346	1,145	1,081	1,346	1,145	1,081	1,346
Number of countries	96	100	102	96	100	102	96	100	102
R^2 (within)	0.846	0.948	0.884	-	-	-	0.334	0.521	0.540
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Parentheses provide heteroskedasticity robust standard errors, except for marginal effects.
[a] Log likelihood calculated using nonadaptive Gauss-Hermite quadrature.
***, **, & * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively.

The estimated coefficients of long/short-term orientation, given in
Table 7, are generally found to be negative—apart from $Enpov1$ as the regressand in the fixed effects estimation (column (1))—and statistically significant at the 1% level of significance—except for $Enpov2$ as the regressand in the Lewbel (2012) estimation (column (8)). The positive coefficient of long/short-term orientation has a magnitude of 0.00622, while its negative counterparts have magnitudes (or absolute values) ranging between 0.00248 and 42.57. The marginal effect, in the logistic regressions, of a long/short-term orientation increase of 1-unit is a reduction in the probability of energy poverty: between 0.114 and 0.458 percentage points.

The estimated negative effect of long/short-term orientation on energy poverty is economically justifiable as cultures which are more open to preparing and adapting for the future are more likely to alleviate energy deprivation. The solution to energy poverty often requires reallocation

of resources in a society (culture) and breaking away from long-held policies and institutions as well as behaviors and customs by consumers and producers alike (Denton et al., 2003). The positive coefficient in column (1) of

Table 7 may be concerned with uncertainty involved in the tradeoffs between pragmatism and traditionalism/conservatism when solving energy deprivation problems—perhaps, in a similar vein to that of uncertainty avoidance in Table 4.

Table 7: Effect of long/short-term orientation on energy poverty

	Regressand								
	Fixed effects			Logit [a]			Lewbel (2012)		
Regressors	$Enpov1$ (1)	$Enpov2$ (2)	$Enpov3$ (3)	$Enpov1$ (4)	$Enpov2$ (5)	$Enpov3$ (6)	$Enpov1$ (7)	$Enpov2$ (8)	$Enpov3$ (9)
Age dependency ratio, old	0.00458**	0.00128	0.0114***	-0.287**	-87.83***	0.72[illegible]***	0.00468*	0.00331	0.00173
	(0.00232)	(0.00244)	(0.00281)	(0.117)	(0.161)	(0.134)	(0.00280)	(0.00439)	(0.00962)
Consumer price index	-0.00125***	-0.000972**	-0.00211***	-0.00392	-42.[illegible]2***	-0.0340***	-0.000390	-0.000348	-0.000962
	(0.000440)	(0.000397)	(0.000423)	(0.0176)	(0.0253)	(0.00959)	(0.000396)	(0.000664)	(0.000883)
Current account balance	0.00307***	-0.000762	-0.00150	[illegible].37[illegible]**	-3.332***	-0.0258	0.00586***	-0.000111	0.0102**
	(0.000889)	(0.00123)	(0.00186)	(0.152)	(0.180)	(0.0252)	(0.00146)	(0.00224)	(0.00471)
Log of GDP per capita	-0.139***	-0.175**	-0.182***	-19.29***	-3,365***	-2.658***	-0.171***	-0.291***	-0.226***
	(0.0394)	(0.0720)	(0.0616)	(5.662)	(2.896)	(0.502)	(0.0150)	(0.0184)	(0.0383)
Labor force participation rate	0.00139	0.00925***	0.00226	-0.118**	-40.44***	0.110***	-0.00108	0.00545***	-5.78e-05
	(0.00398)	(0.00317)	(0.00323)	(0.0501)	(0.0978)	(0.0354)	(0.00147)	(0.00201)	(0.00354)
Manufacturing, value added	-0.00564**	0.00138	0.00255	0.0691	149.7***	-0.118**	-0.00341***	0.00468*	0.00350
	(0.00266)	(0.00220)	(0.00286)	(0.106)	(0.147)	(0.0523)	(0.00129)	(0.00241)	(0.00463)
R&D expenditure	0.0267*	0.0468***	-0.0635***	3.316***	-2,247***	-3.310***	0.0832***	0.0579***	0.0423
	(0.0137)	(0.0134)	(0.0237)	(0.915)	(5.215)	(1.002)	(0.0103)	(0.0128)	(0.0376)
Long/Short-term Orientation	0.00622**	-0.0208***	-0.0288***	-0.339***	-42.57***	-0.0593***	-0.00404**	-0.00248	-0.0159***
	(0.00287)	(0.00520)	(0.00475)	(0.109)	(0.0633)	(0.0138)	(0.00161)	(0.00246)	(0.00565)
Marginal effects (Long/Short-term	-	-	-	-0.00126***	-0.00458	-0.00114***	-	-	-

Orientation)				(0.000105)	(0.00422)	(0.000209)			
Observations	1,069	1,009	1,258	1,069	1,009	1,258	1,069	1,009	1,258
Number of countries	87	91	93	87	91	93	87	91	93
R^2 (within)	0.825	0.923	0.827	-	-	-	0.279	0.518	0.313
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Parentheses provide heteroskedasticity robust standard errors, except for marginal effects.
[a] Log likelihood calculated using nonadaptive Gauss-Hermite quadrature.
***, **, & * denote statistical significance at the 1%, 5%, and 10% levels of significance, respectively.

The estimated coefficients of the cultural dimensions in Table 3 to

Table 7 generally have the expected signs and are similar in magnitude to those in Table 2. Thus, the inferences made from Table 2 are corroborated by that from Table 3 to

Table 7.

Considering the control variables in Table 3 to

Table 7, their estimated effects are found to be mixed. The statistically effect of age dependency ratio is generally negative in the logit and Lewbel (2012) estimates, with some positive coefficients (including log-odds) in the fixed effects estimates. It can be argued that, on average, elderly, albeit economically inactive, residents are not energy deprived due to greater access to funds—income, wealth, properties, etc.—which allows affordability and access to energy. Consumer price index generally coincides with lower odds of energy poverty based on our estimates—perhaps due to inflation being associated with higher incomes (per capita GDP). It may also be attributed to the improvements in energy efficiency and intensity in response to soaring energy and general price levels, which may eventually solve the energy deprivation problem, especially in developing economies (He et al., 2016).

The current account balance has a mixed effect on energy poverty. This is likely due to the current account being affected by energy commodities prices (including shocks) and exchange risks, as well as vice-versa, which influence affordability and access to energy products like a double-edged sword (Chaudhry et al., 2020; Sahoo et al., 2020; Shafiullah et al., 2020a; Shafiullah et al., 2020b). An increase in GDP per capita reduces the prevalence of energy poverty. This comes as no surprise as the literature, e.g., Shahbaz et al. (2020), generally agrees that energy consumption is a positive function of per capita income.

Labor force participation rate also has mixed effects on energy poverty, as higher incomes—especially that of female members—lead to households diversifying energy sources as well as increasing usage of energy (Burke & Dundas, 2015). The impact of increasing manufacturing value added as a share of GDP is generally mixed in the fixed effects, logit, and Lewbel (2012) regressions. This may be attributed to differences in technical changes in manufacturing—i.e., labor saving (Harrod neutral) vs. labor augmenting (Hicks neutral) technical changes—eventuating in different countries as well as time periods which affect individual and/or household incomes, eventually impacting energy affordability and access. Additionally, growth in manufacturing's share of GDP has repercussions for income and wealth inequality of a society—in turn resulting in discriminatory allocations of energy resources.

The estimated coefficients of R&D are mixed—as both negative and positive coefficients are significant. A negative coefficient implies that the greater the R&D expenditure as a fraction of the GDP, the lower is the likelihood of energy poverty. This comes as no surprise as higher levels of R&D expenditure bring about new technologies which improve access to cleaner energy sources and affordability by lowering prices, in line with the extant literature such as Popp (2001) and Sagar & Zwaan (2006). A positive coefficient is puzzling but may imply the double-edged sword of R&D—technological progress can be labor saving or capital augmenting. New technology may affect energy poverty outcomes through distributional channels—income, wealth, availability of resources, etc.—as well as render households susceptible to price and supply fluctuations, costly shifts, etc. (Popp, 2001; Alem et al., 2016).

4.2 Diagnostic and validity checks

Table 8 provides some diagnostic test results from the estimated fixed effects model equation (4). The Breusch-Pagan Lagrange Multiplier Test, otherwise known as the ‘poolability test’, is applied to determine whether a panel effect exists in our specified model and necessitates a panel econometric analysis. As can be seen, the $\bar{\chi}^2$ test statistic (in column (1), Table 8) rejects the null of zero variance across countries (no panel effect) is rejected at the 1% level of significance—based on the *p*-values in column (2) of Table 8—for all energy poverty indicators and cultural dimensions (15 variants). As a result, we can conclude that estimating a panel regression is imperative.[***]

Then, the second diagnostic test—the Breusch-Pagan/Cook-Weisberg Test for heteroskedasticity—is conducted on the fixed effects estimates from equation (4), in the absence of robust standard errors, to determine the presence of heteroskedasticity. Based on the χ^2 test statistics and associated *p*-values in columns (3) and (4) of Table 8, the null of homoskedasticity can be rejected at the 1% level of significance for all 15 variants of the specified models. This implies the presence of heteroskedasticity in our model equations and validates the use of robust standard errors in the empirical estimation exercise. The estimated fixed effects models in Table 3 to
Table 7 exhibit very high R^2 (within)—with the explanatory powers ranging between 82.5% (column (1),
Table 7) and 94.8% (column (2) of Table 3 and
Table 6) of the variations in the energy poverty measures.

Table 8: Diagnostic tests, fixed effects models

		Breusch-Pagan LM Test [a]		Breusch-Pagan/Cook-Weisberg Test [b]	
		Test statistic ($\bar{\chi}^2$)	*p*-value	Test statistic (χ^2)	*p*-value
Regressand	Cultural dimension	(1)	(2)	(3)	(4)
Enpov1	Power Distance	1581.26***	0.00	1495.87***	0.00
Enpov2	Power Distance	3813.78***	0.00	204.06***	0.00
Enpov3	Power Distance	3502.26***	0.00	133.41***	0.00
Enpov1	Uncertainty Avoidance	1558.57***	0.00	1495.87***	0.00
Enpov2	Uncertainty Avoidance	3790.03***	0.00	204.06***	0.00
Enpov3	Uncertainty Avoidance	3509.17***	0.00	133.41***	0.00
Enpov1	Individualism	1556.10***	0.00	1495.87***	0.00
Enpov2	Individualism	3818.15***	0.00	204.06***	0.00
Enpov3	Individualism	3498.09***	0.00	133.41***	0.00
Enpov1	Masculinity	1596.93***	0.00	1495.87***	0.00
Enpov2	Masculinity	3881.66***	0.00	204.06***	0.00
Enpov3	Masculinity	3528.72***	0.00	133.41***	0.00
Enpov1	Long/Short-term	1488.16***	0.00	1456.78***	0.00
Enpov2	Long/Short-term	3541.31***	0.00	212.88***	0.00
Enpov3	Long/Short-term	2699.27***	0.00	190.92***	0.00

[***] Since specified model equations incorporate country fixed effects by design—i.e., the cultural dimensions, the Hausman test for systemic variations in the fixed and random effects estimates is not applied.

[a] Breusch-Pagan Lagrange Multiplier test for random effects. H_0: The variance across countries (panel effect) is equal to zero.
[b] Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. Test applied on fixed effects model in absence of robust standard errors. H_0: Homoskedasticity of residuals.
*** Denotes rejection of the respective null at the 1% level of significance.

Table 9 presents the estimated test statistics and corresponding *p*-values from the for endogeneity and instrument identification tests. As can be seen from columns (1) and (2), the null hypothesis of exogeneity of each cultural dimension is rejected at the 1% level—implying possible endogenous determination of the cultural dimensions within the specified models. This validates the implementation of Lewbel's (2012) heteroskedasticity identified endogenous regression estimator. Columns (3) and (4) of Table 9 show that the null of under-identified instruments is rejected—at the 1 and 5 percent levels—for all five cultural dimensions. The internally generated instruments are, thus, found to be correlated with each of the cultural dimensions. The Hansen test statistics and *p*-values, in Table 9, columns (5) and (6), fail to reject—at the 1 and 5 percent levels of significance—the null of validity of all internal instruments. Therefore, the Kleibergen-Paap and Hansen tests demonstrate the appropriate (just) identification of the Lewbel (2012) estimates.

Table 9: Tests for endogeneity and instrument identification

Cultural dimension	Durbin-Wu-Hausman Test [a]		Kleibergen-Paap rk LM Test [b]		Hansen Test [c]	
	Test statistic (F) (1)	*p*-value (2)	Test statistic (χ^2) (3)	*p*-value (4)	Test statistic (J) (5)	*p*-value (6)
Power Distance	9.076***	0.003	21.760***	0.003	10.358	0.110
Uncertainty Avoidance	15.711***	0.000	18.051**	0.012	10.299	0.113
Individualism	15.711***	0.000	31.318***	0.000	11.675	0.070
Masculinity	9.076***	0.003	21.236***	0.003	10.570	0.103
Long/Short-term	14.428***	0.000	23.350***	0.002	10.714	0.098

[a] Durbin-Wu-Hausman test for endogeneity. H_0: Regressor in question is exogenous. Test applied on 2SLS regression in absence of robust standard errors.
[b] Kleibergen-Paap rk LM test for under-identification of instruments, in Lewbel (2012) estimates. H_0: Instruments are uncorrelated with the endogenous regressor (i.e., model is under-identified).
[c] Hansen J test for overidentification/validity of instruments, in Lewbel (2012) estimates. H_0: All instruments are valid.
*** & ** Denote rejection of the respective null at the 1% and 5% levels of significance, respectively.

4.3 Robustness checks

The robustness of the findings from Table 3 to

Table 7 is validated by classifying each energy indicator—energy consumption, access to clean fuels and technologies for cooking, and access to electricity—into quartiles and implementing them as dependent variables in multinomial regressions based on equation (4). The fixed effects and Lewbel (2012) estimators are only applied to these multinomial regressions, since the dependent variables are no longer binary. *A priori*, the signs of the estimated coefficients of the cultural dimensions from the multinomial regressions are required to be opposite to that of the regressions incorporating binary energy poverty measures. For example, power distance should, on average, reduce energy consumption, access to clean fuels and technologies for cooking, and access to electricity to validate the findings of Table 3.

The estimated results from such robustness checks can be found in Error! Reference source not found.**:** Error! Reference source not found. **to** Error! Reference source not found.**. Despite providing some mixed results in certain quartiles, the multinomial regression estimates support the overall conclusion from the regressions employing binary energy poverty variables. The mixed results are often observed in the extreme quartiles (particularly in Q1 and Q4)—implying, perhaps, the role of outliers. The explanatory powers (R^2) of the multinominal regressions in** Error! Reference source not found. **to** Error! Reference source not found. **are generally greater than their counterparts in Table 3 to**

Table 7, despite the smaller samples and fewer significant coefficients. Nevertheless, the multinominal regression estimates corroborate the robustness of the findings from the regressions availing the binary energy poverty measures. Overall, our results confirm the mechanism of cultural influence presented in Section 2.1 that natural culture affects energy poverty through attitude and preferences channel, which in turn shape policies charted by institutions.

5 Concluding Comments

In this study, we show that in addition to energy efficiency, income and energy prices, cultural traits significantly explain energy poverty and confirm Greif's (2006) views that culture is an important factor differentiating two countries that are otherwise similar. Our findings are robust to different specifications as well as endogeneity issues. The findings appear to be in concordance with the mechanism of cultural influence on energy poverty outlined in Section 2.1—generally, Power Distance and Masculinity (vs. Femininity) are observed to aggravate the odds of energy poverty while Individualism (vs. Collectivism) and Long/Short-term Orientation (i.e., pragmatism vs. traditionalism/conservatism) are found to reduce the probability of energy deprivation. The effect of Uncertainty Avoidance on energy poverty appears rather uncertain.

The national cultures appear to influence how the individual/household/firm views the risks and rewards associated with funding and/or adopting various, and perhaps new, energy sources. Such decisions also reflect the priority at the micro-level and influence policies and institutions at the macro-level. The latter, in turn, influence collective [national] priorities, which also have a bearing on individual/household/firm attitudes and decisions—creating a feedback loop. This cycle can be vicious or virtuous, depending on societal change and/or institutional reform.

Our research findings have two important policy implications. First, although cultural traits like masculinity, power distance and individualism—among others—are embedded in societies yet policies can better address the channel through which these traits work. As we argue attitude and preferences are the channel through which cultural traits may impact energy poverty, an inclusive policy geared toward female inclusion, less power distance and a more collective approach of institutions toward policy making will help mitigate energy poverty policies.

Second, as we know cultural traits are embedded in societies and take time to change, therefore, we suggest that policies should be aimed both at the macro and at the micro levels. At the macro level, the institutions should modify their policies to mobilize resources toward greater cultural values of equality of power and institute gender balance in societies with shared responsibilities and cooperation to counter energy poverty. At the micro level, there is a need to review education curriculum to tailor the curriculum toward promoting female participation, reducing the hierarchical distances and a collective approach toward solving daily life issues. With the advancement of technology and rapid globalization, the role of multinational technological corporations—i.e., Amazon, Apple, Facebook, Google, Microsoft, etc.—is crucial in adopting and promoting similar values and policies. This is even more important for younger generation as they are more inclined toward using technology and are more likely to be influenced by the technological corporations.

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Author contributions

Conceptualization: Sajid M. Chaudhry; Methodology: Muhammad Shafiullah; Formal analysis and investigation: Muhammad Shafiullah; Writing - original draft preparation: Sajid M. Chaudhry, Muhammad Shafiullah; Writing - review and editing: Sajid M. Chaudhry, Muhammad Shafiullah; Resources: Muhammad Shafiullah, Sajid M. Chaudhry; Supervision: Sajid M. Chaudhry.

Supplementary Data

Supplementary material

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