

Environment, Poverty and Population

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The environmental problems faced by the poor in developing countries are different from those faced by rich countries. Air pollution for the poor is more often due to burning of traditional fuels than vehicle exhaust or industry. Water pollutants come from raw sewage more than industrial runoff. Deforestation threatens the poor due to the loss of energy sources, erosion, and flooding more immediately than global warming and loss of species diversity. The poor suffer from most of the environmental problems of the rich countries, sometimes more severely, but their greatest health risks are from traditional sources of pollution.

The impact of the poor on the environment in developing countries is also different from the impact of human activity in richer countries. The poor, who are mostly rural, have little involvement with industry (pesticide and fertilizer use are exceptions). It is their traditional activities, collecting fuelwood, clearing land, and farming, which have the most environmental impact. Poverty and population pressure can contribute to deforestation due to fuelwood collection and land clearance. They can also force farmers onto marginal unclaimed land causing erosion. Poorly managed property rights and economic instability take away the incentives for poor people to husband their resources sustainably.

This paper will focus on deforestation, energy use by the poor, especially use of traditional fuels, and indoor air pollution. Forests are important for slowing desertification, flooding, deterioration of water supplies, and global warming. Rainforests, the repository of much of the earth's genetic diversity, are almost all in poor countries, where they are threatened by a combination of encroachment by settlers, squatters and logging. Energy is central to the satisfaction of basic nutrition and health needs, and energy consumption constitutes a sizable share of total household expenditure of the poor in developing countries. Indoor air pollution from the burning of biomass fuels is a serious health hazard for many of the poor. Among other major environmental problems faced by the poor are sewage disposal and unsafe drinking water (Thomas and Strauss 1992, Cebu Study Team 1992, Da Vanzo 1988). Public investments to improve water and sanitation are often distributed regressively, and the public good nature of exposure to pathogens deters private investment in better sanitation, even if it were affordable.

The concept of poverty refers to an individual or family's inability to achieve some minimal standard in the consumption of food, clothing, shelter, health, education, sanitation services, and other basic needs. As a reflection of

poverty's multi-dimensional nature and its direct connection to shortfalls in basic areas of human achievement, poverty rates are most naturally conceptualized and measured in terms of the proportion of people who do not achieve specified levels of health, education, and body weight. Operationally, however, poverty standards are typically expressed in a single dimension in terms of the monetary resources that would enable an individual to consume either a fixed bundle of basic goods and services (absolute poverty) or some fraction of the bundle of goods and services that some reference group is able to, or actually does, consume (relative poverty). The "poverty headcount" refers to the proportion of some population whose income or consumption expenditure falls below the specified standard, while the "poverty income gap" refers to the average size of the difference between income/expenditure and the standard, for those below the standard.

Whether measured directly in terms of a range of indicators of basic human outcomes, or indirectly in single monetary dimensions, poverty is indisputably among the world's largest, most urgent, and most fundamental problems. In the most ambitious and careful attempt yet undertaken to measure absolute consumption poverty in developing countries, Ravallion and Chen (1996) estimate that roughly 1.3 billion people in developing countries -- 30

percent of their total population -- consume less than one US dollar per day worth of goods and services (adjusted for differences in the purchasing power of different national currencies using estimates from the Penn World Tables 5.6).

Statistics on the inability of people in developing countries to satisfy basic human needs corroborate the enormous scale of poverty and highlight its breadth and complexity. For example, in comparison with industrial countries, infant and child mortality rates in developing countries are more than five times higher, the proportion of children below age 5 who are underweight is eight times higher, the maternal mortality rate is fourteen times higher, and the proportion of births not attended by trained health personnel is 37 times higher. An estimated 20 percent of people in developing countries do not have access to health services, 30 percent lack access to safe water, and 61 percent lack access to sanitation (see UNDP 1996). Although these and other standard means and ends indicators of poverty are fraught with a variety of conceptual and measurement problems, they collectively paint a highly compelling picture of severe human deprivation in all areas of basic human need, in numbers without historical precedent.

Deforestation, Poverty and Population

Deforestation is most likely where the people near the forest have no incentive to manage the forest sustainably. This can be exacerbated by government subsidies, such as those which induced ranchers to move into the Amazon rain forest (Schmink and Wood, 1987), but it is more often due to poor people encroaching on the forest in search of fuelwood or farmland, and logging activities. The poor are implicated because they are the ones desperate enough to be squatters on land they don't own, and because they are more likely to use wood as their principal source of energy (see below). What can be said about the general relationship between poverty, population, and deforestation across countries?

Table 1 shows the effect of income, income distribution, and population density on deforestation in the 1980s across 57 countries. Disparity in income between the rich and the poor, measured by the Gini coefficient, is strongly related to deforestation. The difference between the expected deforestation in a country with the average income distribution and a country with a Gini coefficient one standard deviation about the mean is 5.0 hectares per thousand persons per year, or almost double the average rate of deforestation (6.7 ha/000 persons/year). Figure 1 shows this relationship more starkly. All the countries but one with a deforestation rate above 5 ha/000 persons/year had a Gini

coefficient above the average of 40. Indonesia is the lone exception. The average rate of deforestation for the countries with below average inequality is 0.3 (ha/000 persons/year), while the average deforestation rate for countries with above average inequality is 10.5 (ha/000 persons/year), thirty times as high.

Income growth is also strongly related to deforestation. Fast-growing countries are less likely to lose their forests. Table 1 shows that countries with GDP per capita growth one standard deviation above the average are expected to lose 4.3 (ha/000 persons/year) less than a country with average economic growth. This shows up clearly in Figure 2. The mean rate of deforestation for countries with positive average income growth from 1980 to 1990 was 2.2 (ha/000 persons/year), while the mean rate for countries with negative growth was 15.3 (ha/000 persons/year), seven times the rate of deforestation.

The regression in Table 1 shows a somewhat lower rate of deforestation in wealthier countries, but the effect of the level of GDP per capita on deforestation is not significant. There is also no significant effect of population density on deforestation.

The cross-country evidence suggests that the marginalization of the poor, reflected in income inequality, and economic mismanagement and instability,

reflected in negative economic growth rates, are major determinants of deforestation. Some of the countries with high deforestation rates, mainly those in Southeast Asia, are also large exporters of timber, but most are not.

Patterns of Energy Use Among the Poor

The poor tend to rely on a significantly different set of energy carriers than the rich, consuming in traditional ways proportionately more wood, dung, and other biomass, and less electricity and liquefied petroleum gas (LPG). This finding is significant in part because indoor air pollution is a major by-product of the use of biomass, which diminishes the quality of life, especially for women and young children. This finding also derives significance from the fact that biomass is significantly more expensive per unit of usable energy than are other energy sources.

Households use fuel in a variety of activities, including cooking, water heating, space heating, and lighting. Different energy carriers can be used in these activities, including firewood, dung, charcoal, coal, kerosene, electricity, and LPG. These carriers form what is commonly referred to as an energy ladder, with each rung corresponding to the dominant fuel used by successive income

groups (see Hosier and Dowd 1987; Reddy and Reddy 1994). Thus, wood, dung, and other biomass, which are burned for use in cooking, represent the lowest rung on the energy ladder, with charcoal and coal (when available), kerosene, electricity, and LPG representing successive rungs.

The ordering of fuels on the energy ladder also corresponds to their efficiency (i.e., the fraction of available energy that is actually applied in a particular end use) and their cleanliness. For example, the cook stove efficiencies of firewood (as traditionally used), kerosene, and gas are roughly 15, 50, and 65 percent, respectively, relative to that of electricity. As one proceeds up the energy ladder, the emission of carbon dioxide, sulfur dioxide, and particulates in the air also tends to decline.

Households must make choices among the energy carrier options available, which they presumably do on the basis of both the households' socioeconomic characteristics and the attributes of the alternative energy carriers. Income is the main characteristic that appears to influence a household's choice of energy carrier (Leach 1992; Reddy and Reddy 1994). Relevant attributes of the energy carriers include accessibility, convenience, controllability, cleanliness, efficiency, current cost, and the expected

distribution of future costs. Because different fuels require different appliances -- stoves, lamps, etc. -- each with their own ranges of costs and rates of depreciation, fuel costs have both fixed and variable components. The importance of this distinction is magnified by the presence of quasi-fixed costs, such as fixed monthly charges for a natural gas or electricity hookup, by the need to make large “lumpy” purchases of some fuels, such as propane gas, and by the need to make sometimes sizable security deposits, either to guarantee the payment of monthly bills or the return of equipment such as LPG canisters. Despite the fact that they are refundable, security deposits impose a cost on households, the magnitude of which depends upon the return on those funds in their next best use (i.e., their opportunity cost).

The division of costs into fixed, quasi-fixed, and variable components is relevant to household decisions about fuel choice, its effect being dependent upon the rate at which a household discounts future benefits, which may be determined in part by the household’s level of wealth and its liquidity. For example, households that apply high discount rates to fuel consumption decisions, because of the high cost of either diverting resources from other uses or of borrowing funds to cover up-front capital costs, will tend to prefer fuel

carriers that involve lower up-front and periodic costs. (See Reddy and Reddy 1994 for pathbreaking evidence that the poor behave as if they have higher discount rates than the rich when making energy carrier decisions.) Fuel costs may be determined either in a market or implicitly in terms of the opportunity cost of time spent gathering the fuel (e.g., firewood).

Table 2 uses cross-country time-series data to examine the linkages between energy consumption and the distribution of income. Energy consumption is measured by the natural logarithm of total energy consumption per capita (in kilograms of oil equivalent, or koe). The table reports estimates of a model fit to data for 114 countries that has the natural logarithm of GDP per capita as the sole independent variable. It also reports estimates of a model fit to data for 55 countries (the only ones for which the requisite data are available) that includes the Gini coefficient (a measure of income inequality that is scaled to vary from 0 to 100, with higher values indicating a more unequal distribution), the percent of the population living in urban areas, and the percent share of industry in GDP. When included with the level of income per capita, the Gini coefficient may be interpreted as an indicator of absolute income poverty, which is generally not measured directly, well, or widely across

countries. (It is an indicator of affluence as well.) The third regression estimates include income, urbanization, industrial share, and energy prices for 40 countries, but exclude the Gini coefficient since too few countries have contemporaneous data on both income distribution and energy prices. The average energy price for a country is the total expenditure on energy divided by the national energy consumption. This provides an average price irrespective of the energy carrier, taking into account consumer substitution towards the cheaper energy carriers in each country. The results in Table 2 are fixed effects estimates, so the independent variables are explaining the change in energy consumption across countries. The fixed effects capture the average level of energy consumption in each country, which is affected by climate and national tastes among other factors.

The estimates in Table 2 show the familiar result that energy consumption per capita is strongly positively associated with income, though at a declining rate. They also show that energy consumption has almost no association with income inequality nor urbanization, and a small positive association with industry share. The association of energy consumption with industry share disappears with the inclusion of average energy prices in the third regression, probably because low energy prices encourage both energy

consumption and industrialization. The energy price elasticity estimate implies that a doubling of energy prices would result in a 13% drop in consumption, which is not a sensitive response, but still an important determinant of consumption that is amenable to policy.

The regressions show that energy consumption is associated with average income levels and prices, but not to income distribution, so that poorer countries will consume less energy, but the shares of income going to the rich and the poor do not affect overall consumption.

Table 3 relates the share of traditional fuel sources (biomass) in total energy consumption to income, income distribution, urbanization, and forest area per person. The first set of results in Table 3 are ordinary least squares estimates while the last set are tobit estimates, which take account of potential biases introduced by the fact that biomass shares of total energy consumption are bounded by, and close to, zero in about half the countries in the sample. (The estimates were computed treating 5 percent as the censoring point; see Figure 3.)

Table 3 reveals that the mix of energy carriers varies strongly with the distribution of income (see also the results in Leach 1992). Reliance on biomass is greater among countries with lower incomes, among countries with

more unequal income distributions, among countries with relatively small urban populations, and among countries with more forest cover per person. The average share of traditional fuel in total energy consumption is 74% for countries with a 1993 GNP per capita less than \$2000, but only 3% for countries with a GNP per capita above \$7000 (Figure 3). The income level and inequality/poverty effects are quite sizable in magnitude: one-standard-deviation increases in log income per capita (at the average level) and in inequality translate, respectively, into a 26 percentage point decrease and an 6 percentage point increase in the biomass share of total energy consumption (95 and 23 percent of the average country biomass share). The tobit estimates suggest even larger effects. These cross-country estimates are thus consistent with the notion of an energy ladder, with both poor countries and the poor within countries disproportionately positioned on the lowest rung, which corresponds to biomass. Insofar as total energy use increases sharply with income, the ladder may also be thought to widen as one climbs its rungs. In results not reported, we find no evidence that total energy consumption or the biomass share is associated with average years of schooling. The results also hold when we use the ratio of income received by the highest and lowest quintiles of the income distribution in place of the Gini coefficient as a measure

of income inequality. The results are robust with respect to econometric corrections for potential heteroskedasticity and when we perform tests for the representativeness of the smaller sample of countries.

Tables 4 and 5 focus on the connection between poverty and energy use at the level of households by reporting tabulations derived from household survey data for Pakistan and Vietnam. The data were collected in the early 1990s as part of the World Bank's Living Standards Measurement Surveys, which include information on a range of measures of household structure, activities, and well being. Insofar as both surveys analyzed here include detailed questions on the sources and uses of energy, as well as a variety of poverty indicators, they are ideally suited to addressing many of the central issues in this study. The Pakistan sample includes 4798 households, while the Vietnam sample includes 4800 households.

Table 4 reports the proportion of poor households (i.e., those in the lowest expenditure quintile) that use different fuels for different household end-uses, as well as differences in the use of alternative energy carriers between rich (i.e., highest expenditure quintile) and poor households. The fuels included are

biomass, kerosene, electricity, and gas; the household activities examined are cooking, space heating, water heating, and lighting. The figures in Table 4 provide further confirmation of the existence of an energy ladder: the poor are far more likely to use biomass or kerosene for each major energy end-use than they are to use gas or electricity. In addition, despite the fact that the rich consume more energy overall than the poor and are thus more likely to consume more of each energy source, they are far more likely to consume fuels at the upper end of the energy ladder. The results in Table 5 for Vietnam reveal a similar pattern of energy use.

Table 6 shows that poor households in Pakistan devote 5.4 percent of their total expenditure to energy services, substantially less than the 22.2 percent share for households in the highest expenditure quintile. This difference reflects the fact that the poor use energy substantially for cooking, whereas the rich use it for cooking, heating water, space heating, and lighting. The estimate for poor households is, however, understated because the poor devote a larger portion of their most important asset, their time, to the production of energy services. For example, Table 7 shows that the poor households devote roughly 100 more hours per year to the collection of

biomass than do the rich households, with most of the time invested by adults.

Table 8 demonstrates that different energy carriers have different costs per unit of usable energy. The table reports the variable, fixed, and total costs of four different fuels used for cooking -- fuelwood (used in traditional ways), kerosene, LPG, and electricity -- based on the household survey data for Pakistan and available estimates of the efficiencies of different energy carriers. The first column reports prices per standard unit of each energy carrier. The second column reports prices of the different energy carriers, after standardizing for differences in their energy content using parameters reported in Dutt and Ravindranath 1993. Firewood has the lowest variable cost per megajoule of energy realized. Electricity is three times as costly per megajoule as wood, while the variable cost per megajoule for kerosene and LPG fall in between. The third column accounts for the actual fuel efficiency in cooking, which depends upon the efficiency of the stove in use. Because kerosene stoves are less efficient than electric or gas stoves, the actual cost of using kerosene is now almost twice that of LPG and electricity. However, most striking is the sharp rise in the relative variable cost of wood, which is most expensive, just above the cost of kerosene.

But before one may conclude on the basis of these figures that the poor pay more for usable energy, one must also take account of differences in the fixed costs associated with different energy carriers. Table 8 thus presents relevant calculations that account for the fixed costs of different energy carriers. There are fixed utility charges associated with the use of electricity, but not with kerosene (which is typically bought in the market) or wood (which is either collected by household members, usually adults, or bought, especially in urban settings). LPG canisters require a substantial deposit which carries an opportunity cost for the user. Furthermore the cost of investing in stoves can be substantial. Gas stoves being the most expensive and wood stoves (which in their simplest version are just comprised of three rocks) costing nothing. Electric stoves (hot plates) are relatively inexpensive. The fourth through seventh columns of Table 8 shows the average total costs of using different fuels including the fixed utility costs, the opportunity costs of canister deposits, and the annualized cost of different stoves. The value of these costs per quantity of cooked food depends on the consumer's discount rate and the level of consumption. Consumers with high discount rates will find expensive stove purchases more onerous because they must invest the money now for future

benefits which they value less than people with low discount rates. The level of consumption matters because a stove becomes more expensive per quantity of food if the household does less cooking. The fourth column of Table 8 shows the average cost of different energy carriers if they consume the equivalent of one kilogram of wood per day, and they have a 10 percent discount rate. Due to the fixed costs of other energy carriers, all the energy carriers cost about the same, except for electricity. However, if the household has to concentrate on their immediate well-being, and has a high discount rate of 75 percent, wood is much less expensive than LPG. This indicates that the investment costs of LPG could be a significant barrier to its use by poor households who have low consumption levels of energy.

The sixth and seventh columns of Table 8 report the relative average cost of energy carriers when fuel consumption is higher, at ten kilograms of wood per day equivalent. At this consumption rate, wood is clearly the most expensive carrier. The lack of effect of the discount rate shows that average investment costs for different carriers are not significant at higher consumption levels.

These calculations demonstrate nonetheless that the poor, with low consumption levels of fuel, pay a higher price per unit of energy services than

do the rich, because they rely so much more heavily on wood. Why do they do this? One reason is that they are credit constrained. If credit were available at a ten percent rate of interest, that would become their relevant discount rate for investing. Another reason is that the rural poor, though not the urban, often collect their wood rather than buying it, and if their shadow wage is below the market wage, the cost of the wood is lower. The main reason, though, is that they consume less energy than the rich, so they want to avoid fixed costs. There is also some evidence that the poor pay more for modern energy carriers. For example, because of the large fixed cost of renting an LPG canister (they require an average deposit of nearly 1000 rupees in Pakistan, which is 135 percent of the average monthly income per person), poor households are likely to have at most one in their homes, which they would often need to fill prematurely at fixed cost, to match the delivery schedules for LPG refills (Robert Williams, personal communication, 1996).

The fact that the poor pay both higher money and time prices for energy services than do the non-poor has a powerful implication: the economic hardship endured by poor households is understated when their income (consumption expenditure) is evaluated in terms of its command over the basket

of goods and services consumed by households with average income or consumption expenditure. If money is to be used to measure poverty and hardship, proper account must be taken of its purchasing power. To illustrate, consider a poor household that derives all of its energy services from purchased biomass using traditional devices. The estimates in Table 8 suggest that this household could consume the same level of energy services at 78, 63, and 44 percent of the cost if it moved up to LPG, electricity, and natural gas, respectively. Given that cash expenditures on energy services account for 8.4 percent of poor urban household budgets in Pakistan (see Table 6), substitution of more efficient energy carriers would confer sizable gains in purchasing power on poor urban households, equivalent to 4 percent of their total income/consumption expenditure. Our analyses of the expenditure patterns of Pakistani households in different income groups suggest that this increase in effective resources would be devoted almost entirely to better satisfying basic needs for food, shelter, clothing, health, education, and additional fuel. Thus, improvements in energy efficiency have considerable potential to reduce poverty in all of its key dimensions.

Indoor Air Pollution

The use of biomass is relatively unfriendly to the health of household members, especially when it is burned indoors without either a proper stove to help control the generation of smoke or a chimney to draw the smoke outside. The use of biomass as a source of energy may diminish the ability of the poor to work productively and increase their medical care needs, in addition to its deleterious environmental consequences outside the household.

There are a number of studies of the health effects of indoor air pollution in developing countries. Most of these studies demonstrate a positive correlation between indoor pollution generated by the use of traditional fuels and the incidence of respiratory illness or congestive heart failure (see Smith 1987 for a thorough review; see also Mumford et al. 1987; Chen et al. 1990; van Horen et al. 1993; and Sims 1994, for examples of recent studies). It is difficult to infer a precise health risk from these correlations given the fact that respiratory illness often develops over a long period of time and also given the possible existence of confounding influences on the prevalence of respiratory illness such as smoking and levels of outdoor air pollution. Indeed, some studies have failed to find evidence of a connection between indoor air pollution and ill health (see Ellegard and Egneus 1993). However, if current use of biomass fuel is a good indicator of long-term exposure and smoking and

outdoor air pollution risks can be independently measured, then these correlations suggest burning traditional fuels may be a significant health risk for the poor.

The 1991 Pakistan Living Standards Survey provides evidence of the harmful health effects of traditional fuel use. Household members reported whether they had suffered from various illnesses in the previous month. One of the broad categories of illness is “cough, flu, and fever” which would include respiratory problems brought on by using biomass fuels. Illness due to indoor air pollution from smoke is usually the consequence of exposure over a long period, but current use of biomass fuels in the household is likely to be a good indicator of long-term exposure. Self reports of illness by over thirty-five thousand household members (with mothers reporting the illness of children under 15) are correlated with the use of biomass fuels for cooking, as well as household expenditure, education, age, sex, tobacco smoking, and living in the city. Probit estimates of the probability of reporting cough, flu, and fever are reported in Table 9. Use of smoke-generating traditional fuels are significantly correlated with this illness. The positive correlation of household expenditure per capita and own education are counter-intuitive but typical for self-reported illness. Richer and more educated people are more likely to consider

themselves sick and seek treatment than the poor, even though objectively their health is better. (The height for age of children in the Pakistan sample, an objective measure of health status, has the expected positive correlation with household expenditure and mother's schooling.) The highest schooling attained by anyone in the household is a measure of family human capital that can improve health, but is not as likely to bias survey respondents' self-perception as own education. It is significantly negatively correlated with illness. Women are estimated to have slightly, but not significantly higher, reported illness, probably because they do the cooking. Illness increases with age except for children under 15. Tobacco and living in the city are positively, but not significantly, correlated with illness.

In terms of lower probability of having a cough, flu, or fever, not using biomass fuels for cooking is like having someone in the household with seven extra years of education, if we take highest schooling in the household as the true effect of school on this kind of illness (the numbers reported in Table 9 are the estimated marginal effects of the independent variables). Cooking with traditional fuels is like being thirty years older. Biomass fuels also appear to be more detrimental to health than tobacco smoking and urban air pollution.

Further Observations

A case can be made in support of the view that patterns of energy consumption among the poor tend to be further immiserizing (see Leach 1992 and Dasgupta 1993). First, because the poor pay more for energy, they are less likely to accumulate the wealth needed to make the investments that are necessary to make use of lower-cost fuels.

... indoor air pollution ...

(Environmental implications of biomass use - deforestation in arid countries.)

These effects are reinforced to the extent that users of biomass are less likely to boil the water they drink, for reasons of either cost or custom. Insofar as the use of biomass may promote deforestation, which is mainly an urban phenomenon, reliance on biomass may also tend to increase its future cost, further diminishing the living standards of the poor.

The linkages between energy and poverty have implications for the development of strategies to alleviate poverty. The standard poverty-alleviation strategies -- macroeconomic growth, human capital investment, and redistribution -- do not address the energy-poverty nexus in developing

countries. If patterns of energy use among the poor depress the nutrition, health, and productivity of the poor, the benefits of economic growth are likely to be absorbed very slowly by the poor. Schooling will continue to promote earning capacity, but by less when biomass is the dominant energy carrier because of poor lighting, lack of access to knowledge via radio and television, and poor school attendance due to respiratory illness.

By contrast, policies and programs that focus more directly on creating opportunities for the poor to increase their use of energy carriers other than biomass or to use biomass in modern ways will allow the poor to enjoy both short-term and self-reinforcing long-term improvements in their standard of living (see Reddy 1991). For example, having utilities amortize the fixed costs of connecting to electricity and natural gas grids will lower what appear to be sizable barriers to the use of low-cost fuel by the poor. So, too, will mechanisms that allow the poor to “rent” the appliances needed to utilize energy carriers such as electricity and LPG or to provide smaller LPG canisters that thereby require smaller deposits. In addition, recent evidence from Argentina shows that households are likely to move up the energy ladder to lower cost and cleaner fuels when energy is priced in a way that spreads out

over time up-front and periodic costs (Carlos Suarez, personal communication, 1996). On the other hand, these same households will revert to the use of traditional energy carriers when up-front and periodic costs of energy are restored, as the case of Chile demonstrates in the wake of widespread privatization of utilities. Such mechanisms effectively involve utilities acting as banks, in an effort to overcome credit market imperfections. The access of poor households to modern fuels can also be improved by the geographic expansion of energy infrastructure.

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Table 1: Forest Loss		
	Forest Loss per capita 1980-90	Means (St. Dev.)
Gini Coefficient (scale: 0-100)	0.57	39.63
	(3.99)**	(8.86)
Growth of GDP per capita (%)	-1.69	1.20
	(2.04)*	(2.52)
Log of Initial GDP per capita	-1.95	8.24
	(1.02)	(0.82)
Population Density (persons/ha)	0.01	3.13
	(0.85)	(9.41)
Constant	2.05	
		(0.11)
Forest Loss per capita 1980-90 (ha/000 person/year)		6.57
		(12.89)
R ²	0.41	
No. of Observations	57	

Absolute values of *t* statistics are in parentheses.

Sources: Level data are for 1980 and change data are for 1980-1990. Forest cover and population density are from the World Bank's 1995 World Data database. The Gini coefficients are from an income distribution database described in Deininger and Squire 1996. Gini coefficients are linearly interpolated when they are missing for 1980, but exist for nearby years. Purchasing power parity GDP per capita estimates are from the Penn World Tables 5.6 (Summers and Heston 1991, 1995).

Table 2. Cross-Country Energy Regressions

	Log of Energy Consumption per capita (koe)			Means (St Dev)		
Log of GDP per capita	1.38 (6.48)**	3.91 (10.10)**	3.06 (4.48)**	7.84 (1.04)	8.47 (0.91)	8.29 (1.07)
Log of GDP per capita ²	-0.040 (2.97)**	-0.186 (8.93)**	-0.150 (3.71)**	62.63 (16.42)	72.48 15.02	8.29 (1.07)
Gini Coefficient (scale: 0-100)		-0.002 (0.97)			37.04 (9.24)	
Urban Population (%)		0.002 (1.13)	0.007 (1.60)		59.83 (23.48)	52.08 (23.59)
Share in Industry in GDP (%)		0.005 (2.75)**	-0.002 (0.52)		35.65	28.85 (10.52)
Log of Average Price of Energy (1985 US\$/koe)			-0.128 (3.78)**		(9.54)	8.15 (1.99)
Constant	-2.27 (2.68)**	-12.87	-8.72 (3.10)**			
Log of Energy Cons. per capita		(8.76)**	(3.10)**	6.09 (1.75)	7.07 (1.39)	6.32 (1.79)
R ²	0.84	0.87	0.91			

No. of Observations	2856	348	108	2856	370	108
No. of Countries	114	55	40	114	55	40

Absolute values of t statistics are in parentheses. ** - significant at 1% level.

Sources: Energy consumption, urban population, share of industry in GDP, and energy prices are from the World Bank's World Data 1995 database. Purchasing power parity GDP per capita is from Penn World Tables 5.6 (Summers and Heston 1991, 1995). The Gini coefficients are from an income distribution database described in Deininger and Squire 1996.

Table 3. Biomass Fuel Consumption

	% Biomass Fuels (OLS)		% Biomass Fuels (tobit)		Means (St. Dev.)
Log of GNP per capita	-187.39	-169.69	-136.56	-125.83	8.32
	(10.00)**	(6.79)**	(2.99)**	(2.23)*	(1.13)
Log of GNP per capita ²	9.88	9.33	6.13	6.63	70.48
	(8.73)**	(6.31)**	(2.16)**	(1.94)	(18.83)
Gini Coefficient (scale: 0-100)		0.67		0.96	38.11
		(2.96)**		(2.48)*	(9.33)
Urban Population (%)		-0.36		-0.71	52.52
		(2.21)*		(2.95)**	(23.50)
Log of Forest Cover per capita		1.32		3.12	7.81
(log of sq.km. per person)		(1.81)		(1.49)	(2.04)
Constant	889.50	764.93	717.43	573.23	
	(11.75)**	(7.48)**	(3.94)**	(2.46)*	
% Biomass Fuels					27.37
					(31.55)
Adjusted R ²	0.71	0.84			

No. of Observations	111	46	111	46	46
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Absolute values of t statistics are in parentheses (Huber/White robust t for OLS).

* significant at 5% level ** significant at 1% level.

Sources: Data are for 1993 or neighboring years. Purchasing power parity GNP per capita, and urban population are from World Bank 1995. The Gini coefficients are from an income distribution database described in Deininger and Squire 1996. Forest cover is from the World Bank's World Data 1995 database. Biomass fuel use is from United Nations 1995. Biomass fuel (traditional fuel) includes fuelwood, bagasse, charcoal, animal wastes, vegetable wastes, and other wastes.

Table 4. Energy Use by Household Consumption Activity and Poverty Status in Pakistan

Fuel and Uses		% Poor Households Using	% Rich Households - % Poor Households
Cooking			
	Gas (Natural and LPG)	3.1	33.3
	Electricity	0.0	2.3
	Kerosene	6.7	12.0
	Biomass fuels	91.4	-30.5
	Cooking inside the house	34.3	-6.5
	Inside & with no chimney	87.9	-13.3
Space Heating			
	Gas (Natural and LPG)	0.1	3.7
	Electricity	0.1	4.3
	Kerosene	0.7	-0.2
	Biomass fuels	27.4	-7.8
Water Heating			
	Gas (Natural and LPG)	2.3	20.1
	Electricity	0.0	1.6
	Kerosene	1.4	4.2
	Biomass fuels	23.0	2.9
Lighting			
	Electricity	57.4	23.5
	Kerosene	81.2	-25.7

1) Biomass is wood, dung, wheat straw, coconut shell, cotton sticks, rice straw, rice hull, corn husk, bagasse, tobacco husk, and other biomass.

2) Poor households are households in the lowest quintile of the distribution of household expenditure per capita. Rich households are in the highest quintile.

Source: 1991 Pakistan LSMS.

Table 5. Energy Use by Household Activity and Poverty Status in Vietnam

Fuel and Uses		% Poor Households Using	% Rich Households - % Poor Households
Cooking			
	Gas (LPG)	0.0	0.1
	Electricity	0.0	6.9
	Kerosene	0.0	13.7
	Charcoal and coal	1.9	26.3
	Wood	52.7	7.6
	Other Biomass	62.6	-40.0
Lighting			
	Electricity	35.1	39.6
	Kerosene	65.0	-39.6

1) Biomass is wood, leaves, rubbish, sawdust, straw, or thatch.

2) Poor households are households in the lowest quintile of the distribution of household expenditure per capita. Rich households are in the highest quintile.

Source: 1992-93 Vietnam LSMS.

Table 6. Household Expenditure Shares by Quintile in Pakistan

	Total Population		Urban Population	
	First Quintile	Fifth Quintile	First Quintile	Fifth Quintile
Food	57.5	29.1	51.5	25.6
Housing	9.6	13.6	14.9	19.0
Clothing	8.4	5.3	6.8	5.4
Health	6.8	9.8	5.8	7.7
Fuel	5.4	22.2	8.4	20.3
Education	2.7	3.4	3.9	4.5
Transportation	0.8	1.8	0.8	2.3
Other	8.8	14.9	7.9	15.1
Total	100.0	100.0	100.0	100.0

n.b. Other expenditure share includes (in order of size) marriage, birth, and funeral ceremonies, toiletries, dowry, recreation and travel, and other expenditures.

Source: 1991 Pakistan LSMS

**Table 7. Household Fuel Expenditure by Quintile in
Pakistan**

	Poor	Rich
Money (1)	1,348	40,132
Time (2)	164.5	61.4

(1) Money is 1991 Pakistani Rupees per year.

(2) Time is the average number of hours per year spent collecting wood or dung.

The poor are households in the first expenditure quintile, and the rich are in the fifth quintile.

Source: 1991 Pakistan LSMS.

Table 8. Cost of Cooking Fuels in Pakistan								
	Price per unit		Price per Energy Content (Rupees/MJ) ¹	Price per Kg. Cooked Food ²	Average Total Cost (Rupees/kg. food) ³			
					1 kg. wood/day		10 kg. wood/day	
					r=10%	r=75%	r=10%	r=75%
Electricity	0.64	/kWh	0.18	0.11	0.19	0.20	0.12	0.12
LPG	5.91	/kg.	0.13	0.12	0.22	0.28	0.13	0.13
Kerosene	6.00	/liter	0.17	0.20	0.21	0.22	0.20	0.20
Wood	1.00	/kg.	0.06	0.22	0.22	0.22	0.22	0.22

¹ Price of fuel/typical energy content of fuel.

² Price per MJ/energy required to cook typical meal x efficiency of stove.

³ Average cost of cooking 1 kg. of food including fixed charges and annual cost of stove assuming consumption of energy equal to 1 kg. or 10 kg. of wood per day. r is the rate of discount used to calculate the annualized cost of stoves.

Units: 1991 Pakistani Rupees unless otherwise stated.

Source: 1991 Pakistan LSMS for fuel prices, stove prices, fixed charges, and total expenditure. Energy content of fuels, energy efficiency of stoves, energy required to cook food, and life of stoves: Dutt and Ravindranath (1993, Table 10 & 11, p. 676, 678).

**Table 9: Indoor Air Pollution in Pakistan:
Effect of Biomass Fuel Use on Cough, Flu, and Fever**

	Had Cough, Flu, or Fever in Last 30 Days	Means (St. Dev.)
Household Cooks with Biomass Fuels	0.0238 (2.63)**	0.83 (0.37)
Log of Household Expenditure per capita	0.0142 (3.19)**	6.21 (0.69)
Own Education (years) a	0.0033 (4.18)**	3.46 (4.54)
Highest Schooling in Household (years) b	-0.0034 (4.38)**	5.49 (4.76)
Female	0.0081 (1.65)	0.49 (0.50)
Age	0.0007 (4.39)**	22.54 (19.40)
Age Spline Under Age 15	-0.0016 (2.67)**	3.01 (4.31)
Tobacco Smoker in Household	0.0065 (1.11)	0.67 (0.47)
Lives in City	0.0091 (1.01)	0.16 (0.37)
Had Cough, Flu, or Fever in Last 30 Days		0.12 (0.32)
No. of Observations	35,677	

^a “Own Education” for children under age 15 is set at the level of the best educated in the household, which seems appropriate since children do not usually care for themselves, nor do they report their own illness in the survey.

^b Highest Education in the Household is the years of schooling of the best educated person in the household.

The regression is a probit regression weighted for the stratified random sample of Pakistan. The estimated marginal effects of the independent variables, not the coefficients, are reported. Absolute values of Huber/White robust *t* statistics for household clusters are in parentheses, testing the hypothesis that the coefficients are zero.

Source: Authors' calculations from the 1991 Pakistan Living Standards Measurement Survey.

BRA - Brazil	CMR - Cameroon	COL - Colombia	CRI - Costa Rica
DOM - Dom. Repub.	GTM - Guatemala		
GUY - Guyana	HND - Honduras	IDN - Indonesia	JAM - Jamaica
MEX - Mexico	MYS - Malaysia		
PAN - Panama	PER - Peru	PHL - Philippines	THA - Thailand
VEN - Venezuela	ZMB - Zambia		

Note that although electricity is least expensive carrier for all average total cost calculations, this does not include the cost of connecting to the grid, which may either be a substantial investment, or may be determined by municipal utility policy which usually does not favor poor neighborhoods.