A Panel Analysis of Income Inequality and Energy Use

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Abstract

This paper investigates the relationship between energy consumption and income inequality in an unbalanced panel of 147 countries over the period 1990 - 2014. Using a variety of panel and dynamic panel methods and controlling for other determinants of inequality, such as education, health, investment, etc., I find a large and strong negative relationship between access to energy and income inequality. Moreover, I demonstrate that greater access reduces the share of income enjoyed by the top 20% and increases the share for the bottom 20%. Results are less robust when the sample is divided into regions and economic 'blocs', but the overall results are unchanged.

JEL Codes: E02, O43, O54, Q43

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Introduction

In his 1996 speech to the Royal Econometric Society President Atkinson (1997) announced that research on income distribution, or inequality, had "come in from the cold". Fast forward to 2013 when Piketty (2013) published *Capital in the Twenty-First Century* – compactly, and thoughtfully, summarized in Piketty (2015) – and one could say income distribution has "come in". What has not yet been fully resolved, however, are the causes of and possible remedies to income inequality. Indeed, there is an ongoing discussion on whether inequality is necessarily a "bad" or simply part of natural economic development, for example Hasanov and Izraeli (2011). Put another way, under what conditions is inequality tolerated in the greater context of economic growth (Hirschman and Rothschild, 1973)?

To that end, the focus of this paper is to investigate the – to date unanalyzed – impacts of access to energy on income inequality. Using an unbalanced panel of 147 countries over the period 1990 to 2014 the primary finding is that access to energy reduces income inequality, using two measures of income inequality. Subsample analysis reveals that energy's impact on inequality varies by region and economic status. I also find that greater energy consumption reduces the top 10% and 20% income shares while increasing the income share of the bottom 10% and 20%.

As discussed in Bourguignon and Morrisson (2002), and seconded by Milanovic (2011), overall global inequality increased from the post-revolutionary era (about 1800) to World War II, and thereafter stabilized through the end of their sample in 1992, supporting the Kuznets's (1955) inverted-U relationship between per capita income and income inequality. However, recently Beddoes (2012) updated their data and show that the Kuznets inverted-U curve found in Bourguignon and Morrisson (2002) has recently become an "italicized n", that is, there has been a recent uptick in inequality. A similar argument can be found in List and Gallet (1999), who showed that the n shape is due, in part, to the shift away from manufacturing towards service production, particularly in advanced countries.

The OECD (2014) confirms the rise of inequality among OECD countries, with the Gini coefficient rising three points over the past two decades. Furthermore, the OECD argues that this increase in inequality has led to a 0.35% decline in annual growth rates for the past 25 years. Adding to the ambivalence, Anand and Segal (2008) establish there is no conclusive evidence as to which direction inequality is heading.

To date, the majority of empirical income inequality literature is concentrated on five major categories: growth, human capital (i.e. education and health), government policy, institutions, and investment. As might be expected, as in the growth literature, there are considerable differences in the direction of the causality, which leads to an endogeneity problem: does lower income inequality improve, say, human capital, or vice-versa?

An intuitively attractive implication of better health is improved income inequality. As in the growth literature, an increase in health increases worker productivity and leads to higher income, which should, in turn, lead to greater equality. Using US county level data, Daly and Wilson (2013) show that, despite earlier research which could not conclusively prove that improved health leads to better income distribution, there *is* a statistically significant negative relationship between mortality and income equality. On the other hand, Deaton (2003), in his survey of the effects of income distribution on health, not vice-versa, is unable to convincingly argue that improved equality unambiguously improves health. Herzer and Nunnenkamp (2011), after correcting for endogeneity, cross-country heterogeneity, and omitted country fixed effects, provide evidence to the contrary. Less ambiguous are the impacts of education on inequality. Again, the intuition is attractive, more education leads to higher productivity and income, reducing inequality, as in Gregorio and Lee (2002).

With respect to the effects of institutions on income inequality, Alesina and Perotti (1996) confirm that reduced equality fuels social discontent which destabilizes the political structure making investment more uncertain potentially undermining future growth. On the other hand, Barro (2000) is unable to corroborate this result, but does find evidence supporting the Kuznets curve. In their examination of corruption and inequality and poverty, Gupta, Davoodi, and Alonso-Terme (2002) demonstrate that rising levels of corruption, and their channels, exacerbate inequality and poverty. Later, Esfahania and Ramírez (2003) find that institutions in concert with better infrastructure can lead to lower income inequality.

Other factors contributing to income inequality include: investment, migration and remittances (Barham and Boucher, 1998); foreign direct investment, (Borenszteina, Gregorio, and Lee, 1998); and fiscal policy (IMF, 2014). Clearly, this is an incomplete list, but points to the general trend in the extant literature.

A key determinant of economic welfare is access to energy, given it impacts on both firm and household production. According to a recent study by the International Energy Agency about 17%, or 1.2 billion of the global population, do not have access to electricity (IEA, 2016). There is a substantial literature dedicated to understanding of how energy consumption contributes to growth, generally using panel cointegration techniques or dynamic panel methods, for example, Lee (2005), Huang, Hwang, and Yang (2008), Belke, Dobnik, and Dreger (2011), Chen, Chen, and Chen (2012), and Herrerias, Joyeux, and Girardin (2013). However, the consensus from this literature is inconclusive. In a survey of the energy and growth literature Ozturk (2010) demonstrates that there is conflicting evidence on the relationship and asks future authors to consider approaches which do not rely on cointegration and/or causality tests. He also suggests that authors conduct a variety of robustness checks by changing the sample period, variables, and/or sample data.

A number of studies have also looked at the relationship between per capita income and environmental quality and/or pollution, producing estimates of the environmental Kuznets curve. In an unbalanced panel of 42 countries Torras and Boyce (1998) find evidence for the Kuznets curve over five sources of pollutants. But Borghesi (2000) finds that depending on the methodology used, pooled OLS versus fixed effect panel, results can be dramatically different, echoing his earlier survey of the environmental Kuznets curve, Borghesi (1999) hinting at the need for more robust estimation, as discussed in Ozturk (2010).

This paper is the marriage of the income inequality literature and research on the effects of energy use on growth. Its closest antecedent is a paper by Padilla and Serrano (2006) which demonstrates that an increase in income inequality leads to inequality in the distribution of CO2 emissions across both countries, e.g. East and West Europe, and income groups, high versus low income. This paper employs a battery of panel regression models – standard random and fixed effects, fixed effect IV and 2SLS, GMM-IV, and system GMM – to determine the effects of energy use on income inequality using two measures of inequality, the Gini coefficient and the ratio of high to low income shares. I then consider impacts on regions and economic 'blocs' to investigate the idiosyncratic impacts of energy on equality. Finally, I exploit data on the top-to-bottom 10% and 20%, respectively, income shares to test energy asymmetries across income strata.

Overall, I find that energy use is strongly correlated to declines in income inequality. Moreover, this result is robust to various specifications, methods, and measures of energy use, income, institutional measures, and definitions of income inequality. Indeed, the results demonstrate that access to energy has a substantial impact on inequality on par with economic growth, and larger than other "traditional" determinants such as institutions, human capital, government consumption, and investment.

The remainder of the paper is structured as follows: Section 1 introduces a simple theoretical model to motivate the empirical analysis; Section 2 outlines the empirical panel model strategy, reviews the data used and discusses the initial results; Section 3 introduces the dynamic panel methods used and sheds light on the overall results; in Section 4, I conduct analysis on subsamples of the data to test for regional and economic structure idiosyncrasies and check for asymmetric effects on income shares. Finally 5 provides some brief summary remarks.

1 A Simple Theoretical Model

Though this paper's focus is the empirical analysis, I begin by constructing a simple two sector and three-input, profit maximizing model to motivate the statistical strategy. Consider a standard Cobb-Douglas production function, which conforms to the Inada conditions, that, in addition to capital and labor, also includes energy as in input. There are two income groups, or "sectors, high (h) and low (ℓ) each with its own specific production function, differentiated by input shares and levels of inputs,

$$Y_i = A_i f(K_i, L_i, E_i) = A_i K_i^{\alpha_i} E_i^{\beta_i} L_i^{(1-\alpha_i-\beta_i)},\ i = h, \ell \tag{1}$$

time subscripts are repressed for clarity. K is capital, E is energy use, L is labor, or more accurately, effective labor, A is a productivity measure and α/β are the output shares of capital and energy respectively. Labor and capital are assumed to be homogeneous and perfectly mobile *within* each income group, but not across sectors, similar to the specific factors trade model. Energy is homogeneous and mobile within and across income groups. Wages in the high income group are assumed to be strictly higher than for low income workers.

Next we define the resource constraints

$$K = K_h + K_\ell,\ E = E_h + E_\ell, L = L_h + L_\ell$$

and aggregate output

$$Y = Y_h + Y_\ell.$$

The total cost constraint is standard,

$$C = \sum_{j=\ell}^{h} (r_j K_j + QE_j + w_j L_j),$$

r, w and Q are the prices of capital, labor, and energy. Because energy is homogeneous across income groups, $Q \equiv Q_h = Q_\ell$, while prices paid to capital and labor differ across sectors.

Of interest to this paper is the effects of energy use on high-to-low relative labor income, denoted $\widehat{w}$. Relative wages are given by the first order condition for high income labor, after substituting in the resource constraints. The income differential across the high and low income sectors is assumed to be positive and equal to

$$\widehat{w} \equiv w_h^* - w_\ell^* = \theta_h \cdot y_h - \theta_\ell \cdot y_\ell, \tag{2}$$

where $y = Y/L$ is per capita output and $\theta = (1 - \alpha - \beta)$ is the output share of labor. It is easy to show how the differential changes with respect to changes in energy shares and access to energy in the production function:

$$\frac{\partial \widehat{w}}{\partial \beta_h} = -Y_h \big[1 - \theta_h(\ln E_h + \ln L_h)\big] \gtrless 0 \tag{3}$$

$$\frac{\partial \widehat{w}}{\partial \beta_\ell} = Y_\ell \big[1 - \theta_\ell(\ln E_\ell + \ln L_\ell)\big] \gtrless 0 \tag{4}$$

$$\frac{\partial \widehat{w}}{\partial E_h} = \beta_h \theta_h \frac{y_h}{E_h} > 0 \tag{5}$$

$$\frac{\partial \widehat{w}}{\partial E_\ell} = -\beta_\ell \theta_\ell \frac{y_\ell}{E_\ell} < 0. \tag{6}$$

y/E is the average level of per capita output per unit of energy. Equations (3) – (4) each have an ambiguous sign and depend on the relationship $1 - \theta(\ln E + \ln L)$. Clearly as the labor share, θ, approaches 0 the sign becomes unambiguously negative in equation (3) and vice-versa in (4). Equations (5) and (6) are less ambiguous and are intuitively attractive, more access to energy in the high sector increases the income differential and the differential compresses when energy is added to the low sector.

This model nests two possibilities with respect to per capita capital and energy:

$$k \equiv k_h = k_\ell \quad \text{and} \quad e \equiv e_h = e_\ell \tag{7}$$

$$\alpha_h = \alpha_\ell \quad \text{and} \quad \beta_h = \beta_\ell \tag{8}$$

First, equation (7) states that per capita capital and energy for use in production is evenly split between high and low income earners, but the input shares differ. The opposite is true in equation (8), input shares are the same, but access to factor stocks differs. Invoking this second condition allows us to simplify equation (2) significantly to

$$\widehat{w} = \theta \cdot (y_h - y_\ell), \tag{9}$$

the wage differential is proportional to the per capita output differential across income groups.

To conclude the analysis, we concentrate on the output differential in (9). First, convert equation (1) into per capita terms,

$$y_i = A_i k_i^{\alpha_i} e_i^{\beta_i}$$

and take the ratio of the high to low sectors

$$\frac{y_h}{y_\ell} = \frac{A_h}{A_\ell} \frac{k_h^{\alpha_h} e_h^{\beta_h}}{k_\ell^{\alpha_\ell} e_h^{\beta_\ell}}.$$

Without loss of generality, assume that the capital and electricity stocks are the same each sector, as in equation (7). Taking natural logs we have

$$(\ln y_h - \ln y_\ell) = \widehat{A}_{HL} + \alpha \ln k + \beta \ln e. \tag{10}$$

where $\widehat{A}_{HL} \equiv \ln(A_h/A_\ell)$, $\alpha \equiv (\alpha_h - \alpha_\ell)$ and $\beta \equiv (\beta_h - \beta_\ell)$. Collectively equations (9) and (10) are the basis of our empirical analysis, substituting (10) into (9) yields

$$\widehat{w} = \theta \widehat{A}_{HL} + \alpha_\theta \ln k + \beta_\theta \ln e \tag{11}$$

where $\alpha_\theta = \theta\alpha$ and $\beta_\theta = \theta\beta$. The implications are straightforward: Changes to total factor productivity and access to energy can expand or contract income inequality, depending on the sign of β_θ. The results of this simple model are similar to those found in the dynamic model of Chatterjee and Turnovsky (2012). In their model, the effects of public goods investment is sensitive to how public investments are financed but they do decrease income inequality in short run, but increase it in the long run.

2 Empirical Model, Data, and Results

We begin our discussion by specifying a standard panel model given by:

$$y_{it} = \alpha + \beta q_{it} + x_{it}'\gamma + \lambda_t + \varepsilon_{it}, \tag{12}$$

where y is a measure of income inequality, given alternatively as $\ln(Gini)$, and the ratio of the 10% and 20% of the richest to poorest income share, $Share_r^{top}/Share_r^{bottom}, r = 10\%, 20\%$. q is the log measure of energy use.x is a vector of control variables. λ_t is a time fixed effect and ε_{it} is a random disturbance, discussed in greater detail in equation (13), below. Ex-ante, estimates of β, δ, and the control coefficient vector, γ, should be negative if the variables reduce income inequality.

The specification in equation (12) is first estimated using panel fixed and random effect models, nested in equation (12). If $\alpha = 0$ and

$$\varepsilon_{it} = \mu_i + u_{it}; u_{it} \sim N(0, \sigma_u^2) \tag{13}$$

we have the fixed effect model where μ_i is a time invariant unobserved state fixed effect and u_{it} is a random disturbance, with the orthogonality condition $E(\mu_i, \varepsilon_{it}) = 0$ equation (12) is the fixed effect model. On the other hand, if μ_i is random with

$\mu_i \sim iid(0, \sigma_\mu^2)$

$E(\mu_i, x_{it}) = 0$, and

$\alpha = 0$

equation (13) is the random effects model. $E(\mu_i, x_{it}) = 0$ represents the orthogonality condition that the fixed effects and regressors are uncorrelated.

2.1 Data and Characteristics

The unbalanced panel sample period covers the years 1990 – 2014 for 147 countries, see Table A1 in the Appendix for a list of countries. With the exception of the institutional variables, discussed below, most of the data are available from the World Bank's World Development Indicators (WDI) collected from various sources. The list of the variables and their sources are in Table 1. British Thermal Unit (BTU) data is from the US EIA. For dependent variables, and as a robustness check, I use three different measures of income inequality: the log of the Gini coefficient;and the ratio of the 10:10 and 20:20 income shares, denoted "10%/20% Ratio" respectively. This measure, or similar to it, for inequality can be found in a number of studies, such as Gottschalk and Smeeding (2000) and Daly and Wilson (2013).

Energy use is given by per capita consumption of kilowatt hours (pc kWhs) and aggregate BTU consumption. According to Foster and Bedrosyan (2014) energy production is the single largest cause of CO2 greenhouse emissions accounting for roughly 41% the global total, so it is also worth considering using CO2 emissions as an instrument for energy consumption. A complication of using this, however, is that the commons nature of pollution makes accounting for emission sources difficult. Nevertheless, CO2 emissions will be used in the the first stage of 2SLS regressions as a robustness check.

The control variables used include those generally found in the inequality and growth literature. First, to account for economic growth and/or technological change, we use per capita real GDP in local currency units. As shown by Nuxoll (1994), using international prices, such as the $US, leads to systematically different growth rates as compared to using GDP in domestic prices, called the Gerschenkron effect. Thus, Nuxoll (1994) suggests that estimates using GDP in the domestic currency are more reliable.[1] Two human capital controls are included: primary education enrollment as percent of school age children and percent of GDP spent on health expenditure. Note that these variables are ex ante "inputs" rather than ex post outcomes, and can thus be intended as investment expenditures with a particular goal in mind, such as income growth, poverty reduction, and/or quality of life improvements. Private non-financial investment and government consumption, both as a percentage of GDP, are used to account for changes in productivity, the accumulation of real assets and infrastructure investment.

Economic composition differences across the countries are proxied by the percent rural population and the value added of manufacturing as percent of GDP. Regional cross sectional heterogeneity is accounted for by time invariant regional fixed effects. Also included is the IMF's global recession indicator used to correct for global downturns. The IMF recession dates correspond to the 2007-08 financial crisis, so this variable also captures this impacts. Variables which are *not* in percent or ratios are in natural logs.

To account for institutional heterogeneity, I use the average of two measures calculated by the Fraser Institute's Economic Freedom of the World index (EFWI) (Lawson and Hall, 2016): the protection of property rights (Area 2C) and extra payments/bribes/favoritism (Area 5Civ, denoted "'Bribe"). Property rights was chosen for a couple of reasons. First, as argued by North and Thomas (1973) and North (1989) well developed institutions contribute to economic growth via incentives, property rights, and the reduction of transaction costs. North (1989) further developed a theory of the impacts of institutional change on economic growth. Acemmoglu, Johnson, and

[1] Per capita real GDP in $US and PPP per capita real GDP in $US were also used with little change in the results.

Robinson (2005) corroborate the findings of North (1981, 1989) and North and Thomas (1973) in that the protection of property rights and the allocation of resources are necessary for economic growth. While this paper does not specifically concentrate on economic growth, the importance of institutions on warrants considering them in the context of income inequality, see Bennett and Vedder (2013).

The category "bribes" is chosen as it is aligned with corruption and rent-seeking which are likely to impact access to energy and serves as an instrument for democracy. Also, there is a literature on corruption and economic performance which makes comparisons to the growth literature possible, for example, Barro (1996), Barro (2000), and Podobnik, Shao, Njavro, Ivanov, and Stanley (2008), and inequality, Gupta et al. (2002).

For sensitivity analysis, and to act as a robustness check, I also used a variety of substitute variables for controls, such as $US PPP per capita real GDP, secondary and tertiary education indicators, and a health variables such as infant mortality rates, life expectancy, etc. with little change in the results.

Descriptive statistics of the unbalanced panel data can be found in Table 2 which includes the number of observations, mean, standard deviation, minimum, and maximum for each of the data. Data at the top of the table are dependent variables. kWhs and BTUs are the variables of interest. CO2 will be used in panel two stage least squares (2SLS) as a robustness check. The education and health data are helpful in making comparisons to the extant literature. The remaining variables are the controls.

Figures 1 and 2 show the mean of the Gini and the 20% income shares over the sample period, with the upper and lower bound for each period. Figure 3 shows the average of per capita kWh use globally, again with the upper and lower bounds. From the first two figures, we can see that income distribution globally has been improving, particularly since 2000. We can also see the impacts of the financial crisis in both figures with a rise in both the Gini coefficient, which rises sharply, and the income ratio post 2010. Over the sample, we also see a steady incline per capita kWhs used since the mid-1990s.

Results

Given the concentration on human capital, education and health, in the literature, I begin by providing results for three "benchmark" RE and FE models: the first uses only the education variable in the analysis, the second only health, and the third uses both. All three include the institutional variable, the mean of the property rights and bribe freedom index. The benchmark models use the same control vector as discussed above, but are not presented to avoid cluttering the results.[2] Results can be found in Table 3. Statistics in parentheses are robust $p-$values. As can be seen only education expenditures have an impact on the Gini coefficient, at standard

[2]All results not presented throughout this paper are available from the author on request

rejection probabilities. Health expenditures actually exacerbate the income ratio using the 10% income ratio. Of note, the estimates for education are the same, at three decimal points, for the more general version of the model, in the bottom panel of the Table. It's also worth note that the magnitude of the estimates are robust to the various specifications.

Turning our attention to the impact of energy on income inequality, the first set of panel RE and FE regressions can be found in Table 4. In the interest in saving space, tables will only include the results for energy, education, health, the mean of the freedom indices, and per capital real GDP. Again robust $p-$ values are in parentheses, stars are used to highlight statistical significance with '*, **, ***' at the 10%, 5%, and 1% levels respectively.[3] The overall R_o^2, the error autoregressive coefficient, ρ, and the number of observations for each model are also tabulated. All models include time fixed effects and the RE models include regional fixed effects to account for heterogeneity.[4] As argued in Borghesi (2000), in examining the relationship between income inequality and the environmental quality, the FE model allows for unmeasurable time invariant country specific fixed effects. He also argues that the RE model assumes that the fixed effects are not correlated with other regressors. Therefore, for example, initial endowments of resources, total factor productivity, etc., are orthogonal to output and inequality. One loss to using the FE model in this context, however, is that we cannot control for regional fixed effects as they are perfectly correlated with country fixed effects. Below, I divide the full sample into regional and 'bloc' subsamples and redo the regression models.

In the interest of preserving space, only the results for kWhs are discussed, however, the results using BTUs are similar. As can be seen in the Table, with per capita kWhs as the energy variable, only in the FE models using the Gini coefficient and the 10% income ratio does energy have any discernible impact on the inequality, and both at the 10% rejection level. A quick robustness check from the lower half of Table 4 provides supporting evidence. Education's impact on income inequality is about the same as in the benchmark models. Secondly, the institutional variable, proxied by the mean of property rights and bribery, raises inequality when the Gini coefficient is used, but has little other explanatory power in the remaining models. Robustness checks using alternative human capital and GDP variables again have little effect on the results.

Investment and government consumption have explanatory power in reducing inequality when using the Gini coefficient, but not the income ratios. It should be reiterated that the government variables is consumption which does not specifically target inequality, as would, say, tax and/or transfer policies. Rather, government consumption would have a more indirect effect on inequality, in the Keynesian sense, through direct public job creation and related indirect employment. Moreover, in low income economies, relatively weak government institutions for tax collecting or transfers, mitigate the effectiveness of redistribution policies. Indeed, even in high income coun-

[3]Regressions using clustered standard errors were also conducted, with little change in the results.

[4]The regions are: Latin America, Africa, the Middle East, Asia, Western and Eastern Europe, and the Russian Federation, examined in Section 4 below.

tries, government represents a large percentage of total employment. For example, public sector employment in Norway accounts for roughly 35% of the total (OECD, 2015).

These results provide some evidence in favor of much of the previous literature of the impacts of human capital on income inequality, for example, Daly and Wilson (2013), Gregorio and Lee (2002), and Castelló and Doménech (2002).

FE-IV Results & 2SLS

However, an issue that may arise, as in the growth literature, there is likely to be some degree of endogeneity in the statistical modeling process. This is, in part, due to the vagaries of the data. First, the frequency of the data, which for many countries is not annual, or indeed at issued at regular intervals. For example, the average number of observations for the Gini coefficient is about 8.04 over the sixteen year sample period. An additional concern is that income inequality variables tend to be very stable over time. We begin by addressing endogeneity, and as a robustness check, by conducting FE panel instrumental variable (IV) estimation using the lagged energy variable and lagged per capita real GDP as instruments. Results for both kWhs and BTUs are in Table 5, control variable results are repressed for clarity. As before, robust $p-$values are used.

First, energy has a statistically significant impact on both the Gini coefficient and the 20% income ratio. Across both definitions of energy, the elasticity of energy is about –0.15 when using the Gini coefficient. For the 20% income ratio, the elasticity is between –2.9 and –7.6 depending on your definition of energy. This difference is because kWhs are defined in per capita terms whereas BTUs are total consumed. The education elasticity remains the same as in the previous cases, but is relatively insignificant compared to energy coefficient estimates. As before, health increases inequality, but only if the dependent variable is the 20% income ratio. Likewise the freedom indices, lead to an increase in the Gini coefficient.

As discussed above, approximately 41% of CO2 emissions are generated by energy production, thus they are good candidate for a 2SLS model, whereby energy is regressed on CO2 in the first stage. RE and FE results of these tests using the Gini coefficient and the income ratios are in Table 6. The energy coefficient estimates with the Gini and 20% ratio are similarly statistically significant, particularly with the fixed effect model, found in the bottom half of the table, and are of the hypothesized sign. Moreover, the estimates are similar to those in previous models. Likewise, education and health coefficients are close to the same magnitude and statistical significance as in previous models. Noteworthy is that the energy estimated elasticities and semi-elasticities are generally greater, in absolute value, than the income estimated coefficients. Improvements to the institutional variables worsen inequality. Finally, in the random effects model, increases in real GDP lead to a statistically significant worsening of inequality.

Taking stock of the results thus far, the improved access to energy has consistent positive impacts for income inequality that is robust to numerous specifications and sensitivity analysis.

Moreover, the estimated coefficients are surprisingly uniform depending on the regresand in each model specification.

3 Dynamic Panel Methods

A further step, is to address endogeneity, or simultaneity, using dynamic panel methods, initially proposed by Anderson and Hsiao (1981). As in the growth literature, the above models are likely to have endogenously determined variables such that $y \Leftrightarrow x$ leading to the simultaneity problem. The argument is as follows, higher income, or less income inequality, leads to higher resource use, and vice-versa. In this context higher levels of output lead to a desire for more energy while energy use improves conditions for equality.

Econometrically, as is well documented, fixed effect models with a lagged dependent variable biases the estimated coefficients, given that $E(y_{it-1}, \varepsilon_{it}) \neq 0$. Without any exogenous regressors Nickell (1981) demonstrated that ρ is biased by $1/T$ so that $bias(\hat{\rho}) \rightarrow 0$ as $T \rightarrow \infty$. Because of this, the panels discussed are only useful with a large time dimension. Moreover, Judson and Owen (1999) demonstrate that the least squares dummy (LSDV) model, i.e fixed effect model with lagged dependent variables, performs badly with small T. They show that the GMM estimator works well with small T while the Anderson and Hsiao (1981) estimator performs well as $T \rightarrow \infty$.

Given these caveats I employ generalized method-of–moments (GMM) based IV estimation which has advantages over standard IV estimation in that GMM is more efficient in the presence of heteroskedasticity. While this may be less of a problem in a single country, across a panel of large and small countries there is a potential for considerable heteroskedasticity.

To remove the panel fixed effects we can employ a dynamic framework by first converting equation (12) into first differences, as in AH:

$$\Delta y_{it} = \varphi_1 \Delta y_{it-1} + \varphi_2 \Delta q_{it} + \varphi_3 \Delta \psi_{it} + \Delta x'_{it}\gamma + \Delta\varepsilon_{it}, \tag{14}$$

where Δ is the one period difference operator. The inclusion of the lagged dependent variable accounts for the dynamic development inequality and/or changes in total factor productivity. By construction, this specification still contains correlation between the errors and lagged dependent variable. As such, we can employ an IV approach using the second or higher order lagged dependent variable as a valid instrument. This strategy can be employed even if φ_{it} follows an $AR(1)$ process by using higher order lagged dependent variables for instruments. This transformation reduces potential biases from omitted variables and the state specific fixed effects, which in standard IV models would be nested in the panel error term in equation (13), μ_i.

However, as outlined above, Judson and Owen (1999) found the AH estimator performs badly with small T. Arellano and Bond (1991) use a GMM approach to exploit the larger amount of information contained in the sample. They argue that AH is consistent but fails to account for all potential orthogonality conditions. In this approach they include lagged levels of the endogenous variable, in differenced form and the exogenous variables. Later Arellano and Bover (1995) and Blundell and Bond (1998), hereafter System GMM, demonstrated that lagged levels are poor instruments for differenced variables, as in equation (14). They modified the AB model to also include lagged differenced variables.

All dynamic models use, in addition to the energy variables and their lag, the two human capital variables, per capita real GDP, and the institutional variable in the vector $\mathbf{x}$. The overall policy variable, government consumption, and economy structural variables, percent rural population and value added by manufacturing, are treated as instruments.

Dynamic Panel Results

The dynamic panel GMM estimates are in Table 7. Estimated coefficients and their respective $p-$values, calculated using two-step GMM standard errors, are organized by estimator and energy variable. Results for the lagged dependent variable are not included, nor are the instrumental variables estimates. Contemporaneous and lagged energy are significant for both the income share regressands. On the other hand, for the Gini coefficient, the contemporaneous energy estimate is positive, but not significant, however, *lagged* energy is negative and significant. Collectively, these results indicate that access to energy may not have an immediate impact on inequality, but take some time to come to fruition, corroborating results from the FE-IV model above.

Turing our attention to the remaining results: educational expenditures now lead to a statistically significant decline in inequality, as does GDP. Results for health and the institutional variable, while significant, yield more ambiguous results. Health reduces inequality when BTUs are used as the energy variable, and reduces the 10% income ratio. The institutional variable generally raises inequality.

4 Subsample and Asymmetric Analysis

Next, we investigate the impacts of energy consumption on individual regions and economic 'blocs' and then consider the impacts of energy use on the the income shares independently of each other. Asymmetric analysis tests if energy use has a different impact on the top and bottom 10% and 20% income shares respectively. Given that we have seen that kWhs and BTUs demonstrate statistically similar results and in the interest of saving space, the estimates presented will only be using per capita kWhs as the energy variable for the remainder of the text. Likewise, I concentrate on the Gini coefficient and the 20% income ratio for the dependent variables.

Regional and 'Bloc' Analysis

Because different regions will respond differently to increases in energy availability, the full sample is divided first into five regions and, secondly, three economic 'blocs'. The regions are: Latin America, Asia, Western and Eastern Europe, and the Russian Federation. Asia includes SE Asia and the Indian subcontinent. Africa and the Middle East have insufficient observations to conduct analysis. The economic 'blocs' are: the current/former Communist economies (Comm), OECD, and non-OECD (denoted –OECD). The term "Communist" is used as a political identifier rather than an economic one.

Reasons for heterogeneity across regions are manifest. Differences in infrastructure, social and legal institutions, historical accident, the level of development and source of energy are explanations for why a different region income distribution reacts differently across the sample. Thus, it is conjectured that greater access to energy will a larger impact on low income than in high income countries. Results using FE model can be found in Table 8, Gini estimates are in the top half and the 20% income share are in the bottom. Briefly, while the signs of the estimates are correct, and similar to previous estimate coefficients, only energy reduces the Gini in Latin America and Eastern Europe with any significance. While there is a significant reduction in the income ratio for OECD countries.

Results for the FE-IV and 2SLS models are in Tables 9 and 10. Most of the FE-IV estimates, Table 9, have the correct sign and are statistically significant, particularly when the Gini is used as the dependent variable. As might be expected, given the non-linear nature of income inequality, the largest elasticities are for the relatively underdeveloped countries in Latin America, Eastern Europe, and the current/former Communist countries. Interestingly, the OECD has a larger, and significant, estimate than the non-OECD countries, though this may be due to better defined rule of law, captured by the institutional variable, than in non-OECD economies. As can be seen the institutional estimate is negative, but not significant, in OECD countries whereas it is positive, and significant, in non-OECD economies. Control estimates are in the neighborhood of previous ones, though, as before, are more significant than in the benchmark FE regional models.

Results for the individual regions using 2SLS are less conclusive, see Table 10. We can see that, with the exception of West Europe, the energy elasticity is negative across all four definitions of freedom, though they are only statistically significant for Latin American and the communist bloc. Finally, the GMM estimates, in Table 11, show no statistically significant contemporaneous effect, but roughly a third of the lagged energy coefficients are significant and signed correctly.

A word of caution may be warranted, some of the estimates may suffer from the power problem and therefore subject to type II errors. For example, the Asian panel has only 36 observations which likely effect the efficiency and consistency of the models, particularly when using a FE model.

Income Shares

While the Gini coefficient meets several criteria required to be a good measure of income inequality – mean independence, population size independence, symmetry, and transfer sensitivity, see Haughton and Khandker (2009) Chapter 6 – it does not allow for decomposing income into shares. By using individual models for each income strata and comparing the results we can gain insight to energy asymmetries. Consider the following panel models

$$S_{it}^T = a_0^T + a_1^T q_{it} + a_2^T \psi_{it} + x_{it}'\gamma^T + \lambda_t^T + e_{it}^T, \quad (15)$$

$$S_{it}^B = a_0^B + a_1^B q_{it} + a_2^B \psi_{it} + x_{it}'\gamma^B + \lambda_t^B + e_{it}^B, \quad (16)$$

where S represents income share and the super-scripts T/B represent the top/bottom 10%/20% income shares. These regressions are nested in equation (11) after removing the conditions found in equations (7) and (8). In the previous regressions there is an implicit assumption that $a_j^T = a_j^B$, however, this need not be the case. Indeed, there is no theoretical or empirical justification for this to be true. If we consider equation (11), $\widehat{w}$ expands and contracts from changes in w_h^* and/or w_ℓ^*. Alternatively, if we look at equation (10), the energey coefficient, β, in the standard panel specification is given as $\beta \equiv \beta_h - \beta_\ell$, which are given as a_j^T and a_j^B above.

Results of this exercise can be found in Table 12 and include both RE and FE models. Immediately apparent from both versions of the regressions is that raising energy use *reduces* the top income shares and *raises* the share of the bottom income group, though with less statistical significance. A Wald test, using a LSDV-SUR model, tests the null hypothesis $a_1^T = a_1^B$. In each case, we can soundly reject the null hypothesis, for the 10% and 20% income ratios, χ^2 ($p-$values) are 29.21 (0.000) and 44.41 (0.000) for the 10% and 20% income shares respectively. Primary education expenditures reduce the upper income groups share while increasing the bottom income share. Perhaps tautologically, the institution variable improves the upper income group, while undermining the lower group's income share.

The FE-IV and FE-2SLS energy estimates are in Table 13 and are similar to those in the standard RE and FE table, but with greater statistical significance. Similarly results are found for the human capital and freedom variables as well. The size of the estimates using the 2SLS model is striking, the top shares lose considerably, estimates of about –22.0, while bottom gains are substantial, between 4.2 and 8.2 depending on income share is measured. Education has the biggest impact using the FE-IV model, and the role of institutions demonstrates substantial gains for the upper income group and losses for the bottom group.

Lastly, the GMM results are tabulated in Table 14. As in the previous dynamic panel models, most of energy's statistically significant impact on inequality comes from lagged energy, but are the same sign as contemporaneous energy in the previous models. In absolute value terms, the decline in the upper income group's share is significantly larger than the gains to the lower income group.

Education and institutions have relatively homogeneous responses as in the previous asymmetric models. Health expenditures favor the high income groups and hurt the low income groups.

Note, this does not imply that all the losses to the top 20% are transferred to the bottom 20% or all the gains for the bottom are at a cost to the top. Rather, this implies that the income distribution is compressed. Put another way, the income distribution becomes less hour-glass shaped. While previous estimates of inequality using the Gini coefficient and income ratio yield a decline in inequality when energy use is increased, they do not necessarily imply *how* the disparity is ameliorated. Nor do they, in the case of the Gini coefficient, discuss the shape of the Lorenz curve as, for any given Gini coefficient, there are an infinite number of Lorenz curves.

5 Summary

In this paper, we examined the relationship between access to energy and income inequality. To date, the majority of the literature on income inequality has concentrated on factors such as per capita GDP, that is the level of development, human capital accumulation, and institutional quality, with varying degrees of success. Using an unbalanced panel of 147 countries over a 25 year sample, I find a strong negative causality between energy use and income inequality that is robust to numerous specifications, techniques and variables. The policy implications are clear, should economies desire to reduce income inequality, improving access to energy will aid this endeavor. Moreover, there is little ambiguity, unlike education and health, about how access to energy can be a positive influence on income distribution.

As a caveat, it should be noted that *how* energy produced is not a topic discussed in this paper. Clearly, there are numerous issues surrounding energy production, primarily negative externalities and costs. Burning fossil fuels leads to rising greenhouse gases and other health related issues; removal of nuclear waste and the containment of nuclear material in the case of power plant failure; destruction of the environment associated with hydroelectric power; and how to provide the infrastructure to disseminate the electricity are a small number of consequences associated with the current state of technology as we segue to greener sources of energy.

In addition, concerns raised by Ozturk (2010) regarding the need for more robust, and varied, econometric methods and data. While this paper presents a battery of results using a fixed vector of human capital, institutional and real GDP variables, the results are robust to other sets of controls. Ideally, as an extension, a longer sample period would be used to corroborate the results presented here, which would also allow for time series analysis.

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Tables

Table 1: Data Description and Sources

	Source
Dependent Variables	
ln Gini Coefficient	World Bank, Development Research Group
Income Share Ratio of 20% and 10%	World Bank, Development Research Group
Energy Variables	
ln Per Capita kWhs	IEA Statistics
ln Total BTU	U.S. Energy Information Administration (US-EIA)
ln CO2 Emission per $GDP	Carbon Dioxide Information Analysis Center
Control Variables	
ln per capita real GDP (local currency units)	World Bank national accounts data, and OECD National Accounts data files
Area 2C: Protection of Property Rights	Fraser Institute
Area 5Civ: Bribery:	Fraser Institute
Adjusted primary enrollment rate (% school age children)	UNESCO Institute for Statistics.
Health expenditure (% GDP)	World Health Organization Global Health Expenditure
Investment non-financial assests (%GDP)	International Monetary Fund, Government Finance Statistics Yearbook
Government consumption (%GDP)	World Bank national accounts data and OECD National Accounts data files
Value Added Manufacturing (%GDP)	World Bank national accounts data, and OECD National Accounts
Percent rural population	World Bank Staff based on United Nations, World Urbanization Prospects
IMF Global Recession	International Monetary Fund

Notes: All data are from the World Bank Development Indicators database except the Freedom indices which are from the Fraser Institute and the BTU data which is from US-EIA

Table 2: Descriptive Statistics

Veariable	N	Mean	Median	St. Dev	Min	Max
ln Gini	1141	3.66	3.65	0.25	2.79	4.19
10% Income Ratio	1140	22.05	12.15	37.35	2.82	755.00
20% Income Ratio	1140	9.72	7.12	7.28	2.23	81.66
ln pc kWhs	3186	7.35	7.60	1.57	2.60	10.91
ln BTUs	3535	-1.35	-1.58	2.26	-6.21	4.78
ln CO2	3902	-1.29	-1.29	0.76	-4.86	1.13
% Primary Educ Enroll	2411	87.95	95.02	16.14	19.15	100.00
Exp Health % GDP	3344	6.12	5.82	2.32	1.45	17.14
Mean Bribe & Property Rights	1830	1.64	1.64	0.35	-0.08	2.26
ln pc RGDP	4199	10.83	10.58	2.37	3.99	17.33
Government %GDP	4008	16.03	15.60	6.35	2.05	76.22
Investment %GDP	3986	23.43	22.20	11.01	-0.69	219.07
% Rural Pop	4297	44.77	44.55	23.65	0	94.58
VA Manuf % GDP	3589	14.86	14.40	7.49	0	47.34
Latin America	4475	0.12	0	0.33	0	1
Africa	4475	0.28	0	0.45	0	1
Middle East	4475	0.07	0	0.25	0	1
Asia	4475	0.12	0	0.33	0	1
W. Europe	4475	0.10	0	0.31	0	1
E. Europe	4475	0.10	0	0.31	0	1
Russian Federation	4475	0.06	0	0.24	0	1
OECD	4475	0.17	0	0.38	0	1
(ex-) Communist	4475	0.16	0	0.37	0	1
IMF Recession	4475	0.35	0	0.48	0	1

Table 3: Random and Fixed Effect Benchmark Models

	Gini		20% Ratio		10% Ratio	
	Random	Fixed	Random	Fixed	Random	Fixed
	Education Only					
% Primary Educ Enroll	-0.003**	-0.005***	-0.116	-0.159	-0.030	-0.036
	(0.019)	(0.005)	(0.709)	(0.718)	(0.484)	(0.550)
R_o^2	0.683	0.000	0.255	0.000	0.598	0.000
Obs.	565	565	565	565	565	565
	Health Only					
Exp Health %GDP	0.005	0.008	-0.897	1.368	0.260*	0.565*
	(0.441)	(0.178)	(0.357)	(0.480)	(0.095)	(0.054)
R_o^2	0.675	0.001	0.250	0.000	0.579	0.011
Obs.	718	718	718	718	718	718
	Education and Health					
% Primary Educ Enroll	-0.003**	-0.005***	-0.098	-0.154	-0.033	-0.034
	(0.019)	(0.006)	(0.753)	(0.727)	(0.438)	(0.579)
Exp Health %GDP	0.001	0.005	-0.861	1.217	0.150	0.432*
	(0.875)	(0.442)	(0.416)	(0.438)	(0.309)	(0.079)
R_o^2	0.682	0.001	0.256	0.000	0.596	0.002
Obs.	565	565	565	565	565	565

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. RE model includes regional dummy variables. Control variables include: per capita real GDP, average bribery and property rights freedom indices, investment share of GDP, government share of GDP, percent rural population, % GDP value added from manufacturing, and time fixed effects.

Table 4: Random and Fixed Effect Models: Per Capita kWhs and BTUs

	Gini		20% Ratio		10% Ratio	
	Random	Fixed	Random	Fixed	Random	Fixed
	kWhs					
ln pc kWhs	-0.050	-0.130*	4.290	-6.180	-0.913	-3.493*
	(0.105)	(0.096)	(0.638)	(0.558)	(0.314)	(0.053)
% Primary Educ Enroll	-0.004**	-0.005***	-0.440	-0.314	-0.050	-0.062
	(0.019)	(0.003)	(0.427)	(0.458)	(0.387)	(0.335)
Exp Health %GDP	0.003	0.004	-0.906	1.313	0.321**	0.464*
	(0.739)	(0.472)	(0.507)	(0.433)	(0.046)	(0.054)
Mean Bribe & Prop Rights	0.151***	0.137***	-25.503	-7.455	1.889	2.728
	(0.001)	(0.004)	(0.225)	(0.572)	(0.175)	(0.162)
R^2_o	0.709	0.024	0.262	0.000	0.615	0.010
ρ	0.884	0.987	0.144	0.763	0.578	0.947
Obs.	541	541	541	541	541	541
	BTUs					
ln BTUs	-0.019*	-0.116***	0.133	-14.183	-0.369	-5.003**
	(0.066)	(0.003)	(0.917)	(0.298)	(0.190)	(0.044)
% Primary Educ Enroll	-0.004***	-0.006***	-0.041	-0.192	-0.033	-0.061
	(0.010)	(0.001)	(0.895)	(0.667)	(0.438)	(0.326)
Exp Health %GDP	0.002	0.005	-0.759	1.144	0.185	0.408*
	(0.802)	(0.418)	(0.481)	(0.464)	(0.262)	(0.085)
Mean Bribe & Prop Rights	0.139***	0.138***	-22.260	-8.401	1.649	2.666
	(0.003)	(0.004)	(0.186)	(0.570)	(0.242)	(0.238)
ln pc RGDP	-0.001	0.128	-1.833	12.253	-0.288	3.680
	(0.953)	(0.255)	(0.300)	(0.629)	(0.178)	(0.309)

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Control variables include: investment share of GDP, government share of GDP, percent rural population, and % GDP value added from manufacturing and time fixed effects. RE model includes regional dummy variables.

Table 5: FE-IV Fixed Effect Model

	Per capita KwHs			Aggregate BTUs		
	Gini	10% Ratio	20% Ratio	Gini	10% Ratio	20% Ratio
ln pc kWhs	-0.148***	-1.848	-2.877*	–	–	–
	(0.005)	(0.892)	(0.067)			
ln BTUs	–	–	–	-0.158***	-18.877	-7.623***
				(0.000)	(0.298)	(0.008)
% Primary Educ Enroll	-0.005***	-0.295	-0.064	-0.006***	-0.241	-0.075
	(0.000)	(0.523)	(0.315)	(0.000)	(0.626)	(0.232)
Exp Health %GDP	0.004	1.399	0.465**	0.005	1.116	0.399*
	(0.394)	(0.405)	(0.024)	(0.274)	(0.497)	(0.062)
Mean Bribe & Prop Rights	0.149***	-9.319	2.747	0.144***	-7.646	2.934
	(0.000)	(0.685)	(0.195)	(0.000)	(0.739)	(0.185)
ln pc RGDP	0.152*	8.067	2.582	0.146*	14.183	4.849*
	(0.081)	(0.713)	(0.200)	(0.069)	(0.549)	(0.067)
$F-$test	10.473	1.330	5.324	10.674	1.541	6.164
Obs.	529	529	529	544	544	544

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Control variables include: investment share of GDP, government share of GDP, percent rural population, and % GDP value added from manufacturing. Includes time fixed effects. Energy variables instrumented with lagged energy and pc Real GDP.

Table 6: 2SLS Fixed and Random Effects Models

	Per capita KwHs			Aggregate BTUs		
	Gini	10% Raio	20% Ratio	Gini	10% Ratio	20% Ratio
	Random Effects					
ln pc kWhs	-0.458***	2.993	-6.428**	–	–	–
	(0.000)	(0.881)	(0.044)			
ln BTUs	–	–	–	-0.172***	3.481	-1.757
				(0.000)	(0.703)	(0.193)
% Primary Educ Enroll	0.001	-0.358	0.042	-0.004***	-0.043	-0.038
	(0.694)	(0.584)	(0.612)	(0.007)	(0.929)	(0.502)
Exp Health %GDP	0.009	-0.669	0.498**	0.004	-0.710	0.292
	(0.120)	(0.701)	(0.021)	(0.417)	(0.696)	(0.134)
Mean Bribe & Prop Rights	0.260***	-24.249	3.915**	0.162***	-15.903	1.872
	(0.000)	(0.116)	(0.035)	(0.000)	(0.192)	(0.142)
ln pc RGDP	0.014	-2.108	-0.054	-0.004	-2.056	-0.322
	(0.135)	(0.139)	(0.812)	(0.655)	(0.163)	(0.162)
R_o^2	0.468	0.260	0.537	0.268	0.242	0.493
ρ	0.830	0.224	0.571	0.882	0.330	0.668
	Fixed Effects					
ln pc kWhs	-0.764***	-92.429	-24.887***	–	–	–
	(0.000)	(0.249)	(0.001)			
ln BTUs	–	–	–	-0.334***	-39.327	-9.941***
				(0.000)	(0.265)	(0.001)
% Primary Educ Enroll	-0.005**	-0.179	-0.039	-0.007***	-0.338	-0.090
	(0.014)	(0.858)	(0.685)	(0.000)	(0.720)	(0.262)
Exp Health %GDP	0.002	0.833	0.343	0.004	1.022	0.383
	(0.796)	(0.784)	(0.234)	(0.369)	(0.720)	(0.113)
Mean Bribe & Prop Rights	0.176***	-4.581	3.816**	0.162***	-5.612	3.211**
	(0.000)	(0.817)	(0.043)	(0.000)	(0.764)	(0.043)
ln pc RGDP	0.419***	46.361	11.965***	0.223***	23.254	5.839**
	(0.000)	(0.287)	(0.004)	(0.000)	(0.432)	(0.020)
R_o^2	0.123	0.010	0.070	0.001	0.000	0.000
ρ	0.997	0.954	0.992	0.995	0.909	0.986
Obs.	538	538	538	561	561	561

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Control variables include: investment share of GDP, government share of GDP, percent rural population, and % GDP value added from manufacturing. Includes time fixed effects. Random effect model includes regional dummy variables. First stage, energy variable is a function of pollution, CO_2.

Table 7: GMM and System GMM

	GMM			System GMM		
	Gini	10% Ratio	20% Ratio	Gini	10% Ratio	20% Ratio
	Per Capita kWhs					
ln pc kWhs	0.014	-16.09***	-2.149***	0.0151	-2.348***	-3.949***
	(0.693)	(0.000)	(0.000)	(0.120)	(0.000)	(0.000)
L.ln pc kWhs	-0.077***	-41.52***	-4.202***	-0.108***	-13.64***	-3.440***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
% Primary Educ Enroll	-0.0023***	-1.458***	-0.053***	0.0001	-2.722***	-0.068***
	(0.000)	(0.000)	(0.000)	(0.500)	(0.000)	(0.000)
Exp Health %GDP	0.005***	-0.410***	0.132***	0.005***	-2.939***	0.413***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Mean Bribe & Prop Rights	0.067***	18.28***	6.232***	0.025***	-22.85***	4.303***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ln pc RGDP	-0.049**	35.75***	-3.511***	0.0129	-0.881***	-0.852***
	(0.049)	(0.000)	(0.000)	(0.509)	(0.000)	(0.000)
Obs.	354	354	354	432	432	432
	Total BTUs					
ln BTUs	-0.014**	-0.170	-0.289***	-0.005	3.911***	1.718***
	(0.029)	(0.251)	(0.001)	(0.358)	(0.000)	(0.000)
L.ln BTUs	-0.013**	-34.17***	-4.645***	0.001	-14.15***	-6.128***
	(0.042)	(0.000)	(0.000)	(0.918)	(0.000)	(0.000)
% Primary Educ Enroll	-0.003***	-1.398***	-0.053***	0.001	-2.577***	-0.063***
	(0.000)	(0.000)	(0.000)	(0.177)	(0.000)	(0.000)
Exp Health %GDP	0.005***	-0.923***	0.075***	-0.0001	-4.795***	-0.184***
	(0.000)	(0.000)	(0.000)	(0.897)	(0.000)	(0.000)
Mean Bribe & Prop Rights	0.090***	17.76***	5.796***	0.002	-34.49***	0.289***
	(0.000)	(0.000)	(0.000)	(0.793)	(0.000)	(0.000)
ln pc RGDP	-0.108***	15.50***	-4.825***	0.00513	-1.805***	-1.520***
	(0.000)	(0.000)	(0.000)	(0.505)	(0.000)	(0.000)
Obs.	358	358	358	436	436	436

Notes: Twostep GMM p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Control variables include: investment share of GDP, government share of GDP, percent rural population, and % GDP value added from manufacturing. Includes time fixed effects. Results for lagged dependent variables are not included.

Table 8: Sub-Sample FE Analysis: Regions and 'Blocs'

	Regions					'Blocs'		
	Latin Am.	Asia	W. Europe	E. Europe	Rus Fed	Comm	OECD	–OECD
	Dependent Variable: Gini							
ln pc kWhs	-0.161**	-0.088	-0.060	-0.337*	-0.131	-0.224	-0.132	-0.077
	(0.034)	(0.593)	(0.598)	(0.057)	(0.389)	(0.128)	(0.136)	(0.442)
% Primary Educ Enroll	-0.004	-0.001	-0.012**	-0.006	0.003	-0.002	-0.005	-0.005***
	(0.462)	(0.817)	(0.042)	(0.268)	(0.615)	(0.627)	(0.291)	(0.004)
Exp Health %GDP	0.006	0.045*	0.014	-0.044**	-0.034	-0.020	0.013	0.004
	(0.385)	(0.060)	(0.481)	(0.029)	(0.253)	(0.420)	(0.475)	(0.527)
Mean Bribe & Prop Rights	0.060	0.249	-0.097	0.096	0.192**	0.125*	-0.039	0.157***
	(0.211)	(0.117)	(0.451)	(0.202)	(0.035)	(0.080)	(0.662)	(0.003)
ln pc RGDP	-0.069	0.123	-0.073	0.288*	0.389**	0.282**	-0.037	0.265**
	(0.219)	(0.820)	(0.824)	(0.071)	(0.021)	(0.021)	(0.820)	(0.047)
R_o^2	0.015	0.056	0.585	0.002	0.024	0.012	0.302	0.012
	Dependent Variable: 20% Ratio							
ln pc kWhs	1.634	0.321	-0.196	-0.737	0.258	-0.178	-1.934*	-2.062
	(0.889)	(0.870)	(0.825)	(0.595)	(0.871)	(0.908)	(0.076)	(0.405)
% Primary Educ Enroll	-0.230	-0.016	-0.100**	-0.034	0.040	-0.004	0.005	-0.069
	(0.492)	(0.778)	(0.045)	(0.467)	(0.408)	(0.903)	(0.909)	(0.367)
Exp Health %GDP	0.070	0.271	0.059	-0.420**	-0.046	-0.157	-0.111	0.475
	(0.912)	(0.214)	(0.711)	(0.029)	(0.843)	(0.481)	(0.524)	(0.119)
Mean Bribe & Prop Rights	2.042	3.179*	-0.531	1.415**	2.139***	1.276**	-0.696	2.720
	(0.786)	(0.053)	(0.638)	(0.032)	(0.001)	(0.025)	(0.428)	(0.264)
ln pc RGDP	-17.733	-1.241	-4.059	-0.511	1.657*	0.314	0.767	7.856
	(0.214)	(0.838)	(0.133)	(0.646)	(0.051)	(0.776)	(0.779)	(0.173)
R_o^2	0.049	0.038	0.389	0.056	0.034	0.029	0.128	0.004
Obs.	136	36	138	99	79	143	204	337

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Includes time fixed effects; constant and control variables exlcuded for clarity.

Table 9: Regional FE-IV Models

	Regions					'Blocs'		
	Latin Am.	Asia	W. Europe	E. Europe	Rus Fed	Comm	OECD	–OECD
	Dependent Variable: Gini							
ln pc kWhs	-0.209***	-0.171*	-0.280**	-0.309***	-0.187	-0.268**	-0.306***	-0.058
	(0.007)	(0.072)	(0.019)	(0.008)	(0.420)	(0.026)	(0.002)	(0.375)
% Primary Educ Enroll	-0.005	-0.001	-0.010**	-0.006*	0.003	-0.002	-0.005	-0.005***
	(0.264)	(0.870)	(0.027)	(0.091)	(0.432)	(0.556)	(0.147)	(0.001)
Exp Health %GDP	0.006	0.052***	-0.003	-0.045***	-0.032	-0.020	0.004	0.003
	(0.177)	(0.002)	(0.793)	(0.001)	(0.115)	(0.209)	(0.729)	(0.551)
Mean Bribe & Prop Rights	0.068*	0.244**	-0.164*	0.110	0.197**	0.169***	-0.062	0.172***
	(0.058)	(0.026)	(0.078)	(0.255)	(0.028)	(0.003)	(0.329)	(0.000)
ln pc RGDP	-0.043	0.315	0.245	0.269**	0.390***	0.263***	0.085	0.248***
	(0.553)	(0.378)	(0.393)	(0.029)	(0.001)	(0.006)	(0.481)	(0.005)
	Dependent Variable: 20% Ratio							
ln pc kWhs	9.684	-0.623	-1.460*	-0.921	0.168	-0.308	-3.616***	-0.144
	(0.383)	(0.583)	(0.094)	(0.340)	(0.931)	(0.784)	(0.001)	(0.963)
% Primary Educ Enroll	-0.202	-0.006	-0.086**	-0.033	0.040	-0.003	0.007	-0.068
	(0.463)	(0.842)	(0.012)	(0.270)	(0.298)	(0.895)	(0.833)	(0.367)
Exp Health %GDP	0.024	0.354*	-0.039	-0.414***	-0.043	-0.160	-0.205*	0.467
	(0.960)	(0.051)	(0.714)	(0.000)	(0.788)	(0.237)	(0.098)	(0.138)
Mean Bribe & Prop Rights	0.775	3.120***	-0.918	1.540**	2.147***	1.558***	-0.928	2.401
	(0.908)	(0.007)	(0.251)	(0.037)	(0.002)	(0.003)	(0.179)	(0.359)
ln pc RGDP	-22.032*	0.926	-2.232	-0.547	1.658	0.158	1.951	7.591**
	(0.069)	(0.816)	(0.277)	(0.587)	(0.117)	(0.848)	(0.331)	(0.030)
Obs.	136	33	138	97	79	141	203	326

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Includes time fixed effects; constant and control variables exlcuded for clarity.

Table 10: Regional 2SLS Models

	Regions					'Blocs'		
	Latin Am.	Asia	W. Europe	E. Europe	Rus Fed	Comm	OECD	–OECD
	Dependent Variable: Gini							
ln pc kWhs	-0.262	-1.030	-0.657***	-114.582	-1.419	-2.843	-1.105*	-0.866***
	(0.212)	(0.360)	(0.009)	(0.989)	(0.126)	(0.370)	(0.051)	(0.000)
% Primary Educ Enroll	-0.005	0.009	-0.006	0.430	0.007	0.016	-0.004	-0.005*
	(0.415)	(0.649)	(0.520)	(0.990)	(0.342)	(0.501)	(0.602)	(0.093)
Exp Health %GDP	0.006	0.128	-0.033	4.607	0.009	0.046	-0.041	0.010
	(0.320)	(0.235)	(0.265)	(0.990)	(0.850)	(0.617)	(0.299)	(0.298)
Mean Bribe & Prop Rights	0.076	0.190	-0.280	-15.595	0.303	0.077	-0.173	0.236**
	(0.228)	(0.682)	(0.145)	(0.990)	(0.106)	(0.723)	(0.250)	(0.025)
	(0.000)	(0.475)	(0.780)	(0.989)	(0.211)	(0.280)	(0.022)	(0.003)
ln pc RGDP	-0.015	2.285	0.790	48.654	0.403***	0.961	0.648	0.414***
	(0.902)	(0.368)	(0.208)	(0.989)	(0.005)	(0.293)	(0.135)	(0.007)
	Dependent Variable: 20% Ratio							
ln pc kWhs	7.034	-13.926	-4.646**	-399.078	-6.491	-17.737	-10.557*	-30.124**
	(0.778)	(0.420)	(0.032)	(0.989)	(0.385)	(0.423)	(0.060)	(0.013)
% Primary Educ Enroll	-0.212	0.135	-0.050	1.483	0.060	0.114	0.013	-0.060
	(0.534)	(0.627)	(0.484)	(0.990)	(0.192)	(0.465)	(0.867)	(0.632)
Exp Health %GDP	0.039	1.534	-0.287	15.819	0.177	0.285	-0.590	0.664
	(0.946)	(0.328)	(0.321)	(0.990)	(0.674)	(0.645)	(0.170)	(0.137)
Mean Bribe & Prop Rights	1.192	2.287	-1.893	-53.381	2.721**	0.956	-1.885	5.692
	(0.902)	(0.747)	(0.254)	(0.990)	(0.024)	(0.508)	(0.151)	(0.159)
ln pc RGDP	-20.617	31.450	2.372	168.272	1.728*	4.862	6.838	13.068*
	(0.153)	(0.416)	(0.644)	(0.990)	(0.058)	(0.414)	(0.120)	(0.083)
Obs.	136	36	138	98	79	143	204	336

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Includes time fixed effects; constant and control variables exlcuded for clarity.

Table 11: Regional GMM

	Regions				'Blocs'		
	Latin Am.	W. Europe	E. Europe	Rus Fed	Comm	OECD	–OECD
	Dependent Variable Gini						
ln pc kWhs	0.132	0.085	-0.127	0.034	-0.0002	0.111	0.018
	(0.118)	(0.208)	(0.435)	(0.783)	(0.998)	(0.125)	(0.696)
L.ln pc kWhs	-0.221***	-0.144**	-0.027	-0.116	-0.082	-0.162**	-0.025
	(0.004)	(0.022)	(0.851)	(0.344)	(0.460)	(0.014)	(0.580)
% Primary Educ Enroll	-0.0005	-0.008	-0.003	0.001	-0.003	-0.009**	-0.002
	(0.793)	(0.149)	(0.414)	(0.822)	(0.283)	(0.019)	(0.148)
Exp Health %GDP	0.001	-0.001	0.012	0.004	0.011	0.011*	-0.003
	(0.750)	(0.892)	(0.257)	(0.750)	(0.253)	(0.080)	(0.383)
Mean Bribe & Prop Rights	0.074***	-0.057	0.068	0.132***	0.101**	-0.025	0.100***
	(0.002)	(0.361)	(0.313)	(0.006)	(0.025)	(0.606)	(0.000)
ln pc RGDP	-0.103*	0.002	-0.056	0.001	-0.023	-0.0606	-0.117***
	(0.076)	(0.988)	(0.521)	(0.991)	(0.717)	(0.261)	(0.001)
	Dependent Variable 20% Ratio						
ln pc kWhs	3.314	0.327	0.197	1.088	0.902	0.730	-3.104
	(0.789)	(0.588)	(0.890)	(0.414)	(0.418)	(0.214)	(0.344)
L.ln pc kWhs	-8.816	-1.017*	0.192	-1.187	-0.430	-1.115**	-4.812
	(0.439)	(0.076)	(0.875)	(0.376)	(0.692)	(0.041)	(0.147)
% Primary Educ Enroll	-0.747***	-0.094**	-0.0001	0.0012	-0.011	-0.066**	-0.110
	(0.005)	(0.046)	(0.996)	(0.963)	(0.623)	(0.029)	(0.211)
Exp Health %GDP	-0.770	-0.014	0.028	0.094	0.045	0.113**	-0.026
	(0.152)	(0.846)	(0.766)	(0.477)	(0.630)	(0.022)	(0.922)
Mean Bribe & Prop Rights	12.53***	-1.223**	0.532	1.135**	0.826*	-0.380	6.530***
	(0.000)	(0.026)	(0.359)	(0.026)	(0.053)	(0.328)	(0.000)
ln pc RGDP	-12.18	-1.281	-1.047	-0.146	-0.503	-0.675	-2.853
	(0.155)	(0.219)	(0.175)	(0.846)	(0.424)	(0.119)	(0.254)
Obs.	95	101	72	63	106	143	211

p-values in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Constant, lagged dependent variable, and control variables exlcuded for clarity. Asia has insufficient observations and is excluded from the results.

Table 12: Asymmetric RE and FE Models

	Top 10%	Bottom 10%	Top 20%	Bottom 20%
Random Effects				
ln PC kWhs	-1.425	0.140	-1.667*	0.358
	(0.126)	(0.301)	(0.082)	(0.185)
% Primary Educ Enroll	-0.067	0.018**	-0.082	0.032**
	(0.266)	(0.035)	(0.161)	(0.043)
Exp Health %GDP	0.156	-0.045	0.202	-0.083
	(0.303)	(0.201)	(0.243)	(0.208)
Mean Bribe & Prop Rights	3.188***	-0.651**	3.878***	-1.351***
	(0.002)	(0.012)	(0.001)	(0.005)
ln pc RGDP	0.160	0.013	0.127	0.026
	(0.479)	(0.759)	(0.623)	(0.765)
R_o^2	0.746	0.601	0.750	0.674
Fixed Effects				
ln PC kWhs	-3.637**	0.465	-3.949**	0.993
	(0.047)	(0.226)	(0.040)	(0.178)
% Primary Educ Enroll	-0.090	0.026***	-0.108*	0.044**
	(0.165)	(0.007)	(0.084)	(0.012)
Exp Health %GDP	0.140	-0.047	0.188	-0.089
	(0.398)	(0.128)	(0.289)	(0.132)
Mean Bribe & Prop Rights	2.882**	-0.619**	3.623***	-1.308***
	(0.014)	(0.024)	(0.005)	(0.009)
ln pc RGDP	1.895	-0.689	2.145	-1.130
	(0.408)	(0.261)	(0.410)	(0.326)
R_o^2	0.195	0.000	0.161	0.005
Obs.	541	541	541	541

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Constant, time fixed effects, and control variables excluded for clarity. Random effect model includes regional fixed effects.

Table 13: Asymmetric IV and 2SLS FE Models

	Top 10%	Bottom 10%	Top 20%	Bottom 20%
FE-IV				
ln PC kWhs	-4.548***	0.380	-4.595***	0.918**
	(0.000)	(0.108)	(0.000)	(0.041)
% Primary Educ Enroll	-0.093*	0.027***	-0.112**	0.045***
	(0.080)	(0.001)	(0.031)	(0.003)
Exp Health %GDP	0.123	-0.046**	0.172	-0.087**
	(0.332)	(0.033)	(0.173)	(0.035)
Mean Bribe & Prop Rights	3.240***	-0.646***	3.986***	-1.374***
	(0.000)	(0.000)	(0.000)	(0.000)
ln pc RGDP	2.103	-0.634*	2.230	-1.058
	(0.125)	(0.087)	(0.153)	(0.132)
$F-$stat	10.730	9.084	12.016	8.556
Obs.	529	529	529	529
2SLS				
ln PC kWhs	-21.486***	4.217***	-23.775***	8.196***
	(0.000)	(0.000)	(0.000)	(0.000)
% Primary Educ Enroll	-0.067	0.022*	-0.083	0.035
	(0.229)	(0.063)	(0.161)	(0.102)
Exp Health %GDP	0.066	-0.033	0.105	-0.060
	(0.695)	(0.356)	(0.558)	(0.349)
Mean Bribe & Prop Rights	3.343***	-0.712***	4.142***	-1.489***
	(0.002)	(0.001)	(0.000)	(0.000)
ln pc RGDP	9.761***	-2.346***	10.874***	-4.309***
	(0.000)	(0.000)	(0.000)	(0.000)
R_o^2	0.208	0.044	0.190	0.078
Obs.	540	540	540	540

Notes: Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Constant and control variables exlcuded for clarity.

Table 14: Asymmetric Dynamic Panel GMM Models

	Top 10	Bottom 10	Top 20	Bottom 20
GMM				
ln PC kWhs	2.047***	-0.110	0.790	-0.269**
	(0.001)	(0.248)	(0.104)	(0.044)
L.ln PC kWhs	-4.641***	0.211**	-3.497***	0.191
	(0.000)	(0.027)	(0.000)	(0.333)
% Primary Educ Enroll	-0.057***	0.007***	-0.051***	0.013***
	(0.000)	(0.000)	(0.000)	(0.000)
Exp Health %GDP	0.091*	-0.042***	0.096***	-0.063***
	(0.077)	(0.000)	(0.006)	(0.000)
Mean Bribe & Prop Rights	2.278***	-0.425***	2.744***	-0.853***
	(0.000)	(0.000)	(0.000)	(0.000)
ln pc RGDP	-2.043***	0.263**	-2.110***	0.974***
	(0.000)	(0.025)	(0.000)	(0.000)
Obs.	354	354	354	354
System GMM				
ln PC kWhs	0.363	0.083	0.930**	0.156*
	(0.300)	(0.214)	(0.019)	(0.080)
L.ln PC kWhs	-4.101***	0.180*	-3.527***	0.764***
	(0.000)	(0.075)	(0.000)	(0.000)
% Primary Educ Enroll	-0.015**	0.007***	-0.001	0.005**
	(0.037)	(0.000)	(0.609)	(0.018)
Exp Health %GDP	0.138***	-0.023***	0.018	-0.082***
	(0.000)	(0.002)	(0.752)	(0.000)
Mean Bribe & Prop Rights	1.768***	-0.207***	1.699***	-0.508***
	(0.000)	(0.000)	(0.000)	(0.000)
ln pc RGDP	0.538***	-0.013	0.053	-0.240***
	(0.003)	(0.770)	(0.822)	(0.000)
Obs.	432	432	432	432

Robust p-values in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Constant and control variables exlcuded for clarity.

Figures

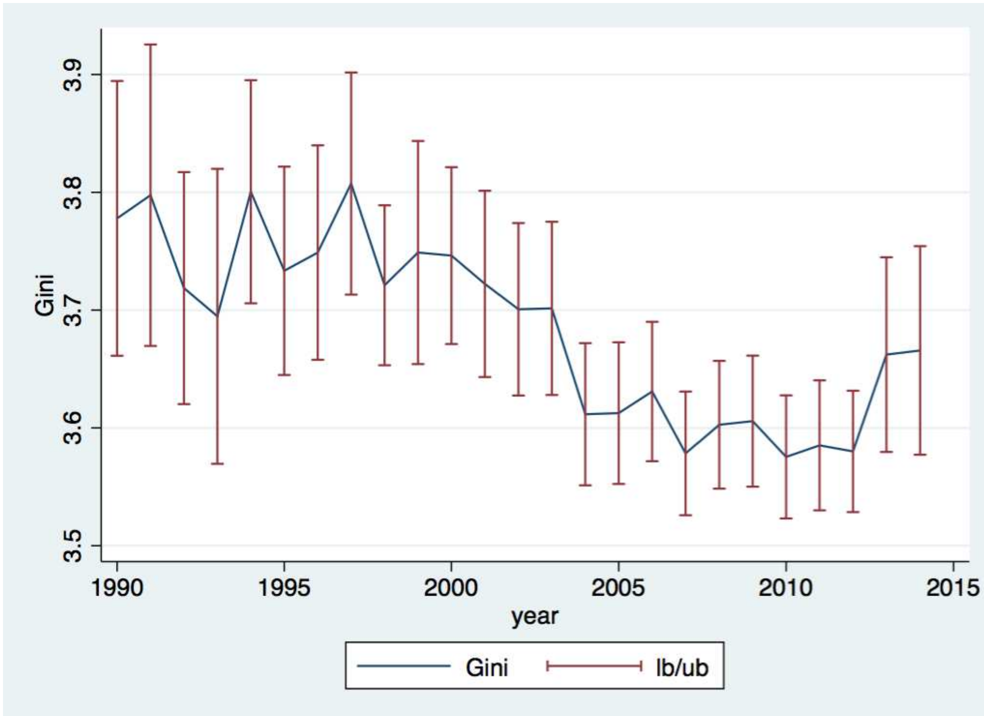

Figure 1: Mean log Gini Coefficient and Upper and Lower Bound

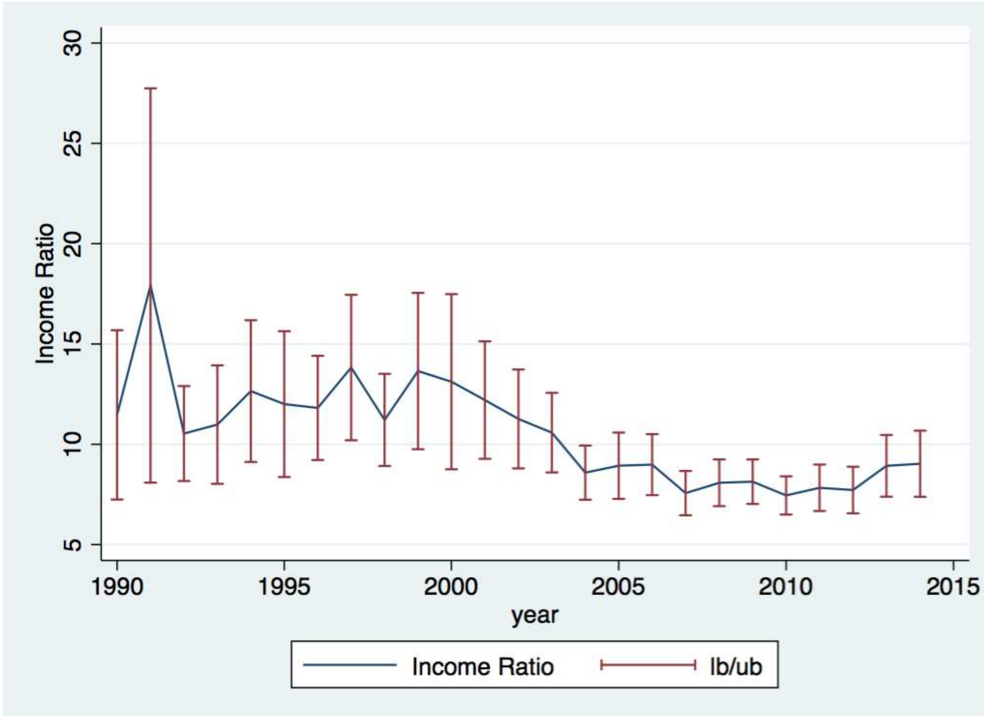

Figure 2: Mean Income Ratio and Upper and Lower Bound

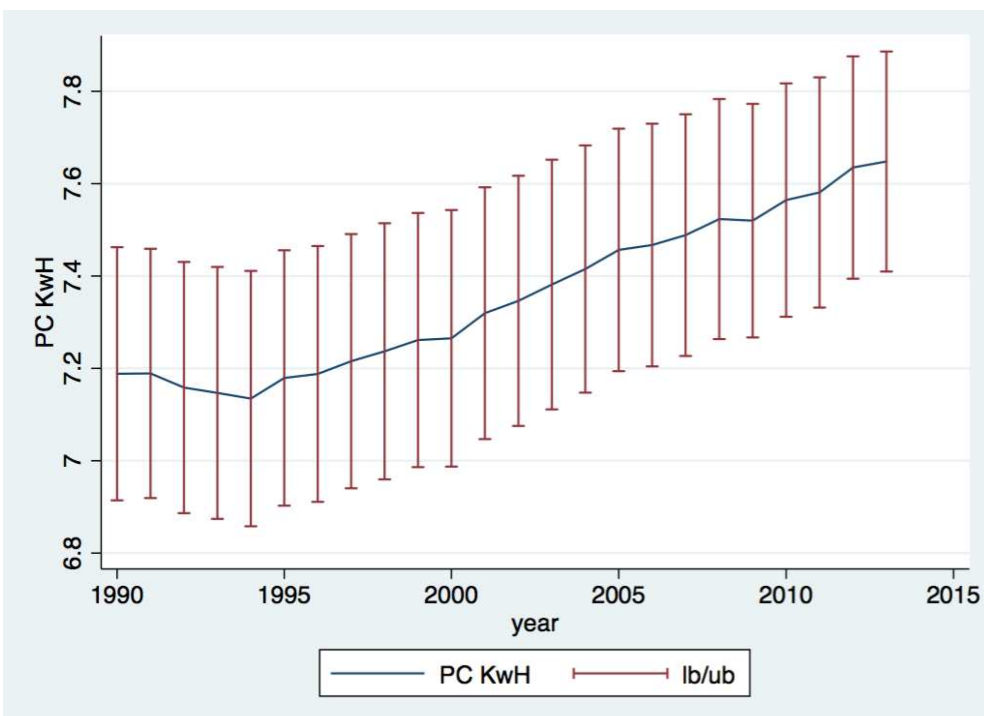

Figure 3: Mean Per capita log kWhs and Upper and Lower Bound

Appendix

A Countries in Sample

Table A1: List of Countries

Country	CID	Country	CID	Country	CID
Albania	ALB	Gambia, The	GMB	Nicaragua	NIC
Algeria	DZA	Georgia	GEO	Niger	NER
Angola	AGO	Germany	DEU	Nigeria	NGA
Argentina	ARG	Ghana	GHA	Norway	NOR
Armenia	ARM	Greece	GRC	Oman	OMN
Australia	AUS	Greenland	GRL	Pakistan	PAK
Austria	AUT	Grenada	GRD	Panama	PAN
Azerbaijan	AZE	Guatemala	GTM	Papua New Guinea	PNG
Bahamas, The	BHS	Guinea	GIN	Paraguay	PRY
Bahrain	BHR	Guinea-Bissau	GNB	Peru	PER
Bangladesh	BGD	Guyana	GUY	Philippines	PHL
Barbados	BRB	Haiti	HTI	Poland	POL
Belarus	BLR	Honduras	HND	Portugal	PRT
Belgium	BEL	Hong Kong SAR, China	HKG	Puerto Rico	PRI
Belize	BLZ	Hungary	HUN	Qatar	QAT
Benin	BEN	Iceland	ISL	Romania	ROM
Bermuda	BMU	India	IND	Russia	RUS
Bhutan	BTN	Indonesia	IDN	Rwanda	RWA
Bolivia	BOL	Iran, Islamic Rep.	IRN	Samoa	WSM
Bosnia and Herzegovina	BIH	Iraq	IRQ	Saudi Arabia	SAU
Botswana	BWA	Ireland	IRL	Senegal	SEN
Brazil	BRA	Israel	ISR	Serbia	SRB
Brunei Darussalam	BRN	Italy	ITA	Seychelles	SYC
Bulgaria	BGR	Jamaica	JAM	Sierra Leone	SLE
Burkina Faso	BFA	Japan	JPN	Singapore	SGP
Burundi	BDI	Jordan	JOR	Slovak Republic	SVK
Cambodia	KHM	Kazakhstan	KAZ	Slovenia	SVN
Cameroon	CMR	Kenya	KEN	South Africa	ZAF
Canada	CAN	Korea, Rep.	KOR	Spain	ESP
Central African Republic	CAF	Kuwait	KWT	Sri Lanka	LKA
Chad	TCD	Kyrgyz Republic	KGZ	Sudan	SDN
Chile	CHL	Lao PDR	LAO	Suriname	SUR
China	CHN	Latvia	LVA	Swaziland	SWZ
Colombia	COL	Lebanon	LBN	Sweden	SWE
Comoros	COM	Lesotho	LSO	Switzerland	CHE
Congo, Dem. Rep.	ZAR	Liberia	LBR	Syrian Arab Republic	SYR
Costa Rica	CRI	Libya	LBY	Tajikistan	TJK
Cote d'Ivoire	CIV	Lithuania	LTU	Tanzania	TZA
Croatia	HRV	Luxembourg	LUX	Thailand	THA
Cuba	CUB	Macedonia, FYR	MKD	Togo	TGO
Cyprus	CYP	Madagascar	MDG	Tonga	TON
Czech Republic	CZE	Malawi	MWI	Trinidad and Tobago	TTO
Denmark	DNK	Malaysia	MYS	Tunisia	TUN
Djibouti	DJI	Mali	MLI	Turkey	TUR
Dominica	DMA	Malta	MLT	Turkmenistan	TKM
Dominican Republic	DOM	Mauritania	MRT	Uganda	UGA
Ecuador	ECU	Mauritius	MUS	Ukraine	UKR
Egypt, Arab Rep.	EGY	Mexico	MEX	United Arab Emirates	ARE
El Salvador	SLV	Moldova	MDA	United Kingdom	GBR
Equatorial Guinea	GNQ	Mongolia	MNG	United States	USA
Eritrea	ERI	Montenegro	MNE	Uruguay	URY
Estonia	EST	Morocco	MAR	Uzbekistan	UZB
Ethiopia	ETH	Mozambique	MOZ	Venezuela, RB	VEN
Fiji	FJI	Namibia	NAM	Vietnam	VNM
Finland	FIN	Nepal	NPL	Yemen, Rep.	YEM
France	FRA	Netherlands	NLD	Zambia	ZMB
Gabon	GAB	New Zealand	NZL	Zimbabwe	ZWE